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STATE OF CALIFORNIA
STATE ENERGY RESOURCES CONSERVATION
AND DEVELOPMENT COMMISSION

IN THE MATTER OF:

WILLOW ROCK ENERGY STORAGE
CENTER

Docket No. 21-AFC-02

COMMENTS OF CALIFORNIA UNIONS FOR RELIABLE ENERGY
ON THE PRELIMINARY STAFF ASSESSMENT

ATTACHMENT D (6 OF 7)

June 16, 2025

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Attorneys for California Unions for Reliable
Energy



Draft Environmental Impact Report

SCH# 2023050214

Volume 1

Chapters 1 through 10

ENTERPRISE SOLAR STORAGE PROJECT

by Enterprise Solar Storage, LLC (PP23401)

Site 1

Zone Change Case No. 60, Map No. 196
Conditional Use Permit No. 62, Map No. 196
Nonsummary Vacations Map No. 196

Site 2

Specific Plan Amendment No. 34, Map No. 196
Zone Change Case No. 61, Map No. 196
Conditional Use Permit No. 63, Map No. 196
Nonsummary Vacations Map No. 196

Site 3

Zone Change Case No. 3, Map No. 195
Zone Change Case No. 62, Map No. 196
Conditional Use Permit No. 2, Map No. 195
Conditional Use Permit No. 64, Map No. 196
Conditional Use Permit No. 65, Map No. 196
Specific Plan Amendment No. 35, Map No. 196
Nonsummary Vacations Map No. 195
Nonsummary Vacations Map No. 196

Site 4

Specific Plan Amendment No. 4, Map No. 212
Zone Change Case No. 4, Map No. 195
Zone Change Case No. 3, Map No. 212
Conditional Use Permit No. 3, Map No. 195
Conditional Use Permit No. 6, Map No. 212
General Plan Amendment No. 3, Map No. 212
Nonsummary Vacations Map No. 212

Site 5 (Substation)

Conditional Use Permit No. 20, Map No. 197



Kern County
Planning and Natural Resources Department
Bakersfield, California
November 2023

Level of Significance after Mitigation

With implementation of Mitigation Measures MM 4.1-4 through MM 4.1-7, impacts would be less than significant.

SCE Transmission Line Relocation and Interconnection Work

Southern California Edison (SCE) will relocate an existing 66 kilovolt (kV) transmission line to remove it from the project footprint. An approximately 20-foot-wide access road will be graded within SCE's right-of-way to facilitate construction and future maintenance of the transmission line. After the relocated transmission line is installed and energized, the old transmission line will be dismantled using equipment used to install and tension the relocated transmission line. Additionally, SCE will interconnect the project's 500 kV transmission line into the SCE-owned Windhub Substation 500 kV banks located on the south side of the facility. It is anticipated that SCE's interconnection work will involve upgrades within the substation footprint and potential relocation of existing high-voltage transmission poles and conductors, and/or installation of new poles and conductors adjacent to or within the footprint of the Windhub Substation. The relocated transmission line and interconnection work would result in less than significant aesthetic impacts and would result in minimal changes to the appearance of existing SCE facilities, producing no noticeable change to existing views. The SCE work would not increase the amount of lighting on-site or result in glare during construction and operation. SCE would implement best management practices during construction and operation, and impacts would be less than significant.

4.1.5 Cumulative Setting Impacts and Mitigation Measures

As presented in Chapter 3, *Project Description*, of this Draft EIR, there are 18 cumulative projects. These have the potential to result in cumulative impacts to aesthetics when considered together with the project. The "scarcity" rating criterion is likely to be impacted by widespread development in the area, as unobstructed views of regional topographical features and undeveloped lands would be less available as acreage is developed with PV panels, wind energy projects, and new transmission lines.

As discussed above, the project would have less than significant impacts as it relates to scenic vistas as project distance, topography, and intervening development would reduce the visual prominence of the proposed solar development. Due to the developed nature of the landscape visible from the PCT (i.e. existing solar facilities, wind energy facilities and transmission line infrastructure) in the general project area, project development would not have a substantial adverse effect on existing views from the PCT. As such, cumulative impacts would be less than significant and not cumulatively considerable.

With regard to impacts related to damaging scenic resources within a scenic highway, the project would not be visible from any Officially Designated State or County Scenic Highway as there are no Officially Designated State or County Scenic Highways in the vicinity of the project site. SR-58 and SR-14, which are in proximity to the project site, are eligible state scenic highways. With the exception of Site 2 (Western) and the gen-tie line, most of the project site would not be clearly visible from the eligible scenic segment of SR-14. Views to the project are available from SR-58, particularly Site 3 (Eastern) located immediately to the south. Components of the project would not substantially alter existing long-distance views of the mountain and valley landscape or other natural features visible from the designated scenic segments of SR-

The importance of coccidioidomycosis as an occupational disease has increased in the southwestern United States. This report discusses the aspects of the disease in terms of its geography, the agent, occupation, dust conditions, and various other factors. A control program is outlined.

EXPOSURE FACTORS IN OCCUPATIONAL COCCIDIOIDOMYCOSIS

Lawrence L. Schmelzer, M.P.H., and Irving R. Tabershaw, M.D., F.A.P.H.A.

THE rapid and increasing influx of industry and agriculture into the southwestern United States has heightened the importance of coccidioidomycosis as an occupational disease. Before 1938, this disease was of little interest because relatively few clinical cases were recognized and the morbidity caused by primary infection was not appreciated. In that year, Dickson and Gifford,¹ reporting on several years of study, clearly established that the benign, primary form of the disease was an important cause of illness in the endemic areas, and that the disease is caused by inhalation of spores of *Coccidioides immitis*. During World War II, coccidioidomycosis was shown to be the cause of significant illness among soldiers in training at camps in the endemic areas. Studies by Smith, et al.,² showed that preventive measures, notably dust control, were effective in reducing the rate of infection and the seriousness of epidemics.

Epidemics have also been reported in susceptible groups of university personnel that entered endemic areas. In 1942, Davis, et al.,³ reported infection in seven of 14 students and staff from Stanford

University who made a field trip to the San Joaquin Valley. In 1954, four students from the University of California at Los Angeles contracted the disease in similar circumstances, and one student, not participating in the field trip, developed disease through the handling of contaminated specimens in the laboratory.⁴ In 1962, 100 per cent infection was reported in a group of 16 persons from UCLA who participated in an archaeological field study near Los Banos, Calif.⁴ Again in 1965 three students from UC Berkeley developed clinical disease after a field trip in the same general area.

Coccidioidomycosis ranks high among the infectious occupational diseases⁵ as shown in Table 1. Further, the case fatality rate closely parallels that of tuberculosis as shown in Table 2.⁶ These rates are based on reported clinically recognized cases. In both diseases, primary infection usually goes unnoticed. Fatality rates for both diseases are considerably less when based on total number of infections.

In spite of the fact that coccidioidomycosis is in most instances inapparent or mild, the disease causes significant dis-

Table 1—Number of disability cases of selected occupational diseases in California by fiscal year of report*

Disease	Number of disability cases			
	1962-1963	1963-1964	1964-1965	3-year total
Coccidioidomycosis	21	34	27	82
Tuberculosis	28	29	24	81
Anthrax, brucellosis, Q fever	11	13	13	37
Psittacosis	1	1	1	3
Tetanus	1	2	1	4

* From: *Work Injuries in California, Quarterly Statistical Summary*. State of California Department of Industrial Welfare, Division of Labor Statistics and Research.

ability in California workers. Although the 106 cases reported in six years⁷ may not appear an unduly large number, the degree of disability in these cases is noteworthy (Table 3).

A large proportion required hospitalization and absence from work lasting weeks or months was not unusual. As late as 1957, coccidioidomycosis caused more disability at Williams Air Force Base in Arizona than any other disease including the upper respiratory infections.⁸ While the average incidence of both infections was the same, the average disability of 34.6 days caused by coccidioidomycosis was seven times higher than that caused by upper respiratory infections.

Since it is not now possible to provide artificial immunity to those entering an endemic area and since susceptibility to coccidioidomycosis is essentially universal, the introduction of industrial or agricultural workers into endemic areas carries with it the responsibility of assessing the hazard of the disease to such populations. None of the exposure factors in the production of coccidioidomycosis is susceptible to control to the degree necessary to prevent infection entirely. Sufficient knowledge of

the direct and predisposing causes of the disease, however, does exist so that it may be possible to reduce both the incidence of infection and its severity.

Geography

Coccidioides immitis has been reported only in the arid and semiarid regions of southwestern United States, in Mexico, Central America, Venezuela, and in the Chaco region of Argentina. The areas of endemicity roughly parallel the boundaries of the lower Sonoran Life Zone, which is characterized by scant rainfall, hot dry summers, alkaline soil, mild winters, sparse flora and fauna and, until recently, few human inhabitants (Figure 1).⁹ The creosote bush, *Larrea tridentata*, is often considered a specific indicator of this life zone.

Evaluation of geography and ecology as exposure factors is complicated by the fact that areas within the lower Sonoran Life Zone may be free of *C. immitis*, and conversely small endemic areas may occur outside the zone. However, the potential of serious sequelae to infection is sufficient justification to consider any entry into suspected endemic areas as leading to exposure to the disease.

Infectious Agent

Spores of *C. immitis* are found in the first few inches of the soil and in larger numbers in the vicinity of rodent bur-

Table 2—Case fatality rates for coccidioidomycosis and tuberculosis in California 1960-1963*

	Case fatality rates†			
	1960	1961	1962	1963
Coccidioidomycosis	8.6	12.8	12.3	11.1
Tuberculosis	15.7	12.7	13.1	12.1

* From: California Public Health Statistical Report 1963, Part II Communicable Diseases, California State Department of Public Health.

† Case fatality rates are per 100 cases reported.

OCCUPATIONAL COCCIDIOIDOMYCOSIS

Table 3—Number of cases of occupational coccidioidomycosis reported in California during the period January, 1959, to March, 1965, by industry*

Industry	Cases reported
Agriculture	32
Animal husbandry	16
Field crops	11
Gardening	3
Other	2
Construction	39
Equipment operator	19
Truck driver-mechanic	6
Building trades	14
Professional	22
Engineer	9
Scientist	8
Geologist	5
Other and unknown	13
Total	106

* From: Summary of Reports of Occupationally Contracted Coccidioidomycosis 1959-1965. California State Department of Public Health, Bureau of Occupational Health.

rows.¹⁰ These spores produce mycelial growth during the winter rains and, as the soil dries in the spring, arthrospores are again produced. Tests have shown that the concentration of arthrospores in the soil is highest at the end of the wet season and becomes lower as the dry season progresses. Season and rainfall patterns must therefore be considered in the evaluation of exposure potential for persons entering endemic zones. Importance of this has been shown by Smith, et al.,² in the San Joaquin Valley, and by Hugenholz in a study of 13 years' experience at Williams Air Force Base in Arizona.¹¹ The average number of infections of base personnel was found to decrease during rainy months and to increase during the dry periods.

The highly infectious nature of *C. immitis* is illustrated by the fact that from seven to 15 arthrospores insufflated intranasally into mice causes infection and dissemination to the liver and spleen in 35 per cent to 40 per cent of susceptible

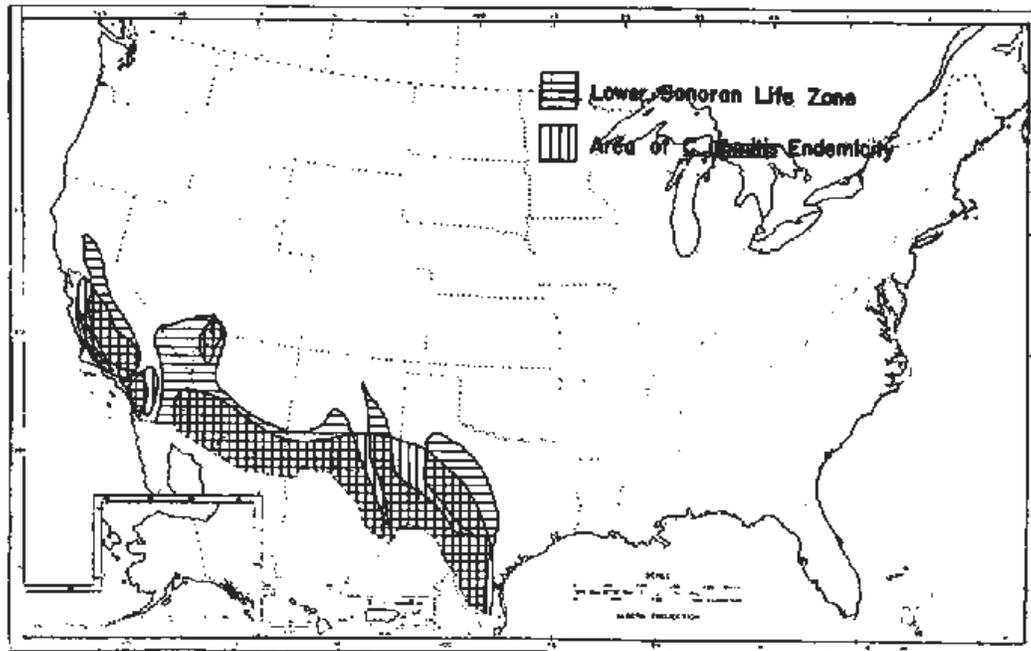


Figure 1—Lower Sonoran Life Zone and area of *Coccidioides immitis* endemicity in the United States [After Smith, C. E.⁹]

animals.¹² The organism has very simple nutritional requirements for growth, grows on practically any medium, and has been shown to prefer a saline environment¹³ including body fluids.

Physical Properties

Typical mature hyphae of *C. immitis* yield barrel-shaped arthrospores, approximately 2.5 microns in diameter and 4 microns long, alternating with smaller sterile cells. The empty cells rupture easily to free the spores, leaving on the latter cell wall fragments which add to the length of the spore and also decrease the apparent specific gravity. Particle dynamics help to explain the highly infectious nature of the *C. immitis* and its wide distribution by winds. The important factors are terminal settling velocity and impingement forces, both of which are proportional to the particle size and specific gravity. Although actual spore dimensions vary and the specific gravity is not accurately known, it can be postulated that effective spore diameter is about 5 microns and its specific gravity is about 0.75. Terminal settling velocity for the spores is 0.01 centimeters per second when computed on the basis of these figures. In comparison, a quartz particle having this terminal settling velocity would have a diameter of 1.4 microns. From this it is clear that spores of *C. immitis* are easily air-borne, settle slowly, can penetrate into the smallest bronchioles and alveoli, and that a significant percentage of retention in the lung can be expected.

Dust Conditions

In the heat of early summer, what little ground cover that exists in the endemic areas withers and dies, winds disturb the surface dust and lift the spores into the air. The slow terminal settling velocity permits the spores to become essentially a permanent atmospheric con-

taminant under turbulent wind conditions. Such conditions are not unusual in arid regions where thermal phenomena generate severe atmospheric disturbances. Very small, intense, local whirlwinds, known as "dust devils," can raise dust containing large numbers of spores if they pass over pockets of high concentration in the soil. Large, rapidly moving air masses are also common, such as the "Santa Ana Winds" which blow from the Mojave Desert south into the San Fernando Valley. These winds will carry spores into nonendemic areas but the concentration will be low because of the nonselective raising of dust. Soil tests, therefore, cannot assure that an area within or close to an endemic zone is free of the organism and surface travel through or near endemic areas has resulted in exposure and infection.

Occupation

Varying racial and sexual susceptibility influences the severity and disability from coccidioidomycosis. However, since it results from inhalation of air-borne arthrospores, occupational factors must be considered in relation to the magnitude of probable dust exposure. It has been shown that a susceptible population entering an endemic area can experience an annual infection rate of about 20 per cent.² No overt dust exposure is necessary; infection can result from wind-borne spores traveling long distances in turbulent air conditions. Labor groups where occupation involves close contact with the soil are at greater risk, especially if the work involves dusty digging operations. The period of disability in cases of occupational coccidioidomycosis reported in California is classified by industry in Table 4.⁷ The significant differences in the periods of disability can be ascribed to the variations in exposure resulting from occupation.

Agricultural workers suffered less dis-

OCCUPATIONAL COCCIDIOIDOMYCOSIS

ability because their exposure is probably to a few spores at a time. In field crop operations, burrowing rodents are not tolerated and the focus of endemicity associated with them is not present. Tilling of the soil will tend to disperse pockets of high spore concentration so that the dust raised can be expected to contain a relatively low concentration of spores. Similarly, a shepherd would not be expected to receive a heavy, concentrated dose of arthrospores. This would tend to produce milder disease and a large proportion of inapparent and mild infections.

In the construction trades, exposures may be very different depending on the specific operations. Pipeline, highway, and utility construction often involves work in remote areas where the soil has not been disturbed and where foci of endemicity are usual. When these foci are disturbed, the dust raised can have a high concentration of spores. Digging of foundation and pipe trenches in residential or commercial buildings can lead to similar massive exposure. Similarly, engineers involved in highway or other heavy construction may be subjected to heavy doses if they are working with the construction crews, but may suffer exposure comparable to an agricultural worker if they are only surveying.

The exposures of professionals are

highly variable and difficult to predict. Groups of paleontologists and archaeologists have suffered 100 per cent infection when their pursuits led them to dig in or around rodent burrows. Other groups digging in endemic areas have completely escaped infection.

Discussion

Prevention of coccidioidomycosis is complicated by the fact that the organism is a natural and persistent inhabitant of the environment. Determination of concentration of spores in specific locations is not feasible because the selection of appropriate sampling sites and identification of *C. immitis* is difficult and time-consuming. Furthermore, as previously mentioned, spores can be air-borne for long periods of time and travel great distances. Consequently, the importation of any susceptible labor force into endemic areas carries with it the responsibility for reducing the rate and severity of infection through whatever dust control measures are possible and for providing a vigorous program of medical surveillance.

Control of dust for the prevention of coccidioidomycosis is not a simple matter because of the wide variations in exposures. General dust control measures can afford some degree of protection to all persons working and living in an en-

Table 4—Number of disability cases of occupational coccidioidomycosis in California by length of disability and industry for the period January, 1959, to June, 1962

Industry	Period of disability in days					Total
	0	1-14	15-29	30-50	>60	
Agriculture	6	0	4	4	4	18
Construction	2	1	0	5	13	21
Professions	5	1	2	6	8	22

From: Summary of Reports of Occupationally Contracted Coccidioidomycosis, 1959-1963. California State Department of Public Health, Bureau of Occupational Health.

demic area. As shown by Smith,² oiling of parade grounds and barracks areas in military establishments reduced the rate of infection. Similarly, planting of trees and lawns around residences and industrial plants can reduce the rate of infection by about half.¹⁴ Further protection can be provided by filtering and conditioning of air supplied to plants and offices, but this is not complete since it does not control infection resulting from exposure outside the working hours. Protection of agricultural workers and animal husbandmen to any realistic degree is exceedingly difficult. Their exposure to dust is an inseparable part of their employment and working conditions preclude the effective use of respiratory protection.

Operators of heavy earth moving equipment can be effectively protected during working hours by providing air conditioned cabs. This not only protects from coccidioidomycosis but also controls exposure to other dust, noise, and engine exhaust fumes. Efficient and comfortable hoods for individual use are now available with powered blowers for providing filtered air. These are useful on smaller earth moving equipment and for semistationary operations such as oil well drilling. Exposures resulting from manual digging are less easily controlled. Continued use of respirators is very uncomfortable in the usually high ambient temperatures, and workers resist use of this kind of protection. The wearing of respirators can, however, be enforced during recognized periods of high exposure. For instance, building tradesmen should wear respirators when digging foundation excavations or pipeline trenches. Similarly, highway engineers can wear respirators when working around earth moving machinery but could dispense with this when surveying ahead of or behind construction crews. Scientists should be protected during actual digging operations but not necessarily during exploration.

Skin testing for previous infection by

C. immitis is easy to perform and defines the immune population. All persons hired for work in endemic areas (or whose assignments take them there) should be tested. Assigning immune workers to operations involving known heavy exposures can effectively reduce the incidence of infection. Hiring life-long residents of the endemic areas can also reduce the incidence of infection since the level of immunity in these people can be expected to be high. This should not, however, be substituted for a program of skin testing and medical surveillance. Negroes and Filipinos have been shown to be more susceptible to developing the highly fatal disseminating form of the disease.¹⁵ Unless such individuals are shown to have developed immunity, they should whenever possible be assigned to work in areas or at jobs where exposure to high concentrations of spores will be minimal.

Periodic medical examinations or interviews are useful to discover a history of low grade or subclinical infection and to evaluate the level of health of the individual. This examination must include repeated skin testing of susceptibles until the patient shows conversion to a positive reaction signifying immunity. Such an individual can then be dropped from medical surveillance for coccidioidomycosis. The medical management of any respiratory ailment suffered by persons at risk who are not immune to coccidioidomycosis should include a skin test.

Research is presently being pursued to develop an effective antigen for producing artificial active immunity to coccidioidomycosis. If successful, this vaccine will make possible the total protection of populations entering endemic areas. However, since man is not the reservoir of the disease, but only an accidental host, eradication will not be possible. Consequently the efforts to prevent disability from coccidioidomycosis must be continued so long as susceptible populations enter endemic areas.

Control Program

A program for limiting the incidence of occupational coccidioidomycosis and reducing the severity of disease in those who become infected would entail the following:

1. Determine if the work location is within the endemic area.
2. Hire resident labor whenever available, particularly if dust exposures may be heavy.
3. Establish a medical program including:
 - a. Skin tests on all new employees. If positive they can be assigned to any job; if negative, especially Negroes and Filipinos, job exposure must be carefully evaluated. If heavy concentration of dust cannot be avoided, those with negative skin tests should not be employed at that job.
 - b. Retest of susceptibles. This should be continued every three to six months until immunity is demonstrated by conversion to a positive reaction.
 - c. Prompt treatment of respiratory illness in susceptibles. Coccidioidomycosis is a suspect in such illnesses (and if such is the case early chemotherapy can reduce the severity).
4. Educate the exposed population.
 - a. New employees should be informed of the potential of infection and its consequences.
 - b. All employees should be advised to seek prompt medical treatment for any respiratory illness and to inform the attending physician of their possible exposure to the fungus, particularly if the physician practices outside the endemic area.
5. Control dust exposure by:
 - a. Oiling or planting of areas around plants, offices, and residences.
 - b. Filtering and conditioning of air supplies to plants and offices; providing air conditioned cabs on heavy equipment.

- c. Providing respirators, air supplied helmets, and the like, as indicated.
- d. Preventing transport of *C. immitis* outside endemic area by thoroughly cleaning equipment and specimens before shipment to other work locations.

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Mr. Schmelzer is environmental health and safety officer, and Dr. Tabershaw is professor of occupational medicine and head, Environmental Health and Safety, Office of Environmental Health, University of California, Berkeley, Calif.

This paper was presented before the Occupational Health Section of the American Public Health Association at the Ninety-Fourth Annual Meeting in San Francisco, Calif., October 31, 1966.

VALLEY FEVER

IT'S IN THE AIR • BE AWARE

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[Prevention Tips](#)

[Resources](#)

[Community Toolkit](#)

[History](#)



Message from the Director

Valley Fever affects thousands of residents in Kern County every year, and its impact can be devastating. As someone who has personally faced the challenges of this illness, I can speak to the gravity of its effects. In May of 2024, I was diagnosed with a rare and severe form of Valley Fever called cocci meningitis. Cocci meningitis is a permanent Valley Fever infection in the brain and spine. This experience has given me an intimate understanding of the long-term consequences Valley Fever can have on our health, as well as the challenges—both positive and negative—that accompany antifungal treatment.

While it is easy to become complacent or desensitized to the warnings about Valley Fever, it is crucial that we remain vigilant. The symptoms of Valley Fever can often be mistaken for other illnesses, but the earlier it is diagnosed, the better our chances of preventing severe complications. I encourage everyone to familiarize themselves with the symptoms of Valley Fever and take them seriously. If you are experiencing symptoms, ask your doctor for a Valley Fever test.

Early diagnosis and treatment can make a significant difference in your health outcome. Let's all work together to raise awareness, promote early detection, and reduce the impact that Valley Fever has on our community. Thank you for visiting our website, and for taking the time to learn more about Valley Fever. Your health matters, and by staying informed, you can protect yourself and your loved ones in our community.

— Brynn Carrigan, Director of Public Health Services



Valley Fever, also called coccidioidomycosis or "cocci," is a disease caused by a fungus that grows in soil and dirt in parts of California and the southwestern U.S. When the soil is disturbed by wind or activity, tiny fungal spores can become airborne and be breathed in, potentially making people and animals sick. The infection usually affects the lungs, causing symptoms like cough, fever, chest pain, and fatigue. While some may experience mild or no symptoms, others can develop severe illness. Early detection is key—if you've had a lingering cough, fever, or painful breathing for more than two weeks, ask your doctor about Valley Fever. It's in the air. Be aware!



Quon Louey
Executive Director,
Telehealthdocs

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Valley Fever: Many Faces, Many Stories

Valley Fever doesn't discriminate—it can affect anyone. The tiny fungal spores that cause it are carried in the air, stirred up by wind or dust, and breathed in without anyone realizing it. Some people may only experience mild symptoms, like a lingering cough or fatigue, while others face severe illness that can last for months or even years. No two experiences are the same.

Behind every case of Valley Fever is a real person with a story to tell—a mother, a teacher, a director, a neighbor. Each journey is different. Their voices bring awareness. Their stories bring hope. These are the faces of Valley Fever.

Have a story you'd like to share?

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Pages



Do you have a question about Valley Fever? Email: valdovinosli@kerncounty.com

VALLEY FEVER

IT'S IN THE AIR • BE AWARE

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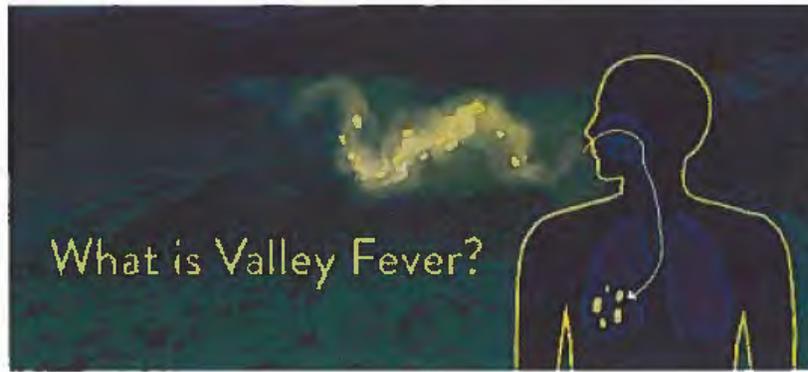
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Early diagnosis and treatment can make a significant difference in your health outcome. Let's all work together to raise awareness, promote early detection, and reduce the impact that Valley Fever has on our community. Thank you for visiting our website, and for taking the time to learn more about Valley Fever. Your health matters, and by staying informed, you can protect yourself and your loved ones in our community.

— Brynn Carrigan, Director of Public Health Services



Valley Fever, also called coccidioidomycosis or "cocci," is a disease caused by a fungus that grows in soil and dirt in parts of California and the southwestern U.S. When the soil is disturbed by wind or activity, tiny fungal spores can become airborne and be breathed in, potentially making people and animals sick. The infection usually affects the lungs, causing symptoms like cough, fever, chest pain, and fatigue. While some may experience mild or no symptoms, others can develop severe illness. Early detection is key—if you've had a lingering cough, fever, or painful breathing for more than two weeks, ask your doctor about Valley Fever. It's in the air. Be aware!



Quon Louey
Executive Director,
Telehealthdocs

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Healt**

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Valley Fever: Many Faces, Many Stories

Valley Fever doesn't discriminate—it can affect anyone. The tiny fungal spores that cause it are carried in the air, stirred up by wind or dust, and breathed in without anyone realizing it. Some people may only experience mild symptoms, like a lingering cough or fatigue, while others face severe illness that can last for months or even years. No two experiences are the same.

Behind every case of Valley Fever is a real person with a story to tell—a mother, a teacher, a director, a neighbor. Each journey is different. Their voices bring awareness. Their stories bring hope. These are the faces of Valley Fever.

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Do you have a question about Valley Fever? Email: valdovinosli@kerncounty.com

Large-Scale Land Development, Fugitive Dust, and Increased Coccidioidomycosis Incidence in the Antelope Valley of California, 1999–2014

Aaron J. Colson · Larry Vredenburg · Ramon E. Guevara · Natalia P. Rangel · Carl T. Kloock · Antje Lauer

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Abstract Ongoing large scale land development for renewable energy projects in the Antelope Valley, located in the Western Mojave Desert, has been blamed for increased fugitive dust emissions and coccidioidomycosis incidence among the general public in recent years. Soil samples were collected at six sites that were destined for solar farm construction and were analyzed for the presence of the soil-borne fungal pathogen *Coccidioides immitis* which is endemic to many areas of central and southern California. We used a modified culture-independent nested PCR approach to identify the pathogen in all soil samples and also compared the sampling sites in regard to soil physical and chemical parameters,

degree of disturbance, and vegetation. Our results indicated the presence of *C. immitis* at four of the six sites, predominantly in non-disturbed soils of the Pond Oban complex, which are characterized by an elevated pH and salt bush communities, but also in grassland characterized by different soil parameters and covered with native and non-native annuals. Overall, we were able to detect the pathogen in 40% of the soil samples ($n = 42$). Incidence of coccidioidomycosis in the Antelope Valley was positively correlated with land use and particulate matter in the air (PM10) (Pearson correlation coefficient >0.5). With the predicted population growth and ongoing large-scale disturbance of soil in the Antelope Valley in coming years, incidence of coccidioidomycosis will likely further increase if policy makers and land developers continue to ignore the risk of grading land without implementing long-term dust mitigation plans in Environmental Impact Reports.

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Introduction

Large-scale land development in the Antelope Valley, located in northern Los Angeles County in California, provides new residences for expanding populations, facilities for businesses, fields for agriculture, and

more recently provided opportunities for renewable energy production. However, arid and semiarid areas in the Southwestern US may require better care in managing soil disturbance from such projects because of greater risk of fugitive dust emissions and coccidioidomycosis, caused by the soil-born fungal pathogen *Coccidioides* spp. Fugitive dust is the suspension of particulate matter in the air by wind or human activities usually indicated as particulate matter up to 10 μm (PM10). The particulate matter is primarily soil but can contain crystalline silica, asbestos fibers, heavy metals, and airborne spores and conidia from microorganisms. Fugitive dust in general can cause breathing difficulties, low acute and chronic respiratory illnesses, increased risk of death from aggravated heart or lung disease [2, 12, 25, 27], increased risk of traffic accidents from poor road visibility [4], and reduced agricultural crop yield and desertification [75]. Fugitive dust emissions observed in the Antelope Valley frequently exceed California standards of 50 $\mu\text{g}/\text{m}^3$ for PM10 (24 h averages) and 30 $\mu\text{g}/\text{m}^3$ (annual arithmetic mean), respectively, which are stricter than federal standards (see <http://www.arb.ca.gov/research/aaqs/caaqs/caaqs.htm> for current California Ambient Air Quality Standards [CAAQS]). The increase in air pollution with coarse particulate matter (PM10) has raised the concern of public health officials and the general public [59], because of increased incidence of coccidioidomycosis among residents of the Antelope Valley (County of Los Angeles Department of Public Health, Annual Morbidity and Specials Studies Reports 2000–2014). Incidence of coccidioidomycosis in the Antelope Valley increased about 13-fold between 2000 and 2014 (supplementary figure S1). Strong Santa Ana winds can deliver dust from the desert to the LA Basin and deliver conidia of the pathogen to an area that is thought to be non-endemic for the pathogen [58].

The Antelope Valley is located in the Western Mojave Desert within the endemic zone of *Coccidioides* spp. which is comprised of certain areas in Arizona, California, Nevada, New Mexico, Texas, Utah, Washington, and Central and South America (see map in [55]). Fugitive dust that carries arthroconidia of *Coccidioides immitis* or *C. posadasii* can cause coccidioidomycosis in humans and animals primarily through inhalation of these dormant forms of the pathogen. Coccidioidomycosis primarily affects the pulmonary system in people and animals [16, 23],

but dissemination of the disease to other organs can occur [28, 57]. Although about 60% of infected people develop mild to no symptoms, the other 40% experience weeks to months of debilitating disease that can include fatigue, shortness of breath, cough, fever, night sweats, loss of appetite or weight, chest pain, headache, body aches, skin rash, and pneumonia [63]. Less than 5% of these patients develop disseminated coccidioidomycosis, which increases the risk of life-long complications and death [23, 43, 71]. Despite considerable efforts, no vaccine to protect humans from coccidioidomycosis currently exists [74].

The issue of fugitive dust carrying *Coccidioides* spp. arthroconidia is important not just for workers involved in land development projects, but also for residents of nearby communities, residents of newly built neighborhoods, and visitors working, studying, or travelling through the area. Furthermore, strong winds can transport conidia far distances, sometimes hundreds of miles, which can cause disease in humans and animals in non-endemic areas [21, 34, 35, 56].

The Antelope Valley of California provides an opportunity to examine how changes in the environment due to large-scale land development effect incidence of coccidioidomycosis in humans. Consisting of over 1800 mi^2 of fertile lands, the Antelope Valley is located approximately 2500 ft above sea level and is part of the “Lower Sonoran Lifezone” [53], sometimes referred to as the “High Desert,” a common name for a subregion located mostly in northwestern San Bernardino County, northeastern Los Angeles County, and far eastern Kern County in areas above 2000 ft in altitude [39, 77]. The valley experiences an annual precipitation of 6–9 inches per year, a mean annual high temperature of 98 °F in the summer and 59 °F in the winter, with temperatures commonly above 100 °F in July and August [51]. Mountains along the Southern and Western border of the Mojave Desert block most of the moisture-bearing westerly winds from the coast, limiting precipitation and air humidity, and strong prevailing winds can result in severe dust storms [62].

The Antelope Valley has the greatest potential for land development in Los Angeles County, and its land use increased notably between 2001 and 2011 (Fig. 1). Guevara et al. [33] showed that disturbance of soil during the “housing boom” that peaked between 2004 and 2005 was positively correlated with a spike in coccidioidomycosis incidence at the same time. In

recent years, the Antelope Valley has become the focus of renewable energy projects to provide solar- and wind-generated energy for Southern California [11, 38]. Solar farms constructed by multiple companies will ultimately cover more than 30,000 acres in the valley (e.g. [17, 19, 31], for an overview of all planned renewable energy projects). Overall, the DRECP affects approximately 22,858,000 acres of semiarid and arid soils in the counties of Los Angeles, Kern, Inyo, San Bernardino, Riverside, Imperial, and San Diego.

Purpose and Scope

This project aimed to determine whether *C. immitis* is established in soils destined for photovoltaic system construction in the Antelope Valley, characterize the ecologic features of *C. immitis* positive sites, and correlate field findings with existing epidemiologic, geologic, and geographic data. Soil samples collected at six photovoltaic system sites either completed or destined for construction by 2014 or 2015 (Bureau of Land Management [BLM], CA, DRECP) were tested for the presence of *Coccidioides* spp. with a culture-independent polymerase chain reaction (PCR)-based approach. The sampled sites included non-disturbed locations covered with natural vegetation, predominantly *Atriplex polycarpa*; disturbed grassland with native and non native annuals; fallow agricultural fields; and land impacted by sheep grazing. With this study, we hope to raise awareness of an increasing environmental health hazard that has been neglected in the past. Policy makers and others involved with large-scale land development projects could use the results from this study to implement better dust control approaches with more stringent requirements to reduce fugitive dust emissions and incidence of coccidioidomycosis and other dust-related illnesses among construction workers and the general public.

Materials and Methods

Soil Sampling Area

All soil sampling sites were located in the Antelope Valley subsection of the Western Mojave Desert in northern Los Angeles County west of the city of Lancaster and south of the rural town Antelope Acres

(Fig. 2). The Antelope Valley watershed is a large topographic depression with no hydrologic outlet to the ocean. The runoff into the basin from surrounding creeks is conveyed via broad ephemeral washes toward several dry lakes. Two large dry basins, or playas, the Rosamond and Roger's dry lake beds (Kern County) form dominant natural landscape features within the Antelope Valley and are located east of the sampling area.

Ecological Landscape Characterization of Sampling Sites

Soil samples were collected at six sites destined for solar panel construction. These locations included site 1: North Lancaster Silverado Project, site 2: West Antelope Silverado Project, site 3: American Silverado Project, site 4A and B: Antelope Silverado Project, site 5: Silver Sun Silverado Project, and site 6: Lancaster WAD Project. Soil parameter information for all sites was obtained from the United States Department of Agriculture (USDA) websoilsurvey database. Coordinates of all sampling spots were documented, and the appearance of soils, as well as the vegetation cover (plant species and degree of coverage and disturbance), was documented. Plant species were identified using the Jepson Desert Manual [5] and other literature [49, 54]. Rodent activity was observed at all sites in form of pellets, burrows or both. Soil samples were collected from soil types that were dominant in the locations destined for solar panel constructions and were collected from 5 to 7 cm depth. The pH of all soil samples was analyzed as well (two replicates). Pictures of all sampling sites can be seen in Fig. 3. Detailed site descriptions can be found in supplementary table S1.

Soil Samples Collection

Thirty-one samples were collected at six sites on May 14 and 16 2014. Three to six individual soil samples (~25 g) were collected aseptically at several individual sampling spots at each of the six locations, using a small garden shovel and 50-ml Falcon tubes. After evaluation of all results from the 2014 sampling set, additional 11 soil samples were collected in May 2016 from site 6 only. All samples were transported to the laboratory on ice to prevent changes in the microbial communities and were stored at -20 °C before being

Fig. 1 Overview of land use in the Antelope Valley in 2001 (a) compared to 2011 with indication of renewable energy projects (b). The six sampling sites investigated in this study are indicated as *yellow circles*. (Color figure online)

processed the following week. The sampling sites were documented photographically, coordinates were determined, and vegetation cover and visual appearance of all soils in regard to disturbance, erosion, rodent activity, soil moisture, and soil color was described.

DNA Extraction and PCR

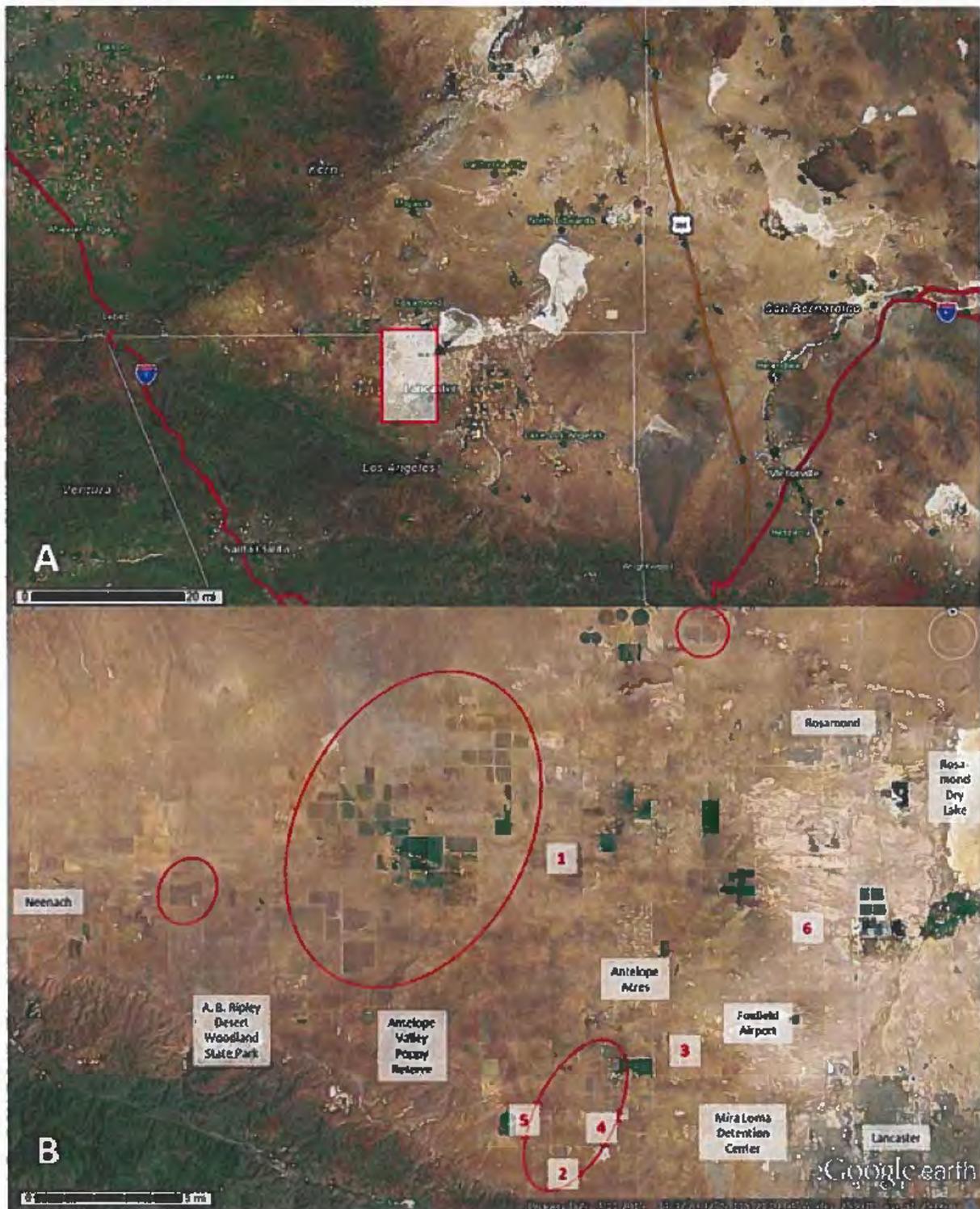
Soil samples were first mixed thoroughly by vortexing until homogenized. Prior to DNA extraction using the Powersoil DNA extraction kit (MoBio, Carlsbad, CA), 0.25 g of each soil sample was transferred into buffer-containing MoBio Powerbead tubes and incubated at 70 °C for 30 min, followed by an incubation step with 100 µl proteinase K (10 mg/ml) at 56 °C for additional 30 min [79] to enhance lysis of microbial spores and conidia. DNA extraction was performed according to the manufacturer's protocol (MoBio, Carlsbad, CA) using a MoBio vortex adapter for the bead-beating process. Two replicates were analyzed for each sample. The amount of DNA was quantified using the Qubit™ 3.0 Fluorometer (Invitrogen Life Technologies, Carlsbad, CA).

To determine the presence of *C. immitis* in all soil samples, a nested PCR approach based on the method published by Baptista-Rosas et al. [7] was used with modifications. A nested PCR can be superior to a one-step PCR method in that it excludes non-target DNA, therefore reducing possibilities of non-specific amplification. As the final diagnostic PCR step, we used 3 different primer pairs: (1) We replaced the originally suggested diagnostic primer pair with the ITSC1Af/ITSC2r primer pair (~220 bp, ITS 2 region) published by Greene et al. [32], which we found superior in specificity for *Coccidioides* spp. than the diagnostic primer pair used in Baptista-Rosas et al. [7] (data not shown), which was originally published by Binnicker et al. [9]. (2) We also used the EC3f/EC100r diagnostic primer set [36, 37] to detect *C. immitis*, which amplifies a ~500-bp amplicon, large enough to distinguish the 2 species within the genus *Coccidioides* and which covers both ITS regions of the ribosomal gene. (3) We also used the diagnostic primer pair ITS1Cf/

ITS1Cr which amplifies a ~130 bp region of the ITS1 region of the ribosomal gene, published by Vargas-Gastéum et al. [76]. Overall, three sets of primers were used for each nested PCR approach. Aliquots of all PCR amplicons were analyzed using 2% (wt/vol) agarose gel electrophoresis to determine the correct size of the amplicons using a PCR marker (Promega G3161) (Promega Madison, WI) and ethidium bromide staining (0.5 mg/l). The first primer combination NSA3/NLC2 targets the ribosomal gene (18S and 5.8S DNA and both ITS regions) of all fungi and results in a ~1,100-bp amplicon. Amplicons from the NSA3/NLC2 combination were then used as a template in a nested PCR approach using primer combination NS11/NLB4 which results in a ~910-bp fragment targeting a fragment of the ribosomal gene of Basidiomycetes and Ascomycetes only (see [7] for details). The final PCR step was the diagnostic PCR using a 1:25 dilution of the amplicons obtained with primer pair NS11/NLB4 as a template and one of the diagnostic primer sets mentioned earlier in a final PCR. All PCR reactions were performed in duplicate, and the PCR cycling conditions as described in the original protocols were used (see Table 1 for details). PCR reactions contained 12.5 µl of GoTaq Green Mastermix (Promega, Madison, WI), 1.5 µl of each primer (10 pmol/µl), 2 µl of DNA extract or 1.5 µl of the product of a previous PCR reaction for the nested PCRs, as well as sterile water to a final volume of 25 µl. Negative control reactions, which contained all reactants with the exception of template DNA, were also included in all amplifications. These controls were carried through the entire nested PCR process along with the environmental products. Leftover PCR amplicons obtained via diagnostic PCR of approximately correct size (~220, ~500, ~130 bp) were subsequently treated with exoSAP-IT (Affymetrix, Santa Clara, CA), sequenced at the Center for Bioinformatics at the University of Florida, and subsequently compared to entries in the GenBank nucleotide database available at the National Center of Biotechnology Information (NCBI) (<http://blast.ncbi.nlm.nih.gov/Blast.cgi>) [1]. The sequencing step was necessary because occasionally false-positive amplicons were obtained.

Analysis of pH

Soil pH was determined on a 1:1 (w/v) soil/water mixture composed of 5 g of soil and 5 mL deionized



water. Samples were stirred before and after an equilibration period of 1 h and were then measured with an Oakton-510 bench-top pH meter (Oakton

Instruments, Vernon Hills, IL) after calibration to pH buffers 4, 7 and 10. Two replicates were performed for each soil sample and the average was determined.

Fig. 2 a Aerial view of the Western Mojave Desert with indication of our sampling area (red rectangle) in the Antelope Valley, west of the city of Lancaster (Los Angeles County). b Aerial photo of the Antelope Valley as of April 2015 (landsat 8). Red numbers indicate all sampling sites (site 1 North Lancaster Silverado project, site 2 West Antelope Silverado Project, site 3 American Silverado Project, site 4A and B Antelope Silverado Project, site 5 Silver Sun Silverado Project, site 6 Lancaster WAD project). The red circles indicate areas where photovoltaic stations were constructed between 2009 and 2015. Construction sites outside these circles were not completed when this study was undertaken. The city of Lancaster is indicated in the lower right corner of the photo, south of the Rosamond dry lake bed. Also indicated are the Antelope Valley Poppy Reserve, the Arthur B. Ripley Desert Woodland State Park and the Mira Loma Detention Center. The settlement Antelope Acres is situated between the construction sites west of Foxfield Airport. (Color figure online)

Results

DNA Extraction and PCR

DNA of high quality was successfully extracted from all samples as confirmed by 2% agarose gel electrophoresis and subsequent ethidium bromide staining which resulted in distinct bands of non-sheared DNA. The amount of DNA extracted from 0.25 g of soil varied between soil samples and ranged between 29.2 and 9780 ng/ml. Site 6 had the smallest amount of DNA extracted (29.2–2420 ng/ml), whereas DNA extractions from samples collected at site 4 resulted in the highest amount of extracted DNA (3840–9780 ng/ml) (Table 2).

The nested PCR approach to detect *Coccidioides* spp. confirmed DNA of fungal origin in all soil samples and also confirmed DNA of Ascomycetes and/or Basidiomycetes in 90% of the samples. An example of nested PCR results including all three individual PCR steps with all diagnostic primer pairs is shown in Fig. 4 for a subset of samples. Table 2 summarizes the results of all PCRs and includes the closest matches in the GenBank nucleotide database for all sequenced amplicons. After comparing all sequences to entries in the Genbank nucleotide database, 17 soil samples (40.48%) were found positive for the pathogen with PCR amplicons of 99 or 100% similarity to a *C. immitis* entry in the GenBank nucleotide database (6.7, collected in 2016, showed a faint band of correct size with primer pair ITS1Cf/ITS1Cr which could not be confirmed by sequencing). Two additional soil samples resulted in

amplicons that were 89% related to *C. posadasii* (sites 4B3 and 5.4 collected in 2014). Most of the false-positive PCR products were related to fungi in the order Capnodiales (*Cladosporium* spp.). In some occasions multiple species contributed to an amplicon, resulting in a “noisy” sequence that could not be identified. PCR products obtained with diagnostic primer pair EC3f/EC100r resulted more often in false-positive results than PCR products obtained with primer pair ITS1Af/ITS2r. Diagnostic primer pair ITS1Cf/ITS1Cr was the most specific of all three primer pairs tested, resulting in no false-positive amplicons. This primer pair was also the most sensitive one, because it detected the pathogen in 23.81% of the samples (28.57% if the two unconfirmed samples are considered as well). Primer pair EC3f/EC100r detected the pathogen in 11.9% of the samples, while primer pair ITS1Af/ITS2r detected *C. immitis* in 19.05% of the samples. Samples 6.2 collected in 2016 was the only sample that tested positive for the pathogen with all three diagnostic primer pairs. Five samples collected in 2014 and one sample collected in 2016 were indicated positive with two out of the three diagnostic primer pairs. Individual sampling spots where the pathogen was detected are shown in supplementary figure S2. Examples of high-quality sequences obtained with all 3 diagnostic primer pairs were deposited in the GenBank nucleotide database available at the National Center for Bioinformatics and Information (NCBI) (Accession No. KY306689–KY306699).

Characterization of Soil Samples

Variation in soil characteristics was observed for all sampling sites (USGS Soil Survey Antelope Valley, www.usdawebsoilsurveydatabase; Table 3; and supplementary figure S3). Soils in the sampling area varied in soil parent material, and in regard to chemical and physical parameters, as indicated by different USDA soil map units. Overall, the soil types that were the most common in our sampling area were characterized as Hesperia fine sandy loam (~10% of the sampling area), Greenfield sandy loam (~18%), Cajon loamy sand (~5.5%), Pond loam (5%), Rosamond fine sandy loam (~4%), Sunrise sandy loam (~6.5%); several others each covered <4% of the study area. Soils belonging to the Pond-Oban complex covered a large area of the valley around Rosamond and Roger’s

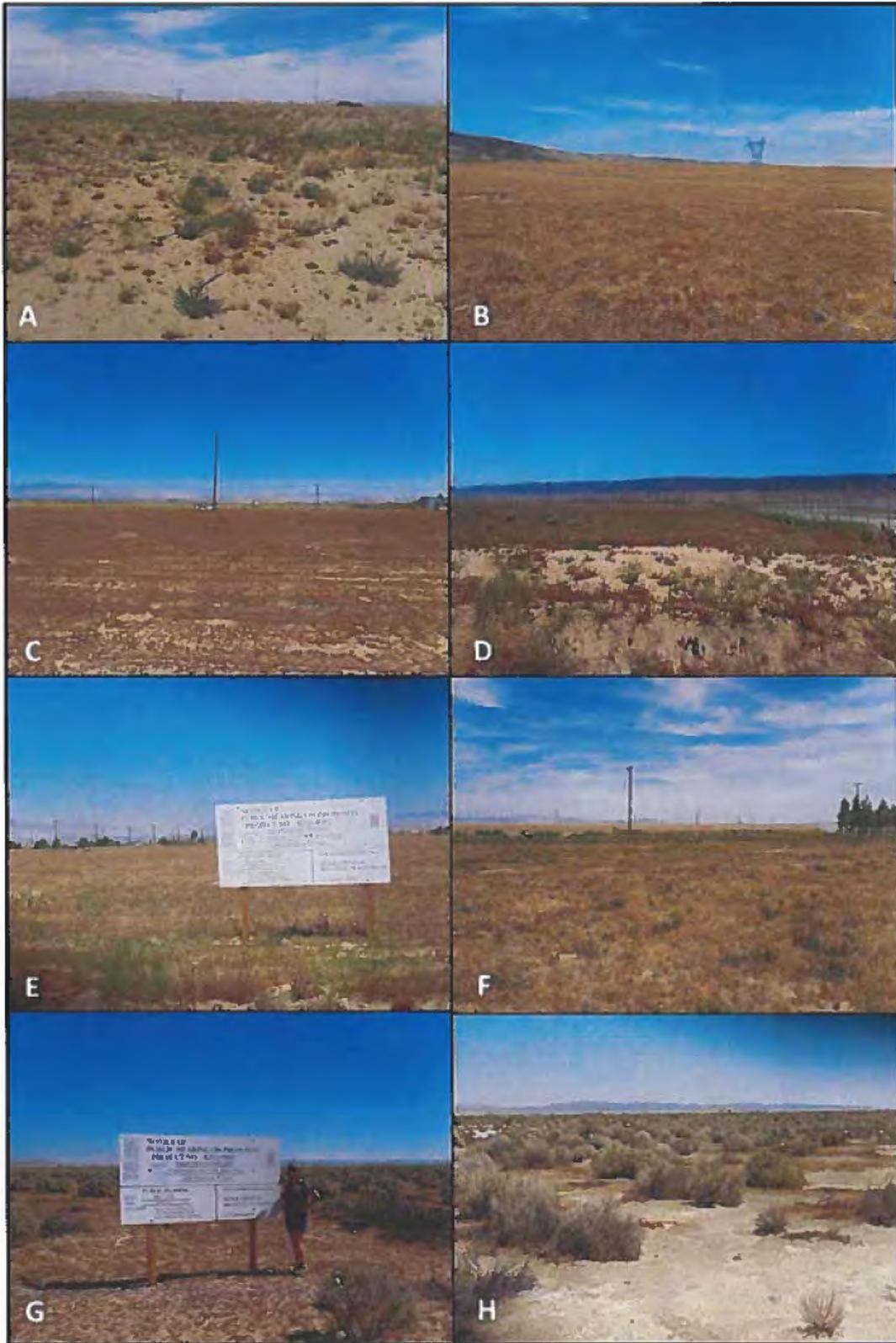


Fig. 3 Landscape overview of all sampling sites at the time of sampling (May 2014). **a** Site 1, a disturbed site with scattered native and non native vegetation. **b** Site 2, grassland with native and non native annuals. **c** Site 3, disturbed land with scattered native and non-native vegetation. Surrounding areas grew rabbit brush (*Ericameria nauseosa*) (as can be seen in the background). **d** Site 4A, a disturbed area with scattered native and non native vegetation. **e** Site 4B, grassland with native and non-native annuals. **f** Site 5, disturbed site with grasses and other non-native and native species. **g** and **h** Site 6, dominated by scattered salt bushes and occasional rabbit brush. Dried *Lastenia californica* can be seen in between the salt bushes (*Atriplex* spp.)

dry lake bed and comprised ~15% of the eastern study area where sampling site 6 was located. Soil pH generally increased with proximity to the Rosamond dry lake bed and ranged between pH 5 and 9.4. The pH varied considerably for subsamples from sites 2, 4A and 6, but were more uniform among samples from sites 1, 3, 4B and 5. Furthermore, average soil pH results observed in our laboratory differed from the

averaged values indicated in the USDA websoilsurvey database. For example, fine sandy loam samples from sites 1 and 6 appeared less alkaline when analyzed in our laboratory. Samples positive for *C. immitis* also varied in pH, but the majority of the positive soil samples showed a pH higher than 7 and less DNA could be retrieved compared to samples with a lower pH (Fig. 5; supplementary figure S4). Snail parameters that were indicative of the presence of *C. immitis* in previous research in the Southern San Joaquin Valley (Kern County) [44, 45] predicted site 6 in the Antelope Valley as a potential growth site of the pathogen (Table 3). However, sites 2, 3 and 5 where the pathogen was detected as well were not indicated as potential growth sites based on soil parameters. Other soil types near our sampling sites, such as Rosamond loam and Tray loam, share some of the parameters that were indicative of the presence of the pathogen in the San Joaquin Valley, but these soils were not

Table 1 Position of primers on ribosomal gene (A), all primer pairs used for nested PCR reactions with PCR amplification conditions and references (B)

A		130 bp		220 bp		650 bp		900 bp		1,000 bp	
B											
Primer	Sequence	T _m	Cycling conditions ^a				Expected product size	Reference			
			Annealing temperature (°C)	Temperature (°C)	Time (s)	Number of cycles					
NSA3f	5'-AAACTCTSTCGTGCTGGGGATA-3'	58.1	55	95, 55, 72	30, 40, 40	35	~1100	Martin [50]			
NLC2r	5'-GAGCTGCATCCCAACAACTC-3'	56.8	55				~1100	Martin [50]			
NS1f	5'-GATTGAATGGCTTAGTGAGG-3'	50.8	60	95, 60, 72	30, 40, 40	35	~910	Martin [50]			
NLB4r	5'-GGATTCTCACCTCTATGAC-3'	51.7	60				~910	Martin [50]			
ITSC1Af	5'-CATCATAGCAAAATCAAA-3'	45.3	53	94, 53, 72	60, 60, 60	45	~220	Greene et al. [32]			
ITSC1Ar	5'-AGGCCCGTCCACACAAG-3'	58	53				~220	Greene et al. [32]			
EC3f	5'-ATTAAAGTGGCGTCCGGCTG-3'	58.1	57	95, 57, 72	30, 40, 40	45	~500	Johnson et al. [36,37]			
EC100r	5'-CGATGAAGTGATTTCCCATACA-3'	52.3	57				~500	Johnson et al. [36,37]			
VG-ITSf	5'-GTGGCSTCCGCTGCGCACCTCCCGCGG-3'	78.1	70	95, 70, 72	30, 40, 60	45	~130	Vargas-Gastélum et al. [76]			
VG-ITSr	5'-GCGCAAGCGGGCGATCCCAGCC-3'	76.2	70				~130	Vargas-Gastélum et al. [76]			

f Forward primer, r reverse primer

^a All samples were subjected to an initial melting step of 94 or 95 °C for 10 min and a final extension step of 72 °C for 10 min

Table 2 Results of nested PCRs with indication of closest matches in the GenBank nucleotide database for amplicons obtained with the diagnostic primer pairs ITSC1A/ITSC2r, EC3f/EC100r and ITS1C/ITS1Cr

Sample ID	NSA3/NLC2	NS11/NLB4 <i>Ascomycetes/ Basidiomycetes</i>	ITSC1A/ITSC2r		EC3f/EC100r		ITS1C/ITS1Cr		DNA extracted	
			<i>Coccidioides</i> spp.	% Similarity to closest match in GenBank	<i>Coccidioides</i> spp.	% Similarity to closest match in GenBank	<i>Coccidioides</i> spp.	% Similarity to closest match in GenBank	(ng/ml)	pH
1.1	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 99%	Negative		2800	6.90
1.2	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 94%	Negative		2640	7.13
1.3	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 95%	Negative		1960	7.13
2A.1	Positive	Positive	Positive	<i>Coccidioides immitis</i> , HG380500, 100%	False positive	unc. <i>Capnodiales</i> , JF691038, 93%	Positive	<i>Coccidioides immitis</i> , KM679413, 100%	3320	5.95
2.2	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 94%	Negative		4360	7.28
2.3	Negative	Negative	Negative		Negative		Negative		7280	6.90
2.4	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 90%	Negative		1406	5.24
2.5	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 93%	Negative		1858	6.29
2.6	Positive	Positive	Positive	<i>Coccidioides immitis</i> , HG380500, 100%	Negative		Positive	<i>Coccidioides immitis</i> , KM679413, 100%	4700	7.12
3.1	Positive	Positive	Positive	<i>Coccidioides immitis</i> , HG380500, 99%	False positive	unc. <i>Capnodiales</i> , JF691038, 95%	Positive	<i>Coccidioides immitis</i> , KM679413, 100%	3520	6.73
3.2	Positive	Negative	Negative		?	Multiple sequences***	Negative		3480	6.76
3.3	Positive	Positive	Negative		?	Multiple sequences	Negative		2500	6.03
3.4	Positive	Positive	False positive	unc. <i>Eurotiales</i> , HQ389458, 95%	False positive	unc. <i>Capnodiales</i> , JF691038, 99%	Negative		6620	6.79
3.5	Positive	Positive	Positive	<i>Coccidioides immitis</i> , KJ783449, 100%	Positive	<i>Coccidioides immitis</i> , KJ783449, 100%	Negative		4400	7.11
4A.1	Positive	Positive	False positive	unc. <i>Eurotiales</i> , HQ389458, 96%	False positive	unc. <i>Capnodiales</i> , JF691038, 94%	Negative		3840	6.81
4A.2	Positive	Positive	Smear**		False positive	unc. <i>Capnodiales</i> , JF691038, 96%	Negative		9780	6.50
4A.3	Positive	Positive	Negative		False positive	<i>Ascochyta</i> sp., KC959210, 85%	Negative		6980	5.59
4B.1	Positive	Negative	Smear		False positive	unc. <i>Capnodiales</i> , JF691038, 95%	Negative		4520	7.38
4B.2	Positive	Positive	False positive		False positive		Negative		5900	7.55

Table 2 continued

Sample ID	NSA3/NLC2	NS11/NLB4	ITSC1A1/ITSC2r		EC3f/EC100r		ITS1Cf/ITS1Cr		DNA extracted	
				% Similarity to closest match in GenBank		% Similarity to closest match in GenBank		% Similarity to closest match in GenBank	(ng/ml)	pH
2014	All fungi	<i>Ascomycetes/ Basidiomycetes</i>	<i>Coccidioides</i> spp.	<i>Trichophyton terrestre</i> , LN714614, 96%	<i>Coccidioides</i> spp.	unc. <i>Capnodiales</i> , JF691038, 94%	<i>Coccidioides</i> spp.			
4B.3	Positive	Positive	False positive	<i>Coccidioides posadasii</i> , KF386150, 89%	False positive	unc. <i>Capnodiales</i> , JF691038, 94%	Negative		8020	7.36
5.1	Positive	Negative	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 94%	Negative		7040	6.67
5.2	Positive	Positive	False positive	<i>Cladosporium macrocarpum</i> , KC311478, 95%	False positive	unc. <i>Capnodiales</i> , JF691038, 92%	Positive	<i>Coccidioides immitis</i> , KM679413, 100%	3760	6.44
5.4	Positive	Positive	False positive	no similarity found	False positive	<i>Coccidioides posadasii</i> , JX051631, 89%	Negative		8040	6.69
5.5	Positive	Positive	Negative		False positive	Multiple sequences	Negative		3280	6.75
5.6	Positive	Positive	Negative		False positive	unc. <i>Capnodiales</i> , JF691038, 93%	Negative		7120	6.50
6.1	Positive	Positive	?	multiple sequences	Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Negative		1796	7.44
6.2	Positive	Positive	Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Negative		Negative		1270	8.15
6.3	Positive	Positive	Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Negative		Negative		2420	7.04
6.4	Positive	Positive	Smear		Negative		Negative		2080	7.00
6.5	Positive	Positive	Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Negative		174	9.45
6.6	Positive	Positive	Negative		Negative		Positive	<i>Coccidioides immitis</i> , KM679413, 100%	29.2	8.79
2016										
6.1	Positive	Positive	Negative		Positive	No signal (faint PCR product)	Positive	<i>Coccidioides immitis</i> , KM679413, 98%	120	8.12
6.2	Positive	Positive	Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Positive	<i>Coccidioides immitis</i> , KJ783449, 94%	Positive	<i>Coccidioides immitis</i> , KM679413, 100%	85.8	7.38
6.3	Positive	Positive	Negative		Positive	<i>Coccidioides immitis</i> , KJ783449, 99%	Positive	No signal, faint PCR product	53	6.91
6.4	Positive	Positive	Negative		False positive	Fungal endophyte, KT291114, 94%	Positive	<i>Coccidioides immitis</i> , KM679413, 100%	1014	7.94
6.5	Positive	Positive	Negative		Negative		Negative		324	8.25
6.6	Positive	Positive	Negative		Negative		Negative		55.6	9.53

Table 2 continued

Sample ID	NSA3/ NLC2	NST1/NLBA	ITSC1A/ITSC2r		EC3/EC100r		ITS1C/ITS1Cγ		DNA extracted (ng/ml)
			Ascomycetes/ Basidiomycetes	Coccidioides spp.	% Similarity to closest match in GenBank	Coccidioides spp.	% Similarity to closest match in GenBank	Coccidioides spp.	
2014	All fungi								
6.7	Positive	Positive	Negative	Negative	False positive	Fungal endophyte, KT291114, 96%	Positive	No signal, faint PCR product	964
6.8	Positive	Positive	Negative	Negative	Negative		Negative		210
6.9	Positive	Positive	Negative	Negative	False positive	No similarity found	Negative		458
6.1	Positive	Positive	Negative	Negative	False positive	No similarity found	Positive	<i>Coccidioides immitis</i> , KM679413, 100%	244
6.11	Positive	Positive	Negative	Negative	Negative		Positive	<i>Coccidioides immitis</i> , KM679413, 100%	766

Positive samples and their closest match in the GenBank database are presented in bold

investigated in this study (soils where the pathogen was detected are indicated as positive [bold]).

Environmental Parameters and Incidence of Coccidioidomycosis

Environmental parameters, such as fugitive dust emission (PM10), total annual precipitation (inches), and wind speed (gust max.), were obtained for the Mojave Air Basin for the years 2000–2015. In addition, we obtained land-use data (acres) [15] and coccidioidomycosis incidence data [14] for the same time period and area (Fig. 6). An increase in incidence of coccidioidomycosis over time can be seen with highest incidence in the Antelope Valley in 2005, 2011 and 2014, spiking shortly after years with increased soil disturbance due to the “housing boom” between 2003 and 2007 [33] and the renewable energy boom described in this study. Between 2005 and 2014, the number of approved permits for solar farms and wind parks increased with additional large-scale and small-scale projects pending permission. So far, more than 20,000 acres of land have been disturbed as of 2014 for renewable energy projects in the Antelope Valley and the surrounding foothills of the Tehachapi and San Bernardino Mountains [30, 31]. The acreage of field crops increased by 48% compared to the year 2000 and then steadily declined by 2014 reaching values close to those documented before 2008 (County of Los Angeles Crop and Livestock Report 2014). The correlation between incidence of coccidioidomycosis in the Antelope Valley and the amount of acres of land disturbed for renewable energy projects and amount of acres under agricultural management (field crops) between 2000 and 2014 was strong, as revealed by a correlation coefficient of $r^2 = 0.623$ (Pearson product-moment correlation coefficient) and $r^2 = 0.388$. The correlation between PM10 (Mojave Air Basin) and disease incidence was at best weak with a Pearson coefficient of 0.283 and an r^2 value of 0.0664 (see Fig. 6 for all correlation values). However, the correlation between PM10 and incidence of the disease was strong when only the years between 2009 and 2014 were considered (renewable energy boom), with a Pearson coefficient of 0.641 and an r^2 value of 0.411. To investigate these relationships in more detail, a multiple regression analysis was conducted (Table 4). This analysis shows that neither PM10 nor levels of precipitation appear to have had a



Fig. 4 Displayed are 2% agarose gels after ethidium bromide staining, showing examples of diagnostic PCR results for samples from some locations. Sequences from PCR amplicons circled in black were 99% related to a GenBank database entries of *C. immitis*. White arrows point toward amplicons of correct size including some that were revealed as false positives. **a** Results of

amplification with primer pair ITSC1A/ITSC2r showing amplicons of ~220. **b** Results of amplification with primer pair EC3/EC100r showing amplicons of ~300 bp. **c** Results of amplification with diagnostic primer pair ITS1C/ITS1Cr showing positive results for samples 5.2 and 6.6 (2014). (*C.i.* *Coccidioides immitis* used as positive control; *NC* negative control)

significant relationship with coccidioidomycosis incidence (2000–2014). However, the total acres of land under the three land-use types considered (wind, solar and agricultural) did have a significant, positive relationship with coccidioidomycosis incidence ($p < 0.01$) over the same time period. We investigated the relationship with land use further by conducting a second multiple regression, removing the non-significant factors and disaggregating the three land-use types, to determine whether effects could be attributed to specific type of lands use. This analysis revealed no significant differences between the effects of the different land-use categories (Table 5).

Discussion

A correlation between soil disturbances due to large-scale renewable energy construction projects, agricultural management practices and PM10 fugitive dust emission with increased incidence of coccidioidomycosis was clearly indicated by results of this study. The increasing incidence of coccidioidomycosis in the Antelope Valley of California, which has reached epidemic character, is concerning and shown in supplementary figure S1. The *C. immitis* positive sites detected in this study are located west of the cities of Lancaster and Palmdale and south of the community of Antelope Acres which are part of what is known as the Greater Antelope Valley Economic Alliance (GAVEA) which has experienced a population increase of 24% between 2000 and 2010 (US Census Bureau). It has been predicted that the population will continue to grow another ~46% by 2035, to 758,881

residents [31]. The predicted population growth will result in continued urbanization as of yet unknown proportions, but certainly of significant size. Therefore, it is expected that fugitive dust emissions from ongoing construction sites will continue or even increase. This environmental health hazard will put humans and animals at an increased risk for contracting coccidioidomycosis, especially if dust mitigation continues to be inefficient or absent. In addition to increased urbanization and renewable energy development in this area, an ongoing drought with decreasing precipitation and sinking ground water tables has been blamed for soil erosion and fugitive dust development in the Antelope Valley. The ongoing drought has also resulted in a significant reduction in farming activities over the last years, resulting in large areas of abandoned fields. For example, the farmed acreage of orchards decreased from 2013 to 2014 by 53.06%, and the farmed acreage for grapes decreased by 22.6% during the same time in the County [48].

It has been difficult in the past to determine a clear correlation between incidence of coccidioidomycosis and certain environmental parameters, because of combined immediate or delayed positive or negative effects on the growth of the pathogen in the soil. Previous work by Talamantes et al. [72] determined a weak correlation between precipitation and wind speed and coccidioidomycosis incidence in Kern County. Smith et al. [69] and Kirkland and Fierer [40] had already pointed out that a rainy winter can cause an increase in coccidioidomycosis incidence in the following dry season, especially after a prolonged drought that might have caused a shift in the microbial community toward spore and conidia formers, among

Table 3 Averaged soil physical and chemical parameters for dominant soil types found in our sampling area with indication of soil map unit symbols, as obtained from the USDA websoilsurvey database (pH was also analyzed at CSUB). (Color figure online)

Soil parameters (averaged data)		Sampling sites				
Sites	1*	1, 3*	2*, 4A*, 4B*, 5	2, 4, 5*	8*	
Map unit name	Rosamond fine Sandy loam	Hesperia fine Sandy loam	Greenfield Sandy loam	Aamona coarse sandy loam	Pond Oban complex	
Landform	Alluvial fans	Alluvial fans	terraces, alluvial fans	terraces	Basin floors	
Parent material	Alluvium derived from granite	Alluvium derived from granite	Alluvium derived from granite	Alluvium derived from granite	Alluvium derived from granite	
Map unit symbols	Ro	HkA	GsA/GsC	RcB/RcC	Pk	
Physical parameters						
Surface texture	Fine sandy loam	Sandy loam	Sandy loam	Coarse sandy loam	Fine sandy loam	
Clay (%)	18.8	13	11	7.5	25.7	
Sand (%)	51.9	70.5	66	69.6	46.5	
Silt (%)	29.3	16.5	23	22.9	27.8	
Available water capacity (cm/cm)	0.14	0.13	0.13	0.1	0.08	
Available water supply (0–25 cm)	3.45	2.5	3.25	2.5	2.04	
Organic matter (%)	0.17	0.08	0.75	0.75	0.25	
Water content (15 bar) (%)	12.1	8.1	7.4	6	15.8	
Water content (1/3 bar) (%)	23.3	17.2	16.4	14.7	27.5	
Sat. hydraulic conductivity (Ksat) (µm/s)	21.67	28	28	28	4.8	
Chemical parameters						
pH (websoilsurvey database)	8	7.4	6.7	6.7	8.9	
pH (determined at CSUB)	7.1 (site 1)	6.7 (site 3)	6.4 (site 2), 6.1/6.6 (site 4A/4B)	6.8	8	
CaCO ₃	5	2	0	0	3	
Cation exchange capacity (CEC) (milliequivalents/100 g)	10	7.5	7.5	7.5	15.8	
Gypsum	0	0	0	0	0	
Sodium adsorption ratio (SAR)	0	0	0	0	12.7	
Electrical conductivity (EC) (decisiemens/m)	1.7	0.7	0	0	14	
Wind erodibility index (tons per acre per year)	86	86	86	86	86	
Detection of <i>C. immitis</i>	Negative	Positive	Positive	Positive	Positive	
Soil parameters		Other dominant soils in the sampling area				
Sites	1	3	3	6	2	4
Map unit name	Rosamond loam	Cajon loamy sand	Tray sandy loam, Salina-silt loam	Tray Loam	Hanford Coarse sandy loam	Sunrise sandy loam
Landform	Alluvial fans	Alluvial fans	Basin floors	Basin floors	Alluvial fans	basin floors
Parent material	Alluvium derived from granite	Alluvium derived from granite	Alluvium derived from granite	Alluvium derived from granite	Alluvium derived from granite	alluvium derived from granite
Map unit symbols	Rp	CaA	Tv	Tw	HsC	Sv
Physical parameters						
Surface texture	Loam	Loamy sand	Sandy loam	Loam	Sandy loam	Sandy loam
Clay (%)	20.5	3.7	12.7	20	12.5	1.5
Sand (%)	34.7	83.1	65.8	42.1	68.2	65.9
Silt (%)	44.8	13.2	21.6	37.9	19.3	39.1
Available water capacity (cm/cm)	0.16	0.08	0.1	0.15	0.13	0.12
Available water supply (0–25 cm)	3.85	1.98	2.5	3.5	3.25	3
Organic matter (%)	0.17	0.57	0.58	0.75	0.58	0.25
Water content (15 bar) (%)	12.3	3.3	8.4	12.5	8.9	9.2
Water content (1/3 bar) (%)	27.7	10.9	17.7	27.1	17.8	18.3
Sat. hydraulic conductivity (Ksat) (µm/s)	9	92	21.7	9	28	28
Chemical parameters						
pH (websoilsurvey database)	8.2	7.2	9.1	9	6.7	7.9
pH (determined at CSUB)			Not determined			
CaCO ₃	5	1	3	3	0	8
Cation Exchange Capacity (CEC) (milliequivalents/100 g)	10	3	7.5	7.5	7.5	7.5
Gypsum	0	0	0	0	0	0
Sodium adsorption ratio (SAR)	0	0	3	3	0	0
Electrical conductivity (EC) (decisiemens/m)	1.3	0.2	5	5	0	1
Wind erodibility index (tons per acre per year)	56	134		48	86	86
Detection of <i>C. immitis</i>			Not investigated			

Soil parameters that were indicative of the presence of the pathogen in the Southern San Joaquin valley [44, 45] are indicated in red. Additionally, results from our PCR-based approach to detect *C. immitis* are included (at some sampling sites, more than one soil type was detected; therefore, the soil type of the soil samples analyzed is indicated with an *; soil types where the pathogen was detected are indicated with a red rectangle).

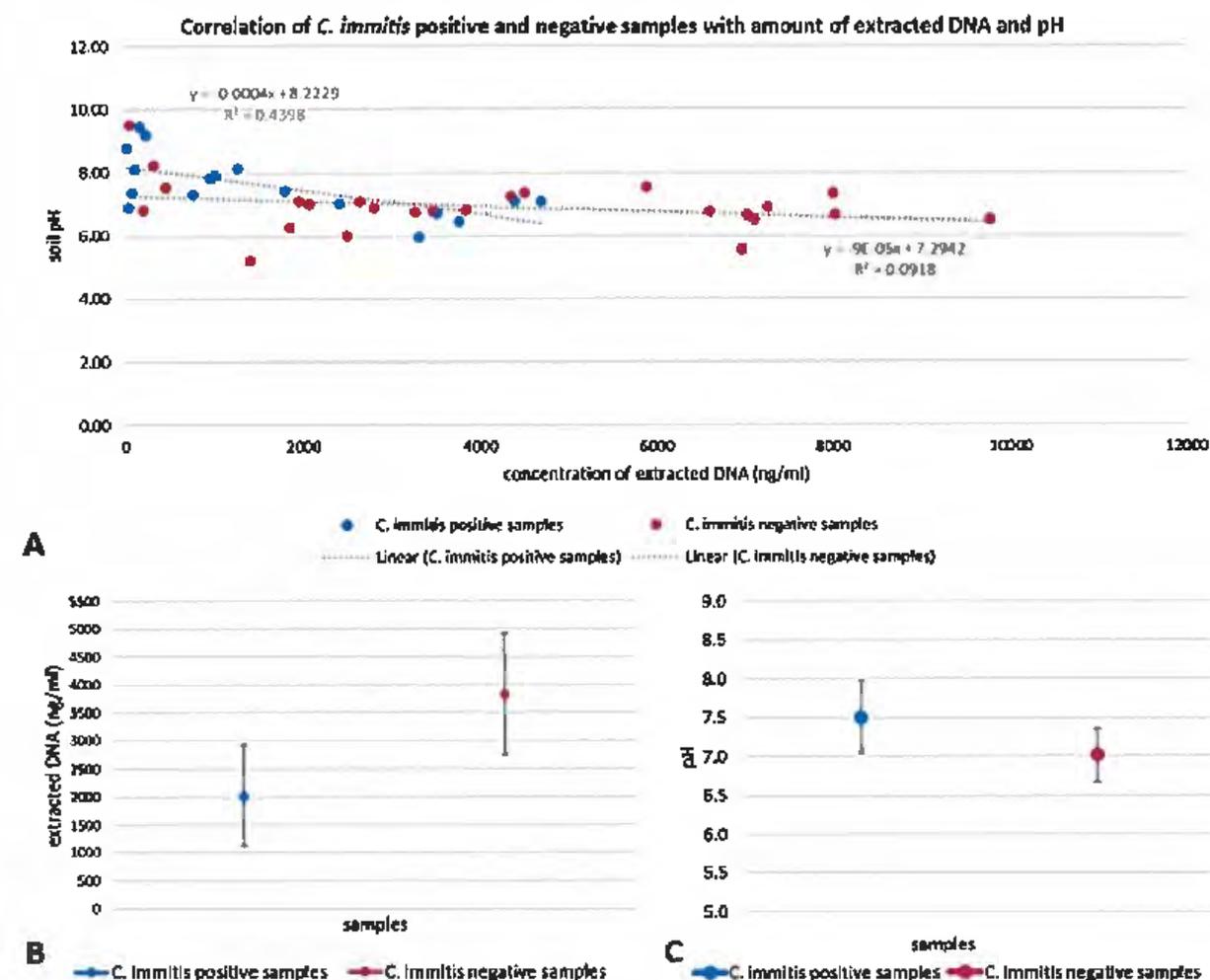


Fig. 5 **a** Correlation between soil pH and amount of extracted DNA. **b** The amount of extracted DNA from *C. immitis* positive soil samples was significantly lower than the amount of DNA extracted from *C. immitis* negative soil samples. **c** The pH of soils in which the pathogen was detected was higher than the pH of

soils that were negative for the pathogen. However, the difference was not significant (data were normally distributed based on the Shapiro-Wilkes test for normality of the residuals). (Color figure online)

them *Coccidioides* spp. In our study, we were able to clearly link land use and soil disturbance to valley fever incidence, but also found a positive correlation between PM10 and wind speed; however, the correlation was rather weak. The continued increase in coccidioidomycosis incidence in 2012 and 2013 when construction of new renewable energy projects slowed down was likely due to the long-term effect of large areas of graded soils, which continue to be a major source of fugitive dust emission in the Antelope Valley and beyond. In the past, California had been plagued with long-term and short-term droughts, for example the prolonged drought from 1985 to 1992

which resulted in increased fugitive dust emissions that reached a 24-h record PM10 concentration of $780 \mu\text{g}/\text{m}^3$ in downtown Lancaster in 1991 (Antelope Valley Air Quality Monitoring District).

We were able to detect the pathogen *C. immitis* predominantly in undisturbed alkaline soils of the Pond-Oban complex, located closest to the Rosamond dry lake bed, a location commonly referred to as “barren land” with different species of salt bushes, that indicate a saline and alkaline environment. Site 6 was the only sampling site that was suspected to harbor *C. immitis* based on averaged soil parameter information (USDA websoilsurvey database) that

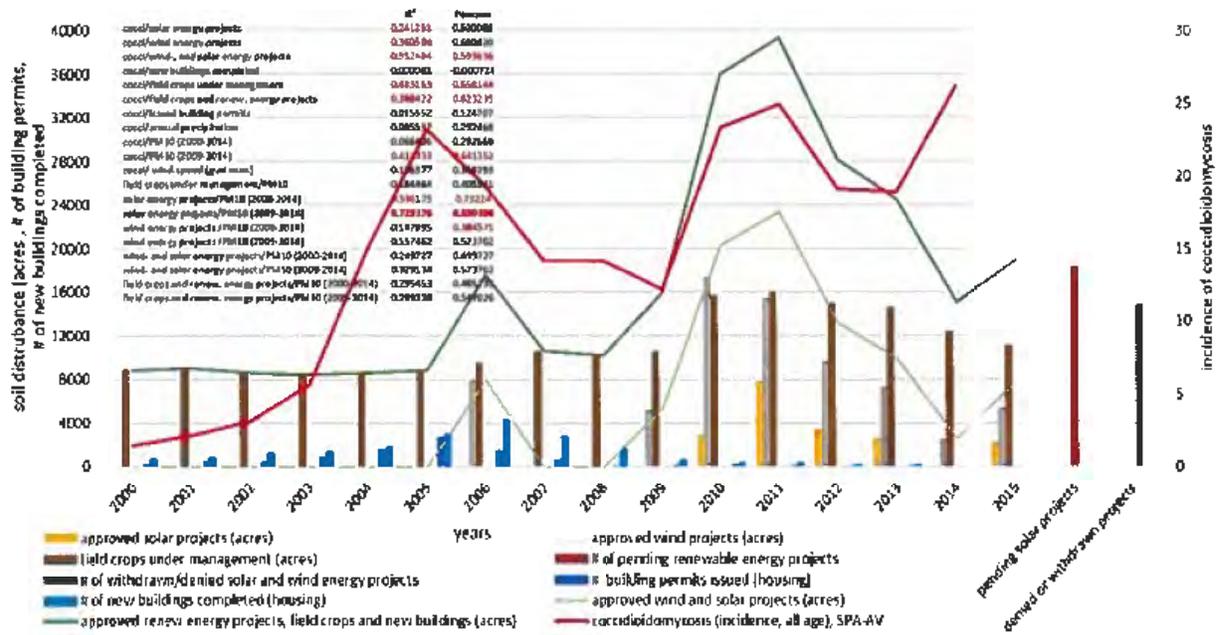


Fig. 6 Increase in soil disturbance over time in the Antelope Valley due to large-scale renewable energy project construction, changes in agricultural management correlated with incidence of coccidioidomycosis. Displayed are approved solar and wind projects (acres), agricultural fields under management (acres), as well as the number of issued building permits and completed buildings (housing developments) between 2000 and 2014. Included in the calculations (but not included in the graph) is also PM10 data (High National 24-Hour Average), precipitation

(inches), and wind-speed data (gust max.) for the city of Lancaster measured at Foxfield Airport (KWJF). Solar and wind farms were graphed one year after the permit approval date because the begin of construction generally began in the year after permits were issued (data sources: www.arb.ca.gov/adam, <http://publichealth.lacounty.gov/acd/Publications.htm>, http://planning.lacounty.gov/assets/upl/project/energy_projects.pdf, <http://pcd.kerndsa.com/planning/renewable-energy>, <http://lacfb.org/crop-reports-2/>)

Table 4 Results of the initial multiple regression model: the model was coccidioidomycosis incidence = PM10 + precipitation + acres of land use (summed across Solar projects, wind projects, and active agricultural use)

	Estimate	SE	t	p
(Intercept)	4.90	3.06	1.61	0.13
PM10	-6.14 × 10 ⁻³	1.06 × 10 ⁻²	-0.580	0.57
Annual Precipitation (in)	1.34	1.08	1.24	0.24
Acres of land use	4.04 × 10 ⁻⁴	1.20 × 10 ⁻⁴	3.36	0.0057**

Final model is: coccidioidomycosis incidence = 4.9 - 0.0062 × PM10 + 1.33 precipitation + 0.00040 land use. $F_{3,12} = 4.8$, $p < 0.05$, multiple $R^2 = 0.54$

were indicative of the presence of the pathogen in the Southern San Joaquin Valley [44, 45]. The Southern San Joaquin Valley Desert is geologically somewhat related to the Western Mojave Desert where the Antelope Valley is located, but differs in elevation and climate [24]. Soils of both locations developed from quaternary alluvium and similar underlying parent material and have been described as alluvial fans or

fan remnants and basin floors, with high concentrations of fine particulate matter that accumulated since the late Pleistocene and earlier. However, the pathogen was also detected in grassland from soils characterized as Greenfield sandy loam, Hesperia fine sandy loam, and Ramona fine sandy loam (sites 2, 3 and 5). The grassland appeared similar to a strong growth site of the pathogen, Sharktooth Hill near Oildale, east of

Table 5 Results of the 2nd multiple regression model: the model was coccidioidomycosis incidence – acres of solar projects + acres of wind projects + acres active agricultural use

	Estimate	SE	t	p
(Intercept)	-6.02	15.8	-0.38	0.711
Solar	8.86×10^{-05}	1.72×10^{-04}	0.052	0.96
Wind	5.16×10^{-05}	7.34×10^{-04}	0.070	0.945
Crop	1.78×10^{-03}	1.66×10^{-03}	1.07	0.306

$$F_{(3,1)} = 2.3, p > 0.1, \text{ multiple } r^2 = 0.36$$

Bakersfield, not far away from a severely disturbed area, the Kern River oilfields, but the physical and chemical parameters of soils from Sharktooth Hill (high clay content) were more similar to those determined at site 6. Fossil diggers repeatedly became infected with *C. immitis* at Sharktooth Hill, where the presence of the pathogen has been confirmed repeatedly [20, 45, 64, 70]. Overall, soils from all *C. immitis* positive sites in the Antelope Valley and the Bakersfield area can be characterized as fine particulate sandy loam. The investigation of other soil types should be included in future studies to refine the set of environmental parameters that are indicative of the presence of the pathogen and to deepen our understanding of the ecology of *C. immitis* in California. The diversity of habitats that *C. immitis* can apparently grow in indicates that the pathogen is able to adapt to somewhat different soil environments or that different ecotypes of the pathogen exist which might explain its “spotty distribution” [6, 20]. Furthermore, it should be noted that site 6 where the pathogen was detected repeatedly had the lowest amounts of extracted DNA. A fungal species such as *Coccidioides* spp. which is missing some key enzymes needed to grow successfully as a saprophyte in soil might benefit from a low diversity of overall soil microbes that could include potential competitors and antagonists [65].

It has been difficult and expensive to detect *Coccidioides* spp. in soil and dust samples in the past [8, 22], but modern culture-independent molecular methods became available in recent years which allow for successful screening of environmental samples for the presence of *C. immitis* and *C. posadasii* [7, 36, 37, 42, 44–46, 66, 76]. However, soil analyses for the detection of soil-borne pathogens, such as *Coccidioides* spp., have not been included in Environmental Impact Reports (EIRs) for any construction

project planned in the Antelope Valley or in other endemic areas of the pathogen in the Southwestern US. The scarcity of experts who are familiar with the procedures to detect the pathogen in its natural environment, additional costs of soil analyses, and a general underestimation of the risk of otherwise healthy people of contracting coccidioidomycosis from dust exposure might explain this potentially risky situation.

Mitigation and regulatory efforts are likely to be inadequate if the current trends in development and associated fugitive dust emissions continue. During spring 2014, fugitive dust emissions in the Antelope Valley negatively impacted air quality to an extent never documented before, reaching values up to and above $1000 \mu\text{g}/\text{m}^3$, which reminded people of the Great Dust Bowl of the 1930's in Oklahoma [47], or the extreme dust storms documented in Owens Valley after the 110 mi² Owens Lake had been dried to support the water thirsty city of Los Angeles for a little more than a decade (1913–1926, feeding the Los Angeles aqueduct, see [60, 67]). Wilken et al. [78] indicated the inability of current dust mitigation strategies to protect construction workers from infections with *Coccidioides* spp. Lack of regulatory expertise and unrealistic expectations have resulted in costly failures of dust mitigation methods in the Western Mojave Desert in the past as described in McRae [52]. Environmental Impact Reports (EIRs) have been particularly criticized for not describing how dust mitigation measures are implemented and supervised, and no long-term dust control mitigation measures are included in the reports [73].

Mitigation and regulations are important considerations because some of the construction projects are in the immediate neighborhood of schools or close to human settlements. For example, the Del Sur Solar Project [Conditional Use Permit (Nos. 14-15 and 14-16)] is located adjacent to and upwind of Del Sur Elementary School. As of October 2012, the enrollment consisted of approximately 750 students in grades K-8 who would be directly and constantly affected by fugitive dust emissions because of daily westerly winds.

Although rarely implemented, potential mitigation procedures have been developed. Re-vegetation of disturbed land as a long-term strategy of dust control has been suggested by the Antelope Valley Dustbusters Taskforce, a group which consists of private

entities, as well as federal, city, and county government representatives [3, 29, 41], but the implementation of their recommendations into Dust Control Plans (DCPs) rarely occurred [10]. Based on 20 years of dust mitigation experience in the Antelope Valley, The Dustbusters Task Force of 1991 developed handbooks for farmer and homeowners in the Antelope Valley which are publicly available at (http://www.kernair.org/Main_Pages/information.html#; see also [18, 29, 61, 68]). Based on the findings of this study, we recommend that EIRs include soil analyses for *Coccidioides* spp. on land destined for construction of any type in endemic areas of the pathogen.

Conclusion

Although the change from non-renewable to renewable energy is generally welcomed in California, disturbing soils in endemic areas of a soil-borne pathogen that already causes disease incidence of epidemic character should only be considered if successful long-term dust mitigation measures are implemented, supervised, and controlled. The increasing demand for renewable energy shows promise for our planet in the future and will reduce some airborne emissions. However, there are hazards when soaring new locations. One such danger is *Coccidioides* spp. arthroconidia becoming airborne when soil is disturbed and dust mitigation measures are inefficient or absent.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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Anthropogenic Degradation of the Southern California Desert Ecosystem and Prospects for Natural Recovery and Restoration

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ABSTRACT / Large areas of the southern California desert ecosystem have been negatively affected by off-highway vehicle use, overgrazing by domestic livestock, agriculture, urbanization, construction of roads and utility corridors, air pollution, military training exercises, and other activities. Secondary contributions to degradation include the proliferation of exotic plant species and a higher frequency of an-

thropogenic fire. Effects of these impacts include alteration or destruction of macro- and micro-vegetation elements, establishment of annual plant communities dominated by exotic species, destruction of soil stabilizers, soil compaction, and increased erosion. Published estimates of recovery time are based on return to predisturbance levels of biomass, cover, density, community structure, or soil characteristics. Natural recovery rates depend on the nature and severity of the impact but are generally very slow. Recovery to predisturbance plant cover and biomass may take 50–300 years, while complete ecosystem recovery may require over 3000 years. Restorative intervention can be used to enhance the success and rate of recovery, but the costs are high and the probability for long-term success is low to moderate. Given the sensitivity of desert habitats to disturbance and the slow rate of natural recovery, the best management option is to limit the extent and intensity of impacts as much as possible.

We've mined it, dammed it, irrigated it, developed it, and subjected it to nuclear assault, yet the desert, somehow both fragile and tough, manages to endure, a rugged old touchstone for us to measure ourselves against.

Malcolm Jones, Jr., 1996

The landscape and native vegetation of the southern California deserts have been significantly altered during the last century by a variety of factors including: livestock grazing (Bentley 1898, Humphrey 1958), introduction of exotic species (Mooney and others 1986, Rejmánek and Randall 1994), off-road vehicle use (see reviews in Webb and Wilshire 1983), urbanization and its attendant effects (Reible and others 1982, Walsh and Hoffer 1991), and military activities (Lathrop 1983a, Prose and others 1987). Extreme temperatures, intense sun, high winds, limited moisture and the low fertility of desert soils make natural recovery of the desert very slow after disturbance (Bainbridge and Virginia 1990). Conditions suitable for plant establishment occur only infrequently and irregularly, and it may take hundreds of years for full recovery to take place without active

intervention. Many of the actions of desert development and utilization have profound effects on ecosystem stability, diversity, and productivity (Rundel and Gibson 1996).

The literature on human impacts to the biotic and physical components of the Mojave Desert is large and diffuse. In this paper we review the major human-induced impacts on the California desert, and the prospects for natural recovery and restoration, by characterizing the effects of past actions on the Mojave Desert ecosystem and other arid lands. In addition, we briefly suggest practical strategies and methods for planning and implementing desert restoration projects and improving recovery of these areas by soil management, transplanting, direct seeding, and other techniques.

Area of Study

Our review focuses on the Mojave and Colorado Deserts of southern California, an area of approximately 10 million ha. The Mojave Desert occupies portions of Inyo, Kern, Los Angeles, Riverside, and San Bernardino counties in California. The geographical and ecological boundaries of the Mojave Desert are

KEY WORDS: Mojave Desert; Colorado Desert; California; Human impacts; Recovery; Restoration

discussed in detail by Vasek and Barbour (1977) and Hickman (1993). The modern plant community of the Mojave has been characterized as "desert scrub" (Turner 1982, Hickman 1993), even though it is composed of several recognizable community types including: creosote bush scrub, saltbush scrub, shadscale scrub, black-bush scrub, and Joshua tree woodland (Vasek and Barbour 1977). Perennial plant diversity is low compared to the Colorado Desert: areas dominated by *Larrea tridentata* and *Ambrosia dumosa* occupy about 70% of the Mojave (Lathrop and Rowlands 1983). More than 250 species of annual plants are found in the Mojave, including 80–90 species that are endemic (Turner 1982). In Death Valley and the Salton Sink, annuals account for 42% and 47% of the local flora, respectively (Johnson and others 1978). Overall plant diversity is low below 1000 m, but increases to levels approaching more temperate habitats at higher elevations (Cody 1986).

The Colorado Desert is that part of the Sonoran Desert found mostly in Imperial and Riverside counties, California (Burk 1977). The Colorado Desert is generally separated from the Mojave Desert to the north by the Little San Bernardino, Cottonwood, and Eagle Mountains. The boundary between the two desert ecosystems is poorly defined to the east of these mountain ranges (Vasek and Barbour 1977). A bimodal rainfall pattern composed of winter frontal systems and summer convectional storms distinguishes the Colorado Desert from the western Mojave Desert (Burk 1977), where most precipitation comes from winter rains. In addition, the region is generally lower, flatter, hotter in the summer and warmer in the winter, and hosts a slightly different flora than the Mojave Desert (Hickman 1993). Dominant vegetation in the Colorado Desert is "Sonoran creosote-bush scrub" (Hickman 1993). Plant communities recognized by Burk (1977) include creosote bush scrub, cactus scrub, wash woodland, palm oasis, saltbush scrub, and alkali scrub. There is broad overlap of plant species between the Mojave and Colorado Deserts, but there are a significant number of freeze-sensitive arboreal species that are found only in the Colorado Desert.

Both deserts are characterized by dominant perennial plant species that are long-lived (Bowers and others 1995), some exceptionally so (Vasek 1980). Density and cover of long-lived species increases with age of the site surface (Webb and others 1987, 1988, Bowers and others 1997).

While our focus is specifically directed to the problems of desert lands in California (most of our experience is in the Colorado Desert), we believe our review will prove useful for desert management in other parts

of the Southwest, northern Mexico, and in other drylands around the world.

Factors Contributing to Habitat Degradation

The following sections summarize major anthropogenic degradation factors in the southern California desert ecosystem other than agricultural development and urbanization. An understanding of the nature and the effect of disturbances is useful in estimating recovery times or determining what course of action may be required to restore a habitat. Table 1 summarizes the estimated time intervals required for affected plant communities to fully or partially recover from human-induced disturbances.

Impacts on the desert can be loosely divided into historic and current impacts. There is rarely a complete distinction between the two but, in general, the historic impacts include such things as overgrazing, aqueduct building, and the operation of the Desert Training Center in World War II. Grazing still continues, but the major impacts from grazing occurred in the mid to late 1800s. A very rough estimate of the magnitude and extent of these different activities is shown in Table 2. The following factors are not presented in order of importance.

Livestock and Grazing

Cattle and sheep have grazed almost continuously through large areas of the region from the mid-1800s to the present, although the numbers have dropped off in recent years. The establishment of ranching fostered the development of a major industry in the western United States that prospered until droughts, harsh winters, and overgrazing caused a series of dramatic herd declines in the late 1800s. Populations of sheep (60,000) and cattle (67,000) peaked in Imperial County in 1920. In 1968 there were 25,000 cattle and 138,000 sheep grazing on Bureau of Land Management (BLM) and National Monument desert lands in California, predominantly in the Mojave (Ruch 1968). In 1979, 1.8 million ha of public lands administered by the BLM in the California desert were grazed by 75,000 sheep and 14,000 cattle (Bureau of Land Management 1980). Excellent histories of grazing in the desert southwest are provided by Humphrey (1958, 1987).

No published studies have yet fully documented the impact of grazing by livestock in the California desert or estimated the time required for heavily grazed areas to recover to pregrazing levels of plant diversity, density, and cover (Oldemeyer 1994). The rarity of undisturbed reference sites and long-term studies makes it difficult to quantify the effects of grazing, but it is possible to

Table 1. Estimated natural recovery times in years for California desert plant communities subjected to various anthropogenic impacts

Impact	Location	$T_{RECOVERY}$	Reference
Tank tracks (military)	eastern Mojave	65,* 76 ^b	Lathrop (1983a)
Tent areas (military)	eastern Mojave	45,* 58 ^b	Lathrop (1983a)
Dirt roadways (military)	eastern Mojave	112,* 212 ^b	Lathrop (1983a)
Tent sites (military)	eastern Mojave	8–112 ^c	Prose and Metzger (1985)
Tent roads (military)	eastern Mojave	57–440 ^c	Prose and Metzger (1985)
Parking lots (military)	eastern Mojave	35–440 ^c	Prose and Metzger (1985)
Main roads (military)	eastern Mojave	100–infinity ^c	Prose and Metzger (1985)
Military	eastern Mojave	1500–3000 ^d	Prose and Metzger (1985)
Townsites	northern Mojave	80–110,* 20–50, ^e 1000+	Webb and Newman (1982)
Pipeline	southern Mojave	centuries ^f	Vasek et al. (1975a)
Powerline	southern Mojave	33 ^b	Vasek et al. (1975b)
Fire	western Colorado Desert	5 ^{b1}	O'Leary and Minnich (1981)
Off-road vehicle use	western Mojave	probably centuries	Webb et al. (1983)
Pipeline (berm and trench)	Mojave Desert	100 ^g	Lathrop and Archbold (1980b)
Pipeline (road edge)	Mojave Desert	98 ^g	Lathrop and Archbold (1980b)
Powerline pylons and road edges	Mojave Desert	100 ^g	Lathrop and Archbold (1980b)
Under powerline wires	Mojave Desert	20 ^g	Lathrop and Archbold (1980b)

*Recovery time to control density.

^bRecovery time to control cover.

^cEstimated recovery time for *Larrea tridentata* to reach control densities.

^dEstimated recovery time ("if at all") for recovery to original vegetative structure assuming establishment of control densities.

^eCompaction recovery time.

^fTotal estimated recovery time.

^g30–40 years assuming linear rates of succession; 3000 years until formation of large creosote clonal rings.

^{b1}Incomplete recovery time in areas of high impact

^gTime for appearance of perennial seedlings. See Brown and Minnich (1986) in section on fire

Biomass recovery assuming that successional vegetative growth is approximated by a straight line. Recovery of long-lived species is estimated to take at least three times longer than indicated.

Table 2. Adverse impacts on California desert, their relative intensity and historical occurrence

Impact	Intensity	Current/historic
Grazing	moderate	primarily historic
Removal of native people	moderate	historic
Invasive plants	moderate/severe	historic/current
Highways	severe	current
Urbanization	severe	current
Off-road vehicles	severe	current
Agriculture	severe	both
Military operations	severe	both
Mining	locally severe	both
Linear corridors	locally severe	current

describe the nature of these impacts and their probable extent. Consequently, conclusions about the effects of grazing on arid ecosystems have been contradictory and controversial (Anonymous 1991, Borman and Johnson 1990, Coe 1990, Field 1990, General Accounting Office 1992, Gillis 1991, Poling 1991). Some argue that grazing is beneficial to rangelands, suggesting that the act of grazing stimulates new plant growth (Savory 1988).

Other putative positive benefits include the dispersal of seeds, production of fertilizer in the form of excrement, and churning of soil generated by moving hooves (but see Ralph and Malocheck 1985). Others point to negative impacts of grazing including: soil compaction and increased erosion, trampling of plants, and overcropping. Grazing effects on arid ecosystems are reviewed in detail by Archer and Smeins (1991).

The effects of overgrazing are far less controversial. As early as the late 1800s there was recognition of dramatic range deterioration in the United States as a result of overstocking of cattle (Bentley 1898). In his report, Bentley concluded that "The ranges have been almost ruined, and if not renewed will soon be past all hope of permanent improvement." In spite of early recognition of a problem, solutions have still not been satisfactorily implemented (General Accounting Office 1992).

The impacts of grazing, whether positive or negative, may be extensive. In a recent biological assessment in the western Mojave Desert of California, 100% of a 234-square-km area was impacted to some extent by

sheep grazing (Tierra Madre Consultants 1991). In a detailed analysis of the effects of sheep grazing on 2.6 square km of desert tortoise habitat, Nicholson and Humphreys (1981) observed soil disturbances in 80% of the area used by sheep. Thirty-three percent of the plot was heavily used by sheep.

Livestock grazing, by its very nature, causes a decrease in plant cover and biomass, at least initially. Decreases in cover have been shown to be associated with a decrease in the diversity and abundance of lizards and other wildlife species in arid ecosystems (Busack and Bury 1974, Germano and Hungerford 1981, Germano and others 1983, Germano and Lawhead 1986). In the Mojave Desert Nicholson and Humphreys (1981) observed large decreases in plant cover in areas grazed by sheep. Similar results were reported by Webb and Stielstra (1979) in the Mojave. In addition, they observed a 60% reduction in above-ground biomass on plots grazed by sheep. Other studies, in American deserts outside of the Mojave Desert, have not detected appreciable differences between grazed and ungrazed plots (Heske and Campbell 1991, Rice and Westoby 1978), but most sites had been grazed before the studies were initiated. An important point to make is that the response of plants to grazing varies according to species, season, plant phenology (Genin and Badan-Dangon 1991), local conditions (drought, edaphic factors, etc.), and past historical use.

Direct effects of grazing on desert animals such as the desert tortoise (*Gopherus agassizii*) are not well documented. Grazing sheep can damage tortoise burrows. Nicholson and Humphreys (1981) reported that of 164 tortoise burrows on a 2.6-square-km study site, 10% were damaged and 4% were destroyed. Most burrows were well protected since they were generally located under shrub cover. Damage was considered to be insignificant since tortoises were often observed digging new burrows in late spring regardless of the availability of existing burrows. Others have gone so far as to suggest that cattle dung actually serves as an important food supply for desert tortoises (Bostick 1990), although this has never been rigorously substantiated (Hal Avery personal communication).

Webb and Stielstra (1979) observed that soils in the Mojave Desert exhibited greater surface strength in areas where sheep bedded and grazed relative to control areas. The greatest compaction occurred in the upper 10 cm but compaction was also observed at lower depths. At the surface, soils are trampled by grazing, often obliterating cryptobiotic soil crusts leading to increased erosional potential. Erosion is of special concern for desert soils because the nutrient capital is often concentrated in the surface soil. Gross disorgani-

zation of community structure is possible with the loss of only a few centimeters of soil (Charley and Cowling 1968).

Even limited grazing can cause significant shifts in vegetation and damage to soil crusts. Kleiner and Harper (1977) found that seven plant species that were common in the ungrazed area were absent or insignificant in a comparable grazed section of Canyonlands National Park. They attributed this in part to changes in cryptobiotic soil crust, which decreased from 38% cover in the ungrazed area to 5% in the lightly grazed area. Grazing also increases the spatial and temporal heterogeneity of water, nitrogen, and other soil resources, fostering increased desertification of productive arid lands (Schlesinger and others 1990).

As stated above, the rate of natural recovery of habitats exposed to grazing depends on the intensity of past grazing and local conditions. In a blackbrush (*Coleogyne ramosissima*) association in Utah and Arizona, shrub cover is greater in areas that have never been grazed than in grazed areas. In the same area, plots protected from grazing for ten years showed no difference from heavily grazed areas indicating slow rates of recovery (Jeffries and Klopatek 1987). Exclusion of grazing for 14–19 years did not allow recovery of native perennial grasses in southeastern Arizona (Roundy and Jordan 1988). In the deserts of Kuwait land degradation does not necessarily stop following protection from grazing (Omar 1991). Drought, erosion, and sand encroachment continue to degrade land in the absence of grazing. Human activities and grazing may hasten degradation, but in concert with drought the three can be devastating.

In a recent review of the effects of grazing on public land in the hot deserts (Chihuahuan, Mojave, and Sonoran) of the American Southwest, the General Accounting Office (1992) concluded that a high environmental cost has been exacted on these fragile ecosystems and that land degradation due to grazing is continuing. The report concluded by noting that the high environmental risks, budgetary costs, low economic benefits, and management problems associated with livestock grazing on hot desert public lands merits Congressional consideration. Recommended options included raising grazing fees or appropriating additional funds to offset costs of administration and monitoring, and discontinuing livestock grazing altogether in hot desert areas.

Different plant communities respond to grazing in a variety of ways related to a complexity of factors. Results for the Mojave Desert suggest that livestock grazing can have locally significant effects on the plants (Figure 1) and ultimately on desert wildlife. Efforts to restore

Figure 1. Cattle grazing can have locally significant effects on vegetation and soils, as shown in this photo of a cattle watering area and corral in what is now the Mojave National Preserve, California. Note the almost total destruction of perennial plants in the immediate area. The visual effect is greatly diminished as distance from the watering area increases. Photo by Jeff Lovich.



degraded rangeland in the Mojave should start by considering the effects of grazing and the potential impacts of soil compaction, erosion, and plant community alteration.

Linear Corridors

Roads, railways, powerlines, and pipelines, some of the most conspicuous elements of the modern Mojave Desert landscape, are all characterized by long and relatively narrow corridors of disturbance. The fact that most linear corridors are narrow does not necessarily imply that their impacts are minimal. According to Brum and others (1983), over 8000 km of overhead power transmission lines were present in the California desert in 1980, impacting more than 28,000 ha of land. An additional 50,000 ha of land will be impacted by the year 2000 if the projected threefold increase in power demand is accurate. Information summarized in the California Desert Conservation Area Plan (Bureau of Land Management 1980) suggests that an additional 2000 km of energy production and utility corridors are needed to meet the needs of southern California to the year 2000.

The immediate effect of linear corridor construction on soil conditions and plant cover is one of nearly complete destruction (Vasek and others 1975a). In some cases recovery is retarded due to operation and maintenance of corridors (Artz 1989). Other negative secondary effects of corridors include mortality of animals along roadways (Rosen and Lowe 1994, Boarman and Sasaki 1996), habitat fragmentation and restriction of movements and gene flow, increased access to remote areas for illegal collection and vandalism of plants and animals (Nicholson 1978, Garland

and Bradley 1984, Boarman and Sasaki 1996, Jennings 1991), and increased erosion (Wilshire and Prose 1987). The steel towers associated with many electrical energy transmission corridors provide nest sites and hunting perches for ravens (*Corvus corax*), a native predator that has increased dramatically in recent years due to human subsidy. The towers may allow ravens to hunt more effectively for the federally threatened desert tortoise (*Gopherus agassizii*) and other desert wildlife (Boarman 1993). Corridors can also serve as a source of exotic invasive plants brought in on construction equipment (Zink and others 1995). Invasive plants prosper in the disturbed conditions and contribute to an increased likelihood of fire. The construction of pipelines for gas, oil, and water and much more destructive than overhead lines because extensive trenching is usually required. This traditionally has led to severe soil impacts (leaving subsoil on the surface), disturbing stabilized crusts and rock surfaces, and concentrating runoff and erosion. More recent pipelines have incorporated some environmental protection and some rehabilitation but the low value of the desert land, the high cost of revegetation, and the lack of money for enforcement and supervision has often led to neglect and minimal treatment.

The impacts of linear structures can extend far beyond the boundaries of the immediate disturbance. Schlesinger and others (1989) studied the effects of diversion structures (earthen dikes) along the Colorado River Aqueduct on plants and soil. The structures were constructed to prevent runoff due to precipitation from washing sediments into open portions of the canal. Large areas downslope of the diversion structures received only incident precipitation, with essentially no runoff from the extensive drainages in the uplands

above the diversion structures. As a result, large areas of desert habitat on the downslope side of the diversion structures had a lower biomass of perennial and annual plants in comparison to adjacent areas with no diversion structures.

Garland and Bradley (1984) observed that some species of rodents in the Mojave of Nevada are more abundant near highways, while others are not. However, reduced abundance may have been an artifact of natural habitat heterogeneity since no mortality was observed during the 11-month study. Another effect of roads is edge enhancement in which perennial shrubs along roadsides are denser, larger, more vigorous, and support greater numbers of foliage arthropods than those away from roadsides (Vasek and others 1975b, Lightfoot and Whitford 1991). Johnson and others (1975) noted that primary productivity, as measured by standing crop, at study sites in the Mojave Desert of California increased about 17 times on the basis of vegetated area alone and 6 times when the area of the bare road surface was included as part of the productive unit. Unpaved roads showed increases of 6 and 3 times, respectively, in each category. Increased water availability from pavement runoff and increased retention of moisture under the pavement are probably responsible for the observed increase in plant vigor, although removal of competing plants that formerly occupied the roadway may confer an advantage to plants along the berm (Vasek and others 1975a). The increase in vigor attracts herbivorous insects (Lightfoot and Whitford 1991).

The effects and recovery of linear corridor construction in deserts have been studied by several researchers. The process of natural recovery, following powerline construction in the Sonoran Desert starts immediately with invasion by pioneering annual species, but perennial species may not return for over five years. The density and diversity of annual species may increase in comparison with undisturbed sites, perhaps due to the removal of large woody species (Hessing and Johnson 1982). An effect that is apparently linked to changes in plant abundance and composition is a reduction in the density, but not the community composition, of arthropods following establishment of access roads for powerline construction (Johnson and others 1983).

In the Mojave Desert, plant cover also increases following powerline construction. The rate of increase and composition of colonizing species varies considerably, confounding the ability to predict succession relative to adjacent undisturbed areas. Ground cover of short-lived perennial species increases in areas of severe disturbance, under the central wires, and along the edge of maintenance roads. After 33 years there was a

noticeable, but not complete, recovery of predisturbance vegetation (Vasek and others 1975b). Natural revegetation (0–41% ground cover) by long-lived perennials has been observed 12 years after construction of a pipeline by trenching, piling, and reilling (Vasek and others 1975a). Disturbed and control areas appear to have similar cover, biomass, and densities of vegetation following partial recovery, but similarities disappear when the proportions of long-lived and dominant species are compared (Lathrop and Archbold 1980a,b). Species with these characteristics are not well represented on disturbed sites.

Management strategies for minimizing the effects of linear corridor construction include: placement of power poles closer to existing access roads, modifying construction techniques for buried pipelines, less frequent road grading, and limiting the width of motorcycle race corridors along powerlines (Artz 1989). Lathrop and Archbold (1980b) proposed several recommendations for routing corridors to minimize environmental impacts including: (1) routing them through gently sloping areas to minimize erosion, (2) routing them through areas occupied by colonizing species such as cheesebush (*Hymenoclea salsola*), (3) avoiding areas dominated by high nitrogen fixation communities such as cat's claw acacia (*Acacia greggii*), and (4) avoidance of undue soil compaction with implementation of soil loosening efforts to aid natural revegetation. Revegetation of linear corridors was evaluated by Kay (1979, 1988), Graves and others (1978), and Brum and others (1983).

The slow recovery of the desert to linear corridor impacts is perhaps best demonstrated by the visibility of many of the old Native American trade routes. Long-term use by foot traffic alone was sufficient to compact the soil and recovery after several hundred years has not been enough to hide these trails (personal observation).

Mining

Mining has been an important activity in the California desert since the late 1880s. Mining communities such as Kokoweef, Hart Mountain, Boron, Johannesburg, and many others have had mostly localized impacts on the desert. The most obvious forms of degradation are pits, ore dumps, and tailings, but the once-great demand for fuel and timber, grazing, and road building associated with mines was unquestionably more important in the past. Fugitive dust and toxic tailings are a more recent concern from some of these mining areas.

The Bureau of Land Management (1980) estimated that 12,545 ha in the California Desert Conservation

Area had been affected by major mining operations. If the many small prospects and adits are included, the area affected by mining would certainly be larger. The brine evaporation and dry lake mine operations are extensive and lead to substantial wind erosion (Wilshire 1983). Another problem is animal mortality at poorly managed cyanide extraction gold mines in the Mojave Desert (Clark and Hothem 1991, Henny and others 1994).

Military Training Operations

Large areas of the California desert have been impacted by temporary and ongoing military activities. Major training exercises included activities by General Patton in the early 1940s, the Desert Strike operation in 1964, and Bold Eagle in 1976. Between 1942 and 1944 more than a million soldiers passed through these training facilities, which covered more than 46,800 square km (Bureau of Land Management, 1990). The camps were effectively small cities, up to 2800 ha in size (e.g., Camp Granite) (Prose and Metzger 1985). Continuing impacts are generated by active military bases including the National Training Center (at Fort Irwin, the Marine Corps Air Ground Combat Center at Twentynine Palms, China Lake Naval Air Weapons Station, and the Chocolate Mountain Aerial Gunnery Range (Lathrop 1983a). Military operations cause intensive damage in many areas but also provide protection of thousands of hectares from other sources of disturbance by prohibiting public access. At Fort Irwin alone, the area in need of remediation is estimated to exceed 50,000 ha.

The recovery of large areas of the eastern Mojave Desert subjected to military training exercises almost 36 years earlier was studied by Lathrop (1983b). Impacted areas included tent sites, roads, and tank tracks. All impacted areas exhibited significant reductions in plant density and cover relative to control areas. Reductions of cover and density were greatest in tank tracks and least in tent areas. Recovery to predisturbance levels of cover and density varied according to disturbance type. Tent areas showed the greatest recovery, and roadways showed the least, reflecting the intensity of disturbance. Recovery in tank tracks was intermediate. Diversity of dominant perennials also varied between disturbed and nondisturbed areas but results were clouded by low species richness at the study sites and small sample sizes of the subdominants. However, diversity in disturbed transects at the Camp Ibis study site was low relative to control sites. Species similarity decreased between control and disturbed transects with increased disturbance and use intensity.

Similar observations and conclusions were reached by Prose and Metzger (1985) and Prose and others

(1987) at abandoned military camps in the eastern Mojave. Long-lived species such as *Larrea tridentata* were dominant in all control areas but percentage cover and density were reduced in impacted areas. Dominant plants in disturbed areas included pioneer species such as *Ambrosia dumosa* and *Hymenoclea salsola*. Percentage cover values for pioneer species in disturbed areas were equal to or greater than control values.

Differences in vegetative structure between control and impacted plots were due to soil compaction, changes in soil texture, removal of the top layer of soil, and alteration of drainage channel density (Prose and others 1987). Penetrometer measurements show that a single pass by a "medium" tank can increase average soil resistance values by 50% relative to adjacent untracked soil in the upper 20 cm, but values of up to 73% were recorded. Dirt roadways could not be penetrated with a penetrometer below 5-10 cm due to extreme compaction. Physical modifications to the soil beneath tank tracks extended vertically to a depth of 25 cm and outward from the track edge to 50 cm (Prose 1985).

Recovery times to predisturbance levels of density and cover were estimated by Lathrop (1983b) assuming linear rates (Table 1). Recovery to predisturbance species composition would require much longer, if it were to occur at all. Areas receiving the greatest amount of soil compaction, such as roadways, require the longest recovery times. Tank tracks and tent areas recover in a shorter amount of time. Overall, recovery in plant density is slow relative to increases in cover. In other words, the number of individuals changes little following recovery from disturbance, but surviving individuals cover larger areas. A major conclusion from Lathrop's study was that recovery to some original level of community composition and stability may not occur in the foreseeable future. However, recovery of comparable disturbed areas has been excellent on restoration test plots at the Marine Corps Air Ground Combat Center near Twentynine Palms, California (Zink personal communication).

Off-Road Vehicles

Off-road vehicle (OHV) use is one of the major recreational activities in the deserts of California. The Motorcycle Industry Council estimated that 4.7 million motorcycles were used by 11.7 million people in 1978 for off-highway recreation in the United States, a figure that does not include dune buggies and four-wheel drive vehicles (Kockelman 1983).

The impacts of OHVs have been well documented (Webb and Wilshire 1983) and include destruction of soil stabilizers (see section on biotic components of soil), soil compaction, reduced rates of water infiltra-

tion, increased wind and water erosion, noise, decreased abundance of lizard populations (Busack and Bury 1974), and destruction of vegetation (Vollmer and others 1976). Compaction of a desert soil reduces the root growth of desert plants and makes it much harder for seedlings to survive (Bainbridge and Virginia 1990, Bainbridge and others 1995a). An excellent review of the effects of OHVs in the Mojave and other deserts is contained in Webb and Wilshire (1983) and the reader is referred to that document for information beyond that presented herein.

Soil compaction is a common effect of any compressive action on most soils. Compaction results from a variety of factors other than OHV use, including trampling by grazers, human trampling (Liddle 1991, 1997), and even raindrops (see review in Webb 1982). In the case of OHVs, compaction occurs at shallow depths related to the geometry of the contact surface between the tire and the soil interface. In one study the greatest increase in soil density occurred at a depth of 30–60 cm after being compacted by a motorcycle (Webb 1983). Soil density increases as a function of the number of vehicle passes, while soil infiltration rate decreases. Soils that are most susceptible to compaction are loamy sands and coarse gravelly soils with variable particle sizes. Wet soils are more susceptible to compaction than dry soil. Soils that are least affected include sands and clays.

Another by-product of heavy OHV use is increased wind and water erosion. The degree of erosion experienced in an area exposed to OHV use is affected by two main factors. First, increased water erosion is partially attributable to decreased infiltration rates due to compaction. Second, OHVs destroy surface stabilizers (see section on biotic components of soil), making soils more susceptible to erosion (Hinkley and others 1983). The enormity of the problem in the Mojave Desert is underscored by the fact that satellite photos revealed six dust plumes covering over 1700 square km of the western Mojave on 1 January 1973 that were attributed to surface destabilization primarily by OHVs (Nakata and others 1976, Gill 1996).

As shown in numerous photographs in Webb and Wilshire (1983), the effects of erosion can have indirect effects, since debris flows (Nakata 1983) can bury plants at some distance from the impacted area. Areas that are least susceptible to water and wind erosion following OHV use are dunes, playas, and areas with abundant coarse surface material (Gillette and Adams 1983, Hinkley and others 1983). Restoration of OHV areas affected by erosion requires actions to not only stop continuing erosion (Harding 1990, Heede 1983, Middleton 1990), but also action to restore past damage.

Desert soils vary in their susceptibility to OHV

damage. Susceptibility is generally high in all areas except barren sand dunes (but see Bury and Luckenbach 1983), and the clay flats of playas. Soil damage caused by OHVs is environmentally significant due to the fact that desert soils may take 10,000 years to develop (Dregne 1983). From this estimate, Dregne concluded that it was futile to speak of disturbed soil recovery in time frames related to human occupancy.

Another major effect of OHV use is the destruction of plants. Lathrop (1983a) examined aerial photographs of nine disturbed and undisturbed areas in the Mojave Desert to assess the effects of OHV usage. Perennial plant density and cover were dramatically reduced in OHV areas. The percentage of cover and/or density in OHV-impacted areas relative to control areas was less than 15% in three of the sites examined. Destruction of plants resulted not only from crushing stems and foliage, the extensive root systems that fill the intershrub spaces, and germinating seeds, but also from the superstructure of the vehicle. The latter factor is important since it is responsible for plant destruction in an area wider than the track width of the vehicle. The wheel tracks of a full-size off-road vehicle operating in an undisturbed area can damage almost 0.5 ha of land with every 6.44 km traveled. Support vehicles, including very large and heavy motor homes, are very destructive, and camping areas are especially hard hit.

An easily detected but poorly understood effect of OHVs is noise. Noise from certain types of OHVs can reach 110 decibels, which is near the threshold of human pain. Brattstrom and Bondello (1983) demonstrated that OHV use in the Mojave Desert caused noise levels that caused hearing loss in animals such as kangaroo rats, desert iguanas, and fringe-toed lizards; interfered with the ability of kangaroo rats to detect predators such as rattlesnakes; and caused unnatural emergence of spadefoot toads that were estivating until the arrival of rain for breeding, a situation that could result in death. The authors noted that although OHVs are not the loudest source of human-generated sound in the Mojave, they occur more frequently than any other high-intensity sound source. In their report, Brattstrom and Bondello recommended that OHV areas be located away from the ranges of "all undisturbed desert habitats, critical habitats, and all ranges of threatened, endangered, or otherwise protected desert species."

The impact of OHV use on desert tortoises in the Mojave Desert of California was examined by Bury and Luckenbach (1986) in an unpublished report. Significantly more tortoises and active burrows were found on a 25-ha control plot than on a similar plot exposed to OHV use. In addition, subadult and adult tortoises on

the control plot exhibited larger body mass than those on the OHV plot.

Impacts related to OHV use present a serious challenge to desert restoration projects for three reasons: (1) the potentially severe impact of OHV use in desert ecosystems, (2) the widespread nature of the OHV impacts in the California desert, and (3) the fact that OHV areas are often located in or near environmentally sensitive habitats. Areas targeted for restoration should be closed to OHV use prior to initiating procedures to ameliorate past damages.

Invasive Plants

Invasive exotic plants have had a significant impact on the natural communities of California (Mooney and others 1986, Rejmánek and Randall 1994), including the southern California desert ecosystem. Invasion has been facilitated by habitat disturbances that allow exotic species to colonize habitats once dominated by native species (Hunter and others 1987). Once established, exotic plants may diminish the abundance of native species due to competitive interactions or by disruption of natural processes such as fire frequency and intensity.

Some of the more important exotic plants in the southern California desert are saltcedar (*Tamarix ramosissima*), also known as tamarisk (Lovich and de Gouvainain 1998), Russian thistle (*Salsola iberica*) (Young 1991), filaree (*Erodium cicutarium*), and several grass species including split grass (*Schismus* spp.) and bromes (*Bromus* spp.) (Brown and Minnich 1986, Hunter 1991). Immense areas of desert are colonized by these species. Although other exotic plants are present in the Mojave Desert, these are important because of their ubiquity.

Exotic plants present two major problems to the integrity of the desert ecosystem. First exotic annuals increase the fuel load and frequency of fire in a community that is poorly adapted to fire. Second, some exotic plants exhibit allelopathic effects that negatively affect native species, especially annuals. Negative interactions have been demonstrated between Russian thistle and other species in the laboratory (Allen 1982a, Lodhi 1979). In addition, competition of Russian thistle with native perennial grasses increases under drought conditions (Allen 1982b), furthering establishment of the exotic. Fortunately, Russian thistle competes poorly with established vegetation and rarely supplants well-established native populations. Unfortunately, once the soil is disturbed and native plants are eliminated, Russian thistle gains a strong foothold (Young 1991). General reviews of the threats posed by exotic species invasions in native ecosystems are summarized by Cheater (1992) and D'Antonio and Dudley (1993).

Air Pollution

One of southern California's most famous exports is smog. While most noticeable in the inland valleys of the state, smog is often transported via atmospheric processes into the Mojave Desert (Pryor and Hoffer 1991). Anthropogenic pollutants include ozone, sulfur dioxide, and various particulates. Atmospheric tracer experiments have shown that pollutants released in the San Fernando Valley impact the southern Mojave Desert towns of Adelanto and Palmdale, while those released in the southern San Joaquin Valley impact the northern Mojave Desert towns of Mojave and China Lake (Reible and others 1982). Experimental tracers used in atmospheric transport studies are diluted by factors of only 2–3 during passage between source and receptor areas. Impacts are maximized during evening and nighttime hours, independent of the time of release in the San Joaquin Valley, because of the diurnal mountain–valley wind cycle. Ozone levels in the Mojave Desert can exceed 100 parts per billion (ppb) or more when offshore wind transports atmospheric pollutants from the Los Angeles Basin (Thompson and others 1984a). By comparison, ozone levels in remote areas range from 20 to 40 ppb.

The most obvious effect of smog in the Mojave Desert has been visibility degradation in an area historically distinguished by extraordinary visibility (Walsh and Hoffer 1991). Median visibility is 48–88 km in large urban areas and 104–128 km in nonurban locations. Visibility has decreased 10%–30% from the middle of the 1950s to the early 1970s at many recording stations (Trijonis 1979).

Much of the visibility loss is related to particulates, including nitrogen-rich compounds. Dryfall of these compounds from air pollution can be a major source of supplemental N for plants. This favors many exotic plant species over native annuals and perennials. Wedin and Tilman (1996) found that half the native plant species in a Minnesota grassland were lost from the community at supplemental N levels mimicking dryfall deposition rates.

A less obvious effect is damage to plants. Stolte (1991) observed injurious effects to desert plants exposed to ozone and sulfur dioxide in laboratory experiments. Annual plant species of the genera *Camissonia* and *Cryptantha* exhibit high sensitivity to both gases. The grass *Oryzopsis hymenoides* exhibits high sensitivity to sulfur dioxide, as do some types of cryptogamic soils. Responses of cryptogamic soils include increased electrolyte leakage, chlorophyll degradation, and reduced nitrogen fixation (Belnap 1991).

Studies of plants from the Mojave and Colorado Deserts show that perennial species vary in their re-



Figure 2. The effects of fire in the desert are obvious in this photo taken near Palm Springs, California, about five years after the blaze. Note the almost complete elimination of perennial shrubs in the burned area to the left. Perennial plant species in the Mojave and Colorado Deserts are long-lived and very sensitive to fire, traits that collectively contribute to the long recovery times typical of many desert plant communities after fire. Photo by Jeff Lovich.

sponae to SO_2 and NO_2 . *Larrea tridentata* is sensitive to fumigation by these pollutants under experimental conditions, displaying extensive leaf injury and reduced growth or dry weight. *Encelia farinosa* and *Ambrosia dumosa* show intermediate responses, while *Atriplex canescens* appears to be resistant (Thompson and others 1980). Sensitivity also varies among native annual plants, with *Camissonia claviformis*, *C. hirtella*, and *Cryptantha nevadensis* exhibiting leaf injury at low concentrations of SO_2 and O_3 (Thompson and others 1984b).

Fisher (1978) suggested that high rates of mortality in desert holly (*Atriplex hymenelytra*) in the northern Mojave Desert (Death Valley) were related to elevated ozone levels. During the summer months he recorded ozone levels that were twice the national standard of 0.08 ppm. Photosynthesis and water use was significantly reduced in greenhouse experiments where seedlings were exposed to 0.15–0.18 ppm ozone for 3 h. Ozone-induced reduction in water-use efficiency was postulated to be the cause of declining *Atriplex* populations in Death Valley.

Additional summaries of the impacts of air pollution in the Mojave and Colorado Deserts are provided by Mangis and others (1991), Thompson (1995), and VanCuren (1995).

Anthropogenic Fire

Fire was not an important factor in shaping the prehistoric structure and dynamics of plant communities in the California desert. The infrequency of fire in the prehuman landscape of the desert was due to limited biomass, large intershrub spacing, low combustibility of some native plants, sparse groundcover to support and propagate combustion, and the absence of human-mediated fire suppression activities (Humphrey

1974, O'Leary and Minnich 1981, Minnich 1983, Brown and Minnich 1986). Such is not the case in other desert and semidesert areas of the American Southwest, including parts of the Sonoran and Chihuahuan deserts, where fire was an important prehistoric agent in maintaining grassland seral stages (Humphrey 1958, 1963, 1987, Reynolds and Bohning 1956).

The proliferation of exotic annual plant species such as *Bromus*, *Schismus*, and *Salsola* has dramatically increased the fuel load and frequency of fires in many ecosystems around the world (D'Antonio and Vitousek 1992), including parts of the California desert (O'Leary and Minnich 1981, Brown and Minnich 1986), in recent years. The frequency of fires in the Colorado Desert of California is further enhanced by the proximity of previously burned areas (Chou and others 1990). Native perennial shrubs are poorly adapted to relatively low-intensity fires as evidenced by low rates of recovery (Figure 2). In the upper Coachella Valley on the east scarp of the San Jacinto Mountains near Palm Springs, California, burned creosote bush scrub is replaced by open stands of *Encelia farinosa*, native ephemerals, and exotic species such as *Schismus* and *Bromus* (Brown and Minnich 1986).

Postfire vegetational recovery along a chaparral-desert ecotone including parts of Anza-Borrego Desert State Park in San Diego County, California was examined by Tratz and Vogl (1977). They observed high recovery (as measured by speed of resprouting) in chaparral shrubs and desert-wash plants, but low recovery in cacti. Herbivorous mammals present before the burn were also present afterwards, since rapid recovery of shrubs provided adequate food supplies for wildlife, even in the first months after the fire. If California desert perennial plant communities are not well adapted

to fires, animals that coevolved in the ecosystem should not be expected to respond favorably to fire either.

According to fire personnel at the California Desert District (CDD) Office of the Bureau of Land Management (BLM), the CDD (including the Mojave and Colorado Deserts) had a ten-year average of 175 fires per year prior to 1992 (range 100–475) that affect an average of 10,927 ha annually (range 607–34,400 ha). The CDD estimates include a very small amount of BLM land outside the desert.

Impacts on Biotic Components of Soil: The Invisible Component of Biodiversity

Although emphasis is often placed on the physical and chemical properties of various soils, they contain important biotic components as well including: soil surface stabilizers such as algae and lichens, nematodes and other metazoans, various bacteria, and mycorrhizae. Odum (1994) referred to these organisms as the invisible component of biodiversity. While not as conspicuous as macrofloral elements, biotic components of soil are important symbionts that are easily destroyed by certain human activities.

Undisturbed desert areas are characterized by the presence of soil stabilizers, including lichen, fungal, bacterial, and algal crusts; desert pavement, mechanical crusts; and chemical crusts. The biotic components of these stabilizers are collectively referred to as cryptobiotic soil. Mineral-derived crusts form under a variety of physical and chemical conditions that may actually be facilitated by biotic components (Elvidge and Iverson 1983, Taylor-George and others 1983). Soil stabilizers are important agents in preventing erosion but are easily disturbed since they occur at the surface. Stabilization mechanisms include binding soil particles with thalial filaments in the case of biotic stabilizers, armoring the surface, and increasing surface roughness. Crusts also provide germination sites for vascular plants (but see Wood and others 1982), and conserve water (see review in Cole 1990). The susceptibility of crusts to damage varies according to the composition of the underlying soil. In soils subjected to large shear stresses, a single pass by a vehicle is capable of destroying well-developed crust. When the forces are mainly compressive, crusts can survive a single pass in a slightly modified form; however, OHV use is capable of quickly eliminating crusts in an impact area (Wilshire 1983).

Considerable research has been conducted on the impacts of grazing and other agents of trampling on cryptobiotic soil crusts. These crusts are very important not only because of the soil-stabilization functions mentioned above, but because they facilitate the accu-

mulation of organic material and soil nutrients, particularly nitrogen in the upper layers of soil (Kleiner and Harper 1977, Johansen 1993), and enhance soil moisture retention (Belnap and Gardner 1993). Research in desert and semidesert areas in Utah and Arizona has consistently shown that cryptobiotic soil is heavily impacted by grazing, even light winter grazing (Kleiner and Harper 1977, Anderson and others 1982, Brotherson and others 1983). Impacts include the destruction of surface pinnacles associated with development of cryptogamic soils (Anderson and others 1982) and the virtual obliteration of biotic elements (Cole 1990). Lichens and mosses are most sensitive to disturbance, with algal components being more resilient (Brotherson and others 1983).

Cole (1990) conducted an interesting experiment at Grand Canyon National Park to examine the effect of trampling by hikers wearing lug-soled boots. Only 15 passes were required to destroy crusts. Visual evidence of biotic components was reduced to near zero after 50 passes. The results of Cole's experiment clearly illustrate the fragility of crusts to trampling.

Cryptobiotic soil recovery may require long time intervals without intervention. Following exclusion of grazing in a Utah semidesert study site, cryptobiotic cover increased from 4%–15% in 14–18 years, but only 1% per year for the next 20 years (Anderson and others 1982). Cole (1990) observed partial recovery from human trampling in one to three years and extensive recovery after five years. However, surface irregularities associated with well-developed cryptogamic cover remained low even after five years, suggesting that recovery was incomplete. Belnap (1993) noted that over 250 years may be required for full recovery on the Colorado Plateau. Recovery was improved but was still very slow when scalped experimental plots were inoculated with crusts from surrounding areas. In the northern Mojave Desert, lichen crusts may not reoccupy heavily disturbed areas even after 63 years (Wilshire 1983). Details of the formation and recovery of chemical and mechanical crusts are discussed in detail by Wilshire (1983). The nitrogen-fixation capabilities of damaged soil may take over 50 years to recover (Belnap 1995).

Important symbiotic relationships have developed between certain species of vascular plants and vesicular-arbuscular mycorrhizal (VAM) fungi and rhizobia. The small-diameter hyphae of symbiotic fungi serve as energy efficient root hairs, enabling the host plant to better absorb nutrients, particularly phosphorus (Bloss 1985) and water (Bethienfalva and others 1984). Rhizobia are bacteria capable of fixing atmospheric nitrogen for use by plants. The importance of VAM fungi in desert plant communities is underscored by the fact

that in a recent survey of 38 plant species (19 families) in Anza-Borrego Desert State Park in the Colorado Desert of California all were colonized by VAM species (Bethlenfalvay and others 1984). Plants naturally associated with VAM that are also found in the western Mojave Desert include *Hymenoclea*, *Ambrosia*, *Opuntia*, and *Larrea*. Bloss (1985) reported numerous plant associations in the Sonoran Desert of Arizona as well.

Previous studies have demonstrated the importance of maintaining and enhancing soil microbes in restoration projects (St. John 1984, Bainbridge 1990). Establishing plants in disturbed areas with marginal soils may be difficult or impossible without the presence of a vigorous population of microbial symbionts. These symbionts are adversely affected by soil compaction. Studies have shown 1–2 m of hyphae per gram of soil in Mojave and Sonoran soils, yet virtually none in disturbed areas (Zink personal communication). Restoration is complicated by the fact that fertilizers can inhibit mycorrhizae growth.

Can the Desert Be Restored?

Plant growth and establishment are naturally slow under the extreme conditions of the desert, and disturbance makes these conditions even more severe (Bainbridge 1990). Disturbance typically reduces both the infiltration of water into the soil and the moisture-holding capacity of the soil (Bainbridge and Virginia 1990). This increases the value of rapid deep root growth, which is made more difficult by increases in soil strength from compaction and reduced soil moisture. These synergistic effects make plant establishment much more difficult after disturbance. Revegetation and restoration work can help mitigate many of these impacts and speed recovery, but the severe conditions and unpredictable rainfall still make restoration of these sites very challenging.

A brief history of revegetation studies in the deserts of California was provided by Kay and Graves (1983). Studies in the Mojave Desert are few and relatively recent. One of the earliest studies evaluated the success of revegetation efforts along the second Los Angeles Aqueduct (Kay 1979, 1988). Construction involved stripping the vegetation from an area 200 km long × 60 m between 1968 and 1970. The seeds of seven species of native plants were distributed at six 2- to 15-ha sites on the aqueduct. The seeds of all but one species, *Atriplex polycarpa*, were from local stock. Surface preparation involved ripping the soil to 25 cm on 60-cm centers to relieve compaction. A rangeland drill was used to set the seeds at a depth of about 1 cm. Success varied among plant species. *Ambrosia dumosa* exhibited good establish-

ment on three of six sites, but only one site had numbers approaching that of adjacent undisturbed areas. *Larrea tridentata* exhibited similar results. The other species, including *Atriplex polycarpa*, *Ephedra nevadensis*, *Hymenoclea salsola*, and *Lepidospartum squamatum*, were totally unsuccessful. *Atriplex canescens* suffered as a result of heavy grazing. The most abundant shrub along the aqueduct, *Chrysothamnus nauseosus*, established itself naturally, although it was uncommon in adjacent undisturbed areas. Kay (1988) concluded that natural revegetation is good in many years and poor in others, while artificial seeding did not consistently hasten or improve plant recovery.

In another experiment along the aqueduct, Graves and others (1978) tested the effects of a single irrigation and the success of direct seeding versus transplanting. The two methods of establishment exhibited widely variable success rates from site to site and according to species, but were not enhanced by irrigation. Substrate characteristics may influence the success of irrigation as measured by the appearance of native winter annuals (Johnson and others 1978).

The overall success of the revegetation attempt along the aqueduct was low. The vast majority of the aqueduct was still a highly visible scar in the early 1980s (Kay and Graves 1983), but recovery was inhibited by grazing and OHV use. Conclusions from the study were that more attention should be focused on establishment of visually dominant species such as *Larrea tridentata*, seeding should take place as soon after disturbance as possible, areas should be protected from grazing and OHV use, and local seed stock should be utilized for all species.

Highway revegetation studies were also reviewed by Kay and Graves (1983). Survival of container-grown shrubs planted in October 1973 and February 1974 at a site in Mojave, California, was 90% in May 1974. The roots of the transplants were exposed after a heavy rain in December 1974, and all plants were dead by October 1975. *Atriplex* spp., *Chrysothamnus* spp., and *Ephedra* spp. exhibited the greatest survival. Success was limited by rabbit overgrazing and competition from Russian thistle (*Salsola*). Container plantings were more successful when planted in the late winter or early spring. Application of fertilizer encouraged both the invasion of native woody shrubs and the nonnative annual grass *Schismus arabicus*.

Others have experienced similar success in revegetation. Brum and others (1983) observed low, long-term seedling establishment for a variety of species under several irrigation treatments along a powerline transmission corridor. The overall germination–establishment rate for seedling and postseedling irrigation success was 0.3%, and 26% for transplanted seedlings. *Larrea* exhib-

ited poor germination under field conditions and responded poorly to all revegetation attempts.

More successful revegetation has been achieved at the Nevada Test Site in the northern Mojave Desert (Romney and others 1990). Greater than 80% survival of transplanted native shrubs and grasses was achieved when plants were protected from jackrabbits and irrigation was provided periodically.

Restoration efforts in the Colorado Desert of California were reviewed by Bainbridge and Virginia (1990). Although the plant communities differ somewhat between the Colorado and Mojave Deserts, both ecosystems pose similar challenges to restoration attempts: high temperatures, intense sunlight, limited moisture availability, high levels of herbivory by rodents and rabbits, and low soil fertility. Much of the success in revegetation experiments in the Colorado Desert is due to efforts to protect plants from herbivores and the use of buried water reservoirs for irrigation. Direct seeding attempts have generally been unsuccessful relative to transplants. *Larrea tridentata*, in particular, responded well to transplanting, especially if pruned prior to planting to increase the root-to-shoot ratio.

Assessing the nature and magnitude of human-induced disturbances makes restoration planning more efficient by enabling limited resources to be directed at critical problems. Ongoing studies (Bainbridge and others 1995a,b) of the effectiveness of desert restoration techniques are steadily advancing our ability to rehabilitate degraded arid lands in the southwestern United States, and the reader is referred to these references for details beyond the brief overview given in this section.

Plant recovery usually requires container-planting activities as well as site improvement. The most common method of direct seeding is simple hand seeding, which allows species to be matched to specific site conditions, appropriate planting depths, and results in a more natural appearance than machine planting. However, limited rainfall and removal of seeds by rodents and harvester ants may severely limit seedling establishment during typical years.

Transplanting is increasingly being used to provide nurse and seed plants for the disturbed areas (Bainbridge and others 1995b). The dominant shrubs and trees of the Colorado Desert are relatively easy to grow in a nursery or maintained landscape setting, and they are well adapted to transplanting with after-care. They are more challenging to establish in the field in a low- or no-maintenance situation, although once established, growth rates can be high. Reestablishment of annuals has been more difficult. New containers and soil mixes have improved plant survival. Deep pipe and buried pot

irrigation and hand watering have also been effective. Tree shelters to limit herbivory and wind damage are also important.

A full appreciation of the ecological setting and adaptation of desert plants can make establishment less costly and more successful, but it is still expensive. The cost of restoring road edge areas in Joshua Tree National Park is fairly well established (after almost 10 years of work) and runs up to \$15,000 per ha to establish large potted perennials in areas that are easily accessed. The cost of duplicating this type of work at remote sites would be much higher. Research conducted by colleagues at San Diego State University has emphasized lower-cost, less-intensive restoration, but the costs (excluding research) are still on the order of \$12,000–25,000/ha. Even these high project costs provide no guarantee of success.

Conclusions

Desert areas disturbed by human activities may take centuries to recover without active intervention. Undisturbed desert soils are often in a relatively stable equilibrium developed over hundreds or thousands of years. Removal of vegetation and disturbance of soil crusts or soil structure can destroy this equilibrium, leading to wind and water erosion that are very difficult or impossible to control without very high investments in material and labor.

One of the key lessons of our research in the Mojave and Sonoran deserts is the critical importance of minimizing the intensity, frequency, and area of disturbance. Past research summarized in this paper has identified the wide range of effects from human disturbance and the difficulty and the high cost of mitigating damage. While recovery rates can be increased with modest expenditures, a major restoration program to improve recovery for just the OHV-damaged areas in the California desert region could exceed one billion dollars. Available funding will permit only a limited restoration for selected sites, even with continuing generous contributions of volunteer labor. Fences, signs, and enforcement to prevent further damage may often be a better investment than intensive restoration.

Recent research in the Mojave Desert demonstrates the benefits that protection can impart, even to previously disturbed areas. Brooks (1995) conducted a comparison between the Desert Tortoise Research Natural Area (DTNA) and unprotected land immediately adjacent. The DTNA was fenced to prohibit both OHV use and sheep grazing between 1978 and 1979. By the time of his study in 1990–1992, Brooks demonstrated that aboveground live annual biomass was generally greater

inside than outside the fenced area, with the exception that the exotic annual grass *Schismus barbatus* produced more biomass outside the fenced area. Percent cover of perennial shrubs, seed biomass, and rodent density and diversity were also greater inside the fenced area.

To be successful, revegetation and restoration require careful attention to ecological relationships, both above and below ground, herbivory, soil characteristics, microclimate, and patterns of moisture availability (Bainbridge 1990, Bainbridge and others 1995a). Undoing the damage done to the soil system by disturbance is a critical step toward recovery and restoration. In general, strategies that recreate or mimic natural conditions are most likely to speed recovery of the entire ecosystem.

Research conducted in the Mojave and Colorado desert ecosystem has important applications for the American Southwest and throughout the world's arid zones. These areas have deteriorated rapidly under pressure from overgrazing, poor farming, and removal of trees and shrubs for fuelwood. The lessons learned in the desert ecosystem of southern California may help people living in these areas to protect or restore the productivity of their lands, and improve their lives.

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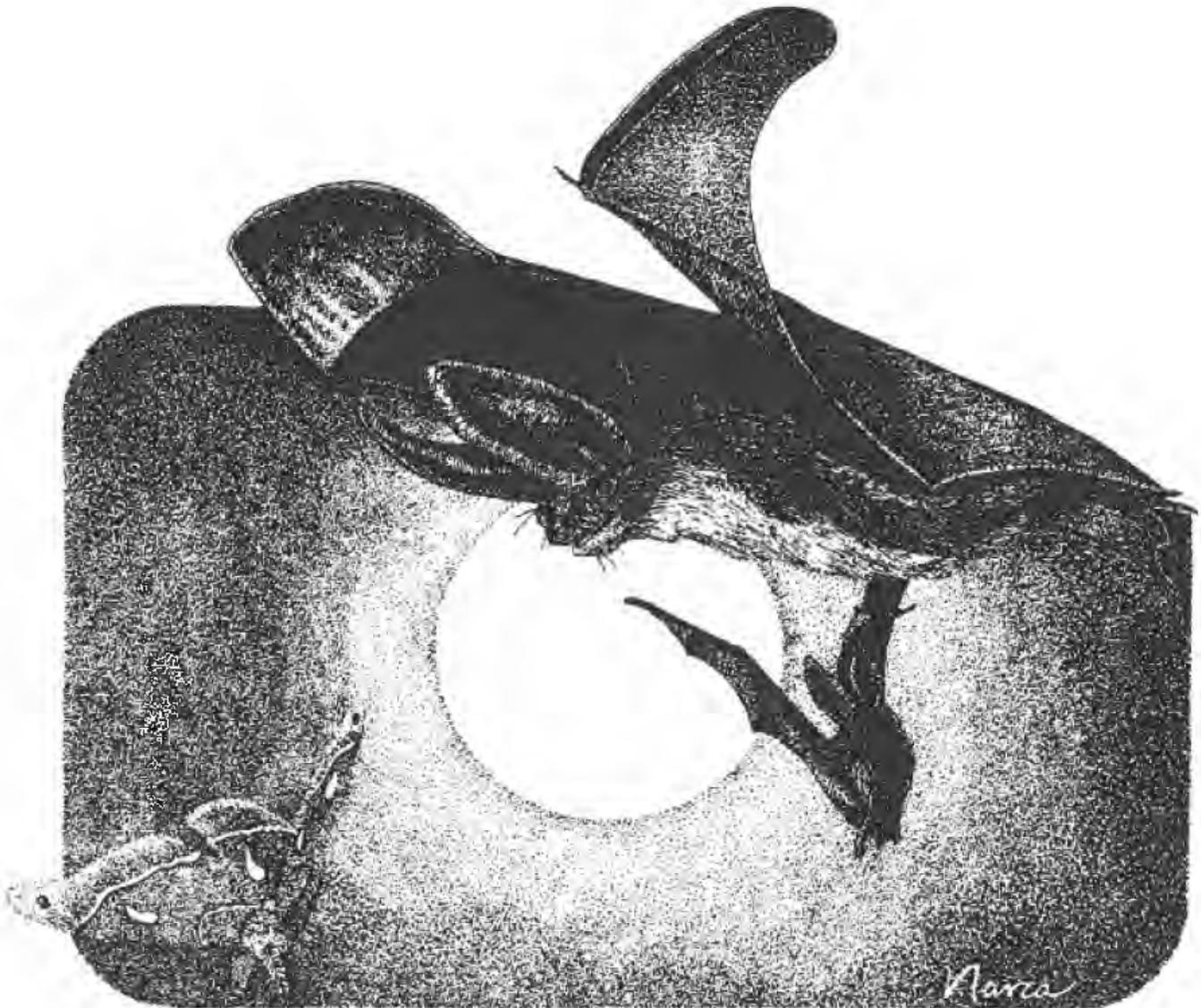
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THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

MAMMALIAN SPECIES OF SPECIAL CONCERN IN CALIFORNIA

by

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Cover: Townsend's Big-eared Bat (Plecotus townsendii)

Page 11: Suisun Shrew (Sorex ornatus sinuosus)

Page 49: White-eared Pocket Mouse (Perognathus alticola)

Page 72: Mountain Beaver (Aplodontia rufa)
Fisher (Martes pennanti)

Artwork by Narca Moore-Craig

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ABSTRACT

The native species of land mammals of California which currently do not have state or federal Threatened or Endangered Species status were investigated in order to identify those potentially threatened with extinction. Investigations concentrated on determining historic and current distributions, habitat associations, population status, and the nature and proximity of threats of extinction. Information was developed primarily from the literature, museum records, and field notes, and from contacts with biologists with knowledge of current developments in the field. Detailed studies were conducted in some areas, but only cursory field work was undertaken in other areas of concern. Populations of 36 species and subspecies were considered to be potentially jeopardized. These are placed in three priority categories. The 13 taxa in the Highest Priority face a high probability of extinction if current trends continue; the 11 taxa in the Second Priority are definitely declining in population size and appear jeopardized, but the threats are less immediate; the 12 taxa in the Third Priority appear not to face extinction soon, but their populations are declining seriously or they are otherwise highly vulnerable to human developments. Information on distribution, population status, habitat, and taxonomy, and recommendations for management actions are presented for each species on the List of Concern. Brief remarks are included for 56 other taxa considered in developing the final List of Concern.

Species limited to or primarily dependent upon riparian and wetland communities have been affected most severely by human developments. Five geographic areas of critical concern are: the Colorado River riparian corridor; the San Joaquin Valley lowlands, including grassland, riparian and wetland communities; the tidal marshes of the Los Angeles Basin; the tidal marshes of San Francisco and San Pablo bays; and the grasslands of the southern California coastal basins. Loss and fragmentation of mature and old-growth forests, lack of data on population structure of some game and fur-bearing species, and human disturbances of sensitive species are other important factors generating concerns for several species.

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RECOMMENDATIONS

In addition to recommendations contained in the species accounts for the preservation of California's mammals, the California Department of Fish and Game and I recommend the following:

1. Give high priority to the preservation and/or restoration of plant communities essential to wildlife:
 - a. Restore and protect riparian forests and wetlands in California, with special attention to those of the Colorado River and the San Joaquin Valley.
 - b. Restore and protect tidal wetlands, especially those in San Francisco, San Pablo, and Suisun bays and those along the southern California coast in Ventura, Los Angeles, and Orange counties.
 - c. Preserve and protect native grasslands and desert shrub communities in the San Joaquin Valley, Salinas Valley, and the southern California coastal basins in Los Angeles, Orange, Riverside, and San Diego counties.
 - d. Preserve and protect mature and old-growth conifer forests in blocks large enough to support species such as Fishers.
2. Propose species on the List of Special Concern that meet the criteria of Threatened or Endangered Species to the California Fish and Game Commission and the U.S. Fish and Wildlife Service for addition to the lists of Threatened and Endangered Wildlife.
3. Initiate programs to determine the effects of hunting and trapping on game and furbearing species on the List of Special Concern and modify regulations as appropriate.
4. Encourage the protection of all species of bats in California and initiate an educational program to inform the public of the role of bats in control of insects and the sensitivity of bats to disturbance in maternity roosts and hibernacula. Support and assist the development of regulations prohibiting the poisoning or killing of bats as control measures in human structures.
5. Encourage governmental, educational, and conservation agencies and institutions involved in wildlife, land, and resource management to give high priority to Species of Special Concern in research programs and land and resource management decisions.
6. Encourage persons with information on Species of Special Concern or other species that may be threatened to bring the information to the attention of the Department of Fish and Game. Revise the List of Special concern every two years to reflect current information on distribution, population status, and management recommendations.

PREFACE

The primary objectives in preparing this document were to identify taxa of mammals in California that had no status as Endangered, Threatened, or Fully-protected, but which appeared to be vulnerable to extinction, and to develop a set of priorities for determining their status and ensuring their survival. As originally conceived and implemented, the project provided no resources for field investigations, although most areas of the state were visited and limited field work was conducted. In the ensuing five years, however, opportunities to conduct more extensive field work in several areas have arisen and the investigations have resulted in removing several species from the draft List of Concern, moving others to lower categories, and elevating others to higher categories. Three species included on the final list were not investigated in the same detail as others, because in the early stages of the project I had decided there were no indications that they were in jeopardy. Subsequent to preparation of the draft final report, however, reconsideration of their status has resulted in their inclusion. I thought it better to include them with only partial data available rather than to delay the preparation of the final report.

A rough draft of the accounts of 52 species and subspecies to be included in this report was prepared and submitted for comment to the California Department of Fish and Game in 1981. A completed draft of the report was submitted later in 1981. The Department of Fish and Game finished its review and returned the draft to me for final revisions in June, 1984. By the time it was returned, considerable new information had been gathered for several species, and substantial revisions were envisioned; in addition, I had incurred a number of commitments that precluded work on the document until fall of 1985. In the interest of making the information that was gathered for the original report available, I have decided reluctantly to forego major revisions. Most sections of the report have been reorganized, 18 species have been deleted from the List of Concern (they are discussed in the section entitled "other candidate species"), three species have been added to the list of concern, and some new information, gathered during subsequent field work by me and others, has been incorporated.

23 February 1986
Turlock, California

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INTRODUCTION

During the past 150 years, 515 species and subspecies of native land mammals have been recorded as occurring in California (Hall, 1981; Williams, 1984), a number much greater than in any comparable political unit north of the American tropics. Seven species, including the Mexican Jaguar (Felis onca arizonensis), Plains Bison (Bison bison bison), Gray Wolf (Canis lupus fuscus and C. l. youngi), California Grizzly Bear (Ursus arctos californicus; taxonomy of Hall, 1984), and the Western White-tailed Deer (Odocoileus virginianus ochrourus), are now extinct or extirpated within California. Coues' White-tailed Deer (O. v. couesi) probably also occurred within California, occupying the riparian forests of the Colorado River floodplain. Specimens are unknown from California, although Hall (1981) listed a record from Ehrenburg, Arizona, on the Colorado River opposite California. This species was probably already rare along the Colorado River by the time rapid immigration triggered by the the gold rush, and has been extinct long since. The Long-eared Kit Fox (Vulpes macrotis macrotis) was driven to extinction by humans in the southern coastal basins of California. Pronghorns (Antilocapra americana americana) have been extirpated from most of their historic range in California, in west-central and southern parts of the state; and Tule Elk (Cervus elaphus nannodes), while no longer threatened with extinction, exist only under full protection. The decline or extinction of most of these species was primarily due to persecution and/or overharvesting by humans.

Twenty-three mammalian species (29 subspecies) in California were designated as Threatened or Endangered species in 1985, including nine marine mammals. The terrestrial species are listed in Table 1, together with those known to be extinct or extirpated from the state. The principal factor jeopardizing the rodents and Kit Fox (Table 1) has been loss of habitat. Human disturbance and intrusion into their habitats have been significant factors in the decline of the Sierra Nevada Red Fox, Southern Wolverine, and the California and Peninsular Bighorn Sheep.

Twenty native game and fur-bearing species of mammals are partially protected by hunting and trapping regulations established by the California Fish and Game Commission and administered by the California Department of Fish and Game. Additionally, the Ringtail (Bassariscus astutus), Fisher (Martes pennanti), and Northern Flying Squirrel (Glaucomys sabrinus) are protected through legislative action or by the California Fish and Game Commission. The White-eared Pocket Mouse (Perognathus alticola), Point Arena Mountain Beaver (Aplodontia rufa nigra), Point Reyes Mountain Beaver (A. r. phaea), and all species of bats are partly protected from taking through restrictions on scientific collection by the California Department of Fish and Game. The Mountain Lion (Felis concolor) is designated as a game species but presently there is no open hunting season.

All other terrestrial species of mammals in California have little or no protection, and for those and many game, fur-bearing, fully-protected, and state Endangered and Threatened species, no management plans are in operation to ensure the preservation of unique populations. Yet, the

California Endangered Species Act of 1970 and subsequent amendments mandate the preservation of all species of native mammals. Rapid agricultural development and urbanization of vast areas in California have profoundly diminished the extent of several biotic communities and jeopardized their unique biotas. For example, the floor of the San Joaquin Valley measures approximately 3.44 million hectares (8.5 million acres). Major plant communities once included valley grassland (dominated by perennial species such as Stipa pulchra and S. cernua), San Joaquin saltbush (dominated by several xeric-adapted and halophytic shrubs, including Atriplex spp., Suaeda fruticosa, Allenrolfea occidentalis, and Ephedra californica), tule marsh (dominated by species of Scirpus and Typha), and riparian forests and savannas (Kuchler, 1977). By 1979, nearly all of this land was developed, either as large urban areas or as cultivated crop land. Less than 60,700 hectares (150,000 acres) were uncultivated, and significant portions of this latter amount were developed for petroleum extraction, strip-mined for gypsum and clay, or occupied by roads, canals, air strips, cities, oil-storage facilities, pipelines, and evaporation and percolation basins. The vast tule marshes were nearly gone; most of those that remained were degraded by seasonal flooding with waters laden with metallic salts drained from irrigated fields. The grassland communities were reduced to small remnants, mostly fringing the valley floor, and their perennial species were largely replaced by exotic species of weedy annuals such as Bromus spp., Avena spp., and Erodium spp. Of the original 404,700 hectares (about 1 million acres) or more of riparian communities in the Central Valley, less than 10% existed in 1979 (Warner, 1979); much of that was significantly degraded in quality.

Populations of mammals native to the arid coastal basins of southern California have been reduced drastically in size as a result of habitat loss. Today, nearly all of the populations of species native to the plant communities on the floor of the southern coastal basins face proximate threats of extinction. The Long-eared Kit Fox succumbed to the pressure of increasing numbers of people in southern California several decades ago (Walshman and Roest, 1977). Other species extirpated there and/or throughout southern California include the Mexican Jaguar (Merriam, 1919; Strong, 1926), Great Basin Gray Wolf (Grinnell et al., 1937), Pronghorn (McLean, 1944), and Coues' White-tailed Deer.

Populations of mammalian species dependent upon freshwater and tidewater riparian and wetland communities have declined markedly in nearly every region within California as a result of loss and degradation of their habitats. White-tailed Deer, dependent upon riparian communities in California, have already been extirpated (see section on Other Candidates in Results section) and several other species are seriously jeopardized.

The rapid, widespread loss of old-growth forests by logging activities raises concerns that cannot be resolved with existing information. Although no mammalian species in California is known to be limited to old-growth forests, a few require extensive tracts of relatively undisturbed forest. Fragmentation and isolation of relatively small blocks of mature and old-growth stands of Yellow Pine, Douglas Fir, Mixed Conifer, and Red Fir by recent forest-management practices has been extensive and could prove to be disastrous for wide-ranging species such as the Fisher and Marten, and for species with limited vagility such as

Table 1. Extinct, Threatened, and Endangered species of land mammals in California as of January, 1986. CE - California Endangered; CT - California Threatened; FE - Federal Endangered; FT - Federal Threatened.

Species	Status
San Joaquin Antelope Squirrel (<u>Ammospermophilus nelsoni</u>)	CT
Mohave Ground Squirrel (<u>Spermophilus mohavensis</u>)	CT
Morro Bay Kangaroo rat (<u>Dipodomys heermanni morroensis</u>)	CE, FE
Giant Kangaroo Rat (<u>Dipodomys ingens</u>)	CE
Fresno Kangaroo Rat (<u>Dipodomys nitratoides exilis</u>)	CE, FE
Stephens' Kangaroo Rat (<u>Dipodomys stephensi</u>)	CT
Salt Marsh Harvest Mouse (<u>Reithrodontomys raviventris raviventris</u> and <u>R. r. halicoetes</u>)	CE, FE
Amargosa Vole (<u>Microtus californicus scirpensis</u>)	CE, FE
Cascades Gray Wolf (<u>Canis lupus fuscus</u>)	Extinct
Great Basin Gray Wolf (<u>Canis lupus youngi</u>)	Extinct
Island Fox (<u>Vulpes littoralis catalinae</u> , <u>V. l. clementae</u> , <u>V. l. dickeyi</u> , <u>V. l. littoralis</u> , <u>V. l. santacruzae</u> , and <u>V. l. santarosae</u>)	CT
Long-eared Kit Fox (<u>Vulpes macrotis macrotis</u>)	Extinct
San Joaquin Kit Fox (<u>Vulpes macrotis nutica</u>)	CT, FE
Sierra Nevada Red Fox (<u>Vulpes vulpes necator</u>)	CT
California Grizzly Bear (<u>Ursus arctos californicus</u>)	Extinct
Southern Wolverine (<u>Gulo gulo luteus</u>)	CT
Mexican Jaguar (<u>Felis onca arizonensis</u>)	Extirpated
Western White-tailed deer (<u>Odocoileus virginianus ochrourus</u>)	Extirpated
California Bighorn Sheep (<u>Ovis canadensis californiana</u>)	CT
Peninsular Bighorn Sheep (<u>Ovis canadensis cremnobates</u>)	CT
Bison (<u>Bison bison bison</u>)	Extirpated

Red Tree Mice. Likewise, some species of bats may depend on roosting sites under loose bark and in hollow cavities of standing trees and foraging sites within the forest, and their populations may be significantly impacted by loss of old-growth forests and current forest-management activities

Concern over the rapid loss of major biotic communities within California and the increasing threats to several species of mammals prompted the Nongame Bird and Mammal Section of the California Department of Fish and Game to initiate this study of potentially threatened species of mammals. The principal objectives were to identify potentially jeopardized populations of mammals within California, and to group them into priority categories for management actions, including proposals for protected status, expenditure of research funds, and preservation of essential habitat.

METHODS

Investigations of potentially threatened mammals were limited to taxa without Threatened or Endangered status at the state or federal level. Taxa concurrently being investigated through other projects of the Department of Fish and Game also were excluded from detailed studies (i.e., some subspecies of the Bobcat, Felis [Lynx] rufus, and the River Otter, Lutra canadensis).

Priorities for the investigations were:

1. species endemic to California;
2. subspecies endemic to California;
3. species and subspecies whose geographic ranges extend beyond California and which appear to be jeopardized throughout their geographic range;
4. populations of taxa threatened within California but which also occur elsewhere and appear not to be threatened throughout their geographic range (e.g., Myotis velifer velifer, the Cave Myotis).

These priorities had some influence on which taxa received greatest consideration for inclusion in detailed investigations. Priority rankings, however, were based solely on the apparent proximity and nature of threats to populations. Locally depleted populations of wider-ranging taxa within California were not studied in detail, with the exception of the American Badger (Taxidea taxus).

A working list of 86 candidate species was assembled first and then information for each candidate was gathered. Blair Csuti (The Nature Conservancy) nominated some of the candidates. Data on life histories, habitat associations, historic and current distributions, systematic status, population status, and nature of potential threats were sought for each candidate. Initially, information was gathered without benefit of field work, being derived instead from published sources, other biologists, and previous field experiences in California. The intent was to develop information needed to direct limited funds for field investigations to studies of biotic communities and taxa with the greatest perceived threats to their existence. During the course of the original investigation, however, most areas in the state where loss of habitat posed a threat to one or more species of mammals were visited. Only cursory field studies were carried out, however, as time and funding did not permit detailed field work. Subsequently, more detailed studies have been conducted in the San Joaquin Valley (Williams, 1985; Glenn Baisey, unpubl. ms.; Cheryl Johnson, unpubl. ms.); San Bernardino Mountains (Sulentich, 1983; Williams, 1983); San Gabriel mountains (Williams, 1983); Tehachapi Mountains (Sulentich, 1983); east-central slope of the Sierra Nevada (Williams, 1984); western slope of the central Sierra Nevada (unpubl. data); San Pablo and Suisun bay marshes (K. Ford, unpubl. data; Williams, 1983); Point Arena area, Mendocino Co. (Dale Steele, unpubl. data); San Francisco Bay (Ford, 1986); San Pablo Creek Marsh (by Foreman; T. Rado, pers. comm.); and on Santa Catalina Island (Collins and Martin, 1985; Williams, 1983). For the majority of the species included here, however, there have been no recent, detailed, field studies undertaken.

Letters and questionnaires seeking information on potentially threatened taxa of mammals were sent to all members of the American Society of

Mammalogists with mailing addresses in California, and to other, selected persons in state and federal agencies, colleges and universities, and natural history museums. Approximately 500 persons were contacted in this manner. Sixteen persons responded to the request for information, and collectively listed 16 species they believed should be investigated. Of the 16, two were species of marine mammals which were not included in this project, and four were species already with state Rare or Endangered status. All of the remainder were already on the working list.

Subsequent to development of the draft report, questions regarding the status of 11 other taxa were raised by Ronald Nowak (Endangered Species Office, U.S. Fish and Wildlife Service). Little additional research was conducted on most of the latter species; reasons for excluding them and other candidate species are given in brief accounts (see section on Other Candidate Species).

Information on the distributions of species on the working lists was developed from the literature and from museum records. No attempt was made to locate all records, although literature and museum surveys were as complete as time and resources permitted. Data on historic distributions were assembled from these sources, but for most taxa no detailed field surveys had been conducted prior to wide spread human developments; thus, the historical distribution records of most species are scanty. Because the investigations included a large number of taxa, and because many museums do not catalog specimens by subspecies, it would have been unreasonable to ask personnel at most museums to furnish the required information. Instead, I visited and obtained distributional data from 13 major natural history museums and acquired information from nine others through correspondence (listed in the Appendix). Additional data from other mammal collections were obtained from the card files at the National Museum of Natural History, where for several decades early in the century the staff recorded specimens known to be housed in other museums. I also contacted several persons directly to inquire about specific taxa and human developments affecting plant communities in selected areas of California. This approach was more productive than broadcasting appeals for input. Unfortunately, however, identifying persons with the information needed was often impractical.

The species accounts in the Results section are arranged in groups by priority category and, within groups, systematically by genera, following Hall (1981). Species and subspecies are arranged alphabetically within genera. Records of distribution are listed alphabetically by county and, within counties, by locality with respect to reference point (e.g., city or physiographic feature). Localities using the same reference point are arranged by compass direction, starting with north and proceeding clockwise. Localities are listed as recorded on specimen tags and in museum catalogs or in the literature. The number of specimens, when known, and the museum of deposition or literature citation conclude each locality record. Cases where localities or identification of specimens seemed erroneous are discussed in the Remarks section.

Statements about habitat associations and population status are necessarily brief for most taxa because of lack of detailed information. Whenever possible, statements were developed primarily from information based on studies of the populations of concern rather than from studies conducted elsewhere. To extrapolate extensively from studies based on

populations outside the area of concern carries a high risk of incorrectly characterizing habitat use and population biology. Comments in the Recommendation sections are suggestions for priority actions and are neither detailed nor complete. Remarks on systematic status are intended to flag potential problems which should be considered in designing studies to elucidate the status of populations. Although neither state nor federal regulations require that a jeopardized population have unique taxonomic identity to be designated Rare, Threatened, or Endangered, the political conflict resulting from unresolved taxonomic controversies involving endangered species is best avoided whenever possible.

In interpreting and compiling the information in this report, and in assigning taxa to priority categories, my philosophy has been to give the benefit of doubt to the species under consideration. I have attempted to convey the essence of available information, but time and resources did not permit detailed field investigations or development of lengthy species accounts. A principal purpose of this report is to stimulate others with information to come forward. I have not cited all of the relevant literature for most taxa, especially reports that added no new information on the limited set of topics included in the accounts.

Scientific names for species are those listed by Jones et al. (1982) unless noted otherwise in the species accounts. Common names are from Grinnell (1933) and Williams (1979), or are ones commonly used by the Department of Fish and Game. Common names for subspecies are generally unnecessary, but, because subspecies can be accorded Threatened or Endangered status under both state and federal regulations, use of common names for subspecies is necessary in this report. Names for subspecies are from the list of Grinnell (1933), but often amended to reflect current taxonomy or to shorten needlessly long names. I coined common names or adopted those of other authors for subspecies not listed by Grinnell (1933). Scientific names for subspecies are from Hall (1981) except in cases where I disagree with his taxonomy or when more recent publications have altered his taxonomic arrangements. Departures from Hall's (1981) subspecies taxonomy are noted in the species accounts.

RESULTS

Of the species and subspecies investigated for this report, 36 warrant greatest concerns. These are listed in Table 2 in three categories: Highest, Second, and Third priorities. The definitions for these categories are based on the perceived proximity of threats of extinction. Species listed in the Highest Priority category appear to face a high probability of extinction or extirpation from their entire geographic range in California if current trends continue. Populations of species in the Second Priority category are definitely jeopardized and declining, but the threats of extinction or extirpation appear less imminent. Populations of species listed in the Third Priority category appear not to face extinction in the near future, but they are declining seriously or are otherwise highly vulnerable to extirpation because of human developments, and require special attention in land- and resource-management decisions. Some species listed in the Second and Third Priority categories are relatively rare and virtually no current data on their distributions and population status are available; when investigated in detail, some of these may be found to face greater or lesser threats. Accounts of species included in the three priority categories are presented in the following section.

Other species investigated, but considered to warrant lesser concerns are listed in the fourth group, entitled Other Candidates, beginning on page 73. Brief remarks on the probable status of these species, deleted from the final List of Concern, are included. Lack of information for some species listed is cause for concern about their status; their delation from the final List of Concern here should not be construed as a definitive indication of their population status.

Major contributing factors in jeopardizing most species on the List of Concern are the diminishment and degradation of natural communities (Table 3 and Species Accounts). Loss of native plant communities in four regions of California present the most acute problems threatening unique (i.e., taxonomically recognized) populations of mammals: the Colorado River riparian communities; the southern California coastal basins from the San Fernando Valley southward to the Mexican boundary, including lowland grassland and desert communities and tidal marshes along the south coast; the San Joaquin Valley desert, grassland, and riparian and wetland communities; and the tidal marsh communities of San Francisco and San Pablo bays. Loss of riparian and wetland communities is no less serious elsewhere, but fewer unique taxa of mammals are threatened. In addition to loss of habitat, disturbances by humans, especially in hibernacula and maternity roosts is perceived as a serious threat to most of the species of bats. Habitat degradation and lack of information on hunter take and population dynamics for use in management are viewed as potential threats to the five species of rabbits and hares, currently designated as game species, on the List of Concern. Cutting and fragmentation and isolation of blocks of mature and old-growth conifer forests pose potential threats to two species on the List of Concern.

Potential occurrences of Species of Special Concern on lands administered by several state and federal agencies are listed in Table 4. Information in Table 4 was developed from a "Federal Public Lands Responsibility Map" of California (1:7500,000 scale; 1978) and from other sources. There is

Table 2. Mammalian species of special concern in California, listed by priority categories. See text for definitions of priority categories. Page refers to starting page of species accounts.

Species	Page
HIGHEST PRIORITY	
Buena Vista Lake Shrew (<u>Sorex ornatus relictus</u>)	13
Suisun Shrew (<u>Sorex ornatus sinuosus</u>)	14
Santa Catalina Shrew (<u>Sorex ornatus willetti</u>)	16
Salt-marsh Wandering Shrew (<u>Sorex vagrans halicoetes</u>)	17
Arizona Myotis (<u>Myotis lucifugus occultus</u>)	19
Arizona Cave Myotis (<u>Myotis velifer velifer</u>)	21
Riparian Brush Rabbit (<u>Sylvilagus bachmani riparius</u>)	23
Point Arena Mountain Beaver (<u>Aplodontia rufa nigra</u>)	24
Los Angeles Pocket Mouse (<u>Perognathus longimembris brevinasus</u>)	25
Pacific Pocket Mouse (<u>Perognathus longimembris pacificus</u>)	27
Tipton Kangaroo Rat (<u>Dipodomys nitratoideus nitratoideus</u>)	28
Colorado River Cotton Rat (<u>Sigmodon arizonae plenus</u>)	30
Yuma Mountain Lion (<u>Felis concolor browni</u>)	31
SECOND PRIORITY	
So. California Salt-marsh Shrew (<u>Sorex ornatus salicornicus</u>)	34
California Leaf-nosed Bat (<u>Macrotus californicus</u>)	35
Townsend's Big-eared Bat (<u>Plecotus townsendii</u>)	37
Pocketed Free-tailed Bat (<u>Tadarida femorosacca</u>)	39
California Mastiff Bat (<u>Eumops perotis californicus</u>)	39
Salinas Pocket Mouse (<u>Perognathus inornatus psammophilus</u>)	42
White-eared Pocket Mouse (<u>Perognathus alticola alticola</u>)	43
So. Marsh Harvest Mouse (<u>Reithrodontomys megalotis limicola</u>)	44
Riparian Woodrat (<u>Neotoma fuscipes riparia</u>)	45
White-footed Vole (<u>Arborimus albipes</u>)	46
Point Reyes Jumping Mouse (<u>Zapus trinotatus orarius</u>)	48
THIRD PRIORITY	
Big Free-tailed Bat (<u>Tadarida macrotis</u>)	50
Pygmy Rabbit (<u>Brachylagus idahoensis</u>)	51
Oregon Snowshoe Hare (<u>Lepus americanus klamathensis</u>)	52
Sierra Nevada Snowshoe Hare (<u>Lepus americanus tahoensis</u>)	54
Western White-tailed Hare (<u>Lepus townsendii townsendii</u>)	55
Point Reyes Mountain Beaver (<u>Aplodontia rufa phaea</u>)	57
Tehachapi Pocket Mouse (<u>Perognathus alticola inexpectatus</u>)	58
Short-nosed Kangaroo Rat (<u>Dipodomys nitratoideus brevinasus</u>)	59
Red Tree Vole (<u>Arborimus longicaudus</u>)	61
Pacific Fisher (<u>Martes pennanti pacificus</u>)	64
American Badger (<u>Taxidea taxus</u>)	66
Channel Islands Spotted Skunk (<u>Spilogale gracilis amphiala</u>)	70

Table 3. Distribution, habitat, and major causes for concern for mammalian species of special concern in California. Refer to species accounts for details. CA - California; CI - Santa Cruz and Santa Rosa islands; CR - Colorado River; des. - desert; disturb. - human disturbances; GB - Great Basin steppes; Mtn. - mountains; N - north; NW - Northwest; Pt. A. - Point Arena area; Pt. R. - Point Reyes area; SB - San Bernardino; SCB - southern California coastal basins; SCM - southern California coastal marshes; SCI - Santa Catalina Island; SPB - San Francisco Bay; SJV - San Joaquin Valley; SN - Sierra Nevada; So - southern; SPB - San Pablo Bay; SV - Salinas Valley; Tr. R. - Transverse Ranges; W - west.

Species	Range	Habitat	Cause for Concern
HIGHEST PRIORITY			
Buena Vista Lake Shrew	SJV	Wetland	Habitat loss
Suisun Shrew	SPB	Salt marsh	Habitat loss
Santa Catalina Shrew	SCI	Riparian	Habitat loss?
Salt-marsh Wandering Shrew	SFB	Salt marsh	Habitat loss
Arizona Myotis	CR	Riparian	Habitat loss, disturb.
Arizona Cave Myotis	CR	Riparian	Habitat loss, disturb.
Riparian Brush Rabbit	SJV	Riparian	Habitat loss
Point Arena Mountain Beaver	Pt. A.	Wetland	Habitat loss
Los Angeles Pocket Mouse	SCB	Grass/Des.	Habitat loss
Pacific Pocket Mouse	SCB	Grass/Des.	Habitat loss
Tipton Kangaroo Rat	SJV	Grass/Des.	Habitat loss
Colorado River Cotton Rat	CR	Riparian	Habitat loss
Yuma Mountain Lion	CR	Riparian	Habitat loss
SECOND PRIORITY			
So. California Salt-marsh Shrew	SCM	Salt Marsh	Habitat loss
California Leaf-nosed Bat	So CA	Grass/Des.	Habitat loss, disturb.
Townsend's Big-eared Bat	CA	Various	Disturb.
Pocketed Free-tailed Bat	So CA	?	Disturb.?
California Mastiff Bat	W CA	Widespread	Disturb., pesticides?
Salinas Pocket Mouse	SV	Grassland	Habitat loss
White-eared Pocket Mouse	SB Mtn.	?	Habitat loss?
So. Marsh Harvest Mouse	SCM	Salt marsh	Habitat loss
Riparian Woodrat	SJV	Riparian	Habitat loss
White-footed Vole	NW CA	Riparian?	Habitat loss?
Point Reyes Jumping Mouse	Pt. R.	Wetland	Habitat loss
THIRD PRIORITY			
Big Free-tailed Bat	So. CA	?	Disturb.?
Pygmy Rabbit	GB	Sagebrush	Habitat loss
Oregon Snowshoe Hare	NE CA	Thickets	Habitat loss
Sierra Nevada Snowshoe Hare	SN	Thickets	Habitat loss
Western White-tailed Hare	GB SN	Grassland	Habitat loss
Point Reyes Mountain Beaver	Pt. R.	Wetland	Habitat loss
Tehachapi Pocket Mouse	Tr. Mt.	Grass/Des.	Habitat loss
Short-nosed Kangaroo Rat	SJV	Grass/Des.	Habitat loss
Red Tree Vole	NW CA	Fir	Habitat loss
Pacific Fisher	N CA	Conifer	Habitat loss, disturb.
American Badger	W CA	All	Habitat loss, taking
Channel Islands Spotted Skunk	CI	?	?

no similar, pictorial summary of state-managed lands nor a central source of information on state-owned lands. Thus, only lands managed by the California Departments of Fish and Game and Parks and Recreation are included. Information displayed in Table 4 should not be construed as indicating non-occurrence on lands administered by other governmental agencies or that other Species of Concern do not occur on lands administered by these agencies.



HIGHEST PRIORITY LIST

Buena Vista Lake Shrew
Sorex ornatus relictus

1932. Sorex ornatus relictus Grinnell, Univ. California Publ. Zool., 38:389. Type Locality: evacuated slough just outside of east side levee, Buena Vista Lake, 290 ft, Kern Co., California.

Distribution: Grinnell (1933) speculated that Buena Vista Lake Shrews once occupied the marshlands of the San Joaquin Valley floor throughout most of the Tulare Basin. He noted that by 1933, their range was much restricted because of the disappearance of lakes and sloughs.

Populations Status: Nothing is known about the current population status of the Buena Vista Lake Shrew. Nearly all of the valley floor in the Tulare Basin is now cultivated. Most of the lakes and marshes have been drained and are also cultivated. All of the Buena Vista Lake bed is cultivated, and most of the canals in the area are steep-sided and kept free of vegetation by use of herbicides. Ornate shrews (Sorex ornatus) may be extant in places such as the Kern National Wildlife Refuge, in wetlands of the Kern River percolation area, and along sloughs and canals on the valley floor leading into Goose Lake, although there are no records of shrews from any of these areas. Any extant populations found within the Tulare Basin may or may not be representative of S. o. relictus. Clark et al. (1982) used pitfall traps in an unsuccessful attempt to capture Buena Vista Lake Shrews on The Nature Conservancy Paine Wildflower Preserve and the Voice of America transmitter site west of Delano.

Habitat: Buena Vista Lake Shrews occupied marshes on the perimeter of Lake Buena Vista (Grinnell, 1932). Farther north, in the San Joaquin Basin, Ornate Shrews live in dense vegetation along streams and sloughs and around the perimeter of tule marshes (unpub. data). Presumably, Buena Vista Lake Shrews occurred in similar wetlands in the Tulare Basin.

Recommendations: A survey for Buena Vista Lake Shrews should be undertaken to establish its distribution and population status and to identify potential threats to remaining populations. Initial efforts should be concentrated around the Buena Vista Lake Aquatic Recreation Area (Lake Webb and Lake Evans), on the Kern National Wildlife Refuge, the Tule Elk Reserve, and along Buena Vista and Goose Lake sloughs. Pitfall traps are most effective for shrews (Williams and Braun, 1983), and can be left in place for extended times offsetting the extra effort required to set them.

Remarks: Nothing has been recorded on this taxon since the original description. The more upland subspecies, S. o. ornatus, occupies the area surrounding the range of S. o. relictus. Intergradation probably occurred along the lower courses of the streams entering the floor of the Tulare Basin.

Distribution Records: KERN CO.: N side Buena Vista Lake, 1 (USNM); east side levee, 298 ft, Buena Vista Lake, 290 ft, 3 (MVZ); Buttonwillow, 1 (CAS).

Suisun Shrew
Sorex ornatus sinuosus

1913. Sorex sinuosus Grinnell, Univ. California Publ. Zool., 10:181.
 Type Locality: Grizzly Island, Suisun Bay, Solano Co., California.
 1979. Sorex ornatus sinuosus, Williams, Ann. Carnegie Mus., 48:426.

Distribution: According to Rudd (1955a), Suisun Shrews occur in the tidal marshes of the northern shores of San Pablo and Suisun bays, as far east as Grizzly Island and as far west as the mouth of Petaluma Creek. Brown and Rudd (1981), however, redefined the western boundary of the range as Sonoma Creek and Tubbs Island. Shrews living in the marshes as far east as Collinsville represent S. o. californicus (Williams, 1983).

Populations Status: At one time, San Pablo and Suisun bays were lined with salt and brackish water marshes, but today marshes are broken into several small, isolated units. The marshes of Suisun Bay are the most extensive, but Suisun Shrew populations there may be threatened in part by management of the marshes to favor growth of Scirpus. Present habitat is much less extensive in San Pablo Bay. Very few of the extant tidal marshes have a full profile of marshland vegetation, and few border on significant upland areas where marshland species can seek refuge from flooding. Suisun Shrews inhabit a smaller area and are more restricted in the habitats they occupy than are Salt Marsh Harvest Mice, an Endangered Species.

The population status of S. o. sinuosus was investigated during spring and summer, 1983, following a winter of record flooding in the marshes of San Pablo and Suisun bays (Williams, 1983). No live Suisun Shrews were captured on any of 34 transects in marshes throughout the geographic range of S. o. sinuosus. One dead shrew was found, however. Subsequent surveys with Sherman live traps found one Suisun shrew in a marsh on the northern perimeter of Suisun Bay in 1985 (K. Ford, pers. comm.). The principal problem in both areas, but most acute in San Pablo Bay, is the lack of upland areas continuous with the marshes where Suisun Shrews and other terrestrial animals can refuge during times of flooding (Williams, 1983). Management of the marshes has not included refuges from flooding as a required element.

Habitat: Suisun Shrews typically inhabit tidal marshes characterized in order of decreasing tolerance to inundation, by Spartina foliosa, Salicornia ambigua, and Grindelia cuneifolia, and brackish marshes dominated by Scirpus californicus and Typha latifolia (Rudd, 1955a). They appear to require dense, low-lying cover where invertebrates are abundant. Rudd stated that structure ("growth form") of the plant community, not species composition, was the determining factor in shrew occupancy. Driftwood and other litter above the mean high-tide line is probably essential for nesting and foraging sites. Upland habitats, continuous with the marshlands, offering sufficient cover and sources of food to sustain shrews during prolonged flooding of marshes and dikes, such as occurred during the winter of 1982-83, are also probably essential (Williams, 1983).

Recommendations: When the results of additional population surveys for Suisun Shrews are completed (U.S. Fish and Wildlife Service, in litt.),

marshland management practices and plans should be reviewed to determine their impact on populations of Suisun Shrews. Acquisition of upland areas for refuge from flooding, or creation of refuge sites on dikes above flood level will probably be required to provide suitable habitat for Suisun Shrews and other small mammals inhabiting the tidal marshes.

Remarks: Rudd (1955a) analyzed structural characters of Sorex ornatus-group shrews from the San Pablo and Suisun bays areas and determined that shrews of the sinuosus type were recognizably distinct from S. o. californicus, but that spatially intermediate populations exhibited some intermediate characteristics. He thought that because the character gradients were rather abrupt, recognition of sinuosus as a species was justified. Brown (1971, and unpubl. dissert., 1970) found that S. ornatus and S. sinuosus had identical karyotypes, which differed from S. vagrans of the San Francisco Bay area. Karyotypes of shrews from populations previously thought to be S. v. vagrans or hybrids of vagrans, ornatus and sinuosus were shown to be identical to the ornatus-sinuosus karyotype. Brown and Rudd (1981) investigated the relationships of these shrews further, determining that sinuosus was best treated as a subspecies of S. ornatus, and restricting the distribution of sinuosus to an area approximately east of Sonoma Creek, but including Tubbs Island within the range of sinuosus.

The disposition of specimens referred to by Rudd (1955a) is not clear. Some of these are in the Museum of Vertebrate Zoology and others are in the collections at the University of California Davis. Differences in the locality descriptions on the specimen labels and in Rudd's (1955a) paper and differences in total numbers of specimens made it difficult to decide if these referred to the same specimens. Several specimens in museums, collected in marshes in San Pablo Bay in Sonoma County are designated as S. sinuosus, but are now considered to be S. o. californicus. Two specimens in the Museum of Vertebrate Zoology from "Solano County; Lake Chabot (seepage area below dam)" were assigned to the subspecies S. o. sinuosus. Lake Chabot is located on a golf course, west of the Solano Co. Fairgrounds. These specimens may be S. o. californicus or S. o. sinuosus; they are not listed below.

Distribution Records: SOLANO CO.: 0.5 mi NE Cordelia Salt Marsh, 5 (MVZ); Gray Goose Duck Club, 1.5 mi SW Suisun, 1 (CAS); Grizzly Island, Suisun Bay, 1 (LAGM), 20 (MVZ), 5 (UDAV), 2 (USNM), 19 (Rudd, 1955a); Grizzly Island, State Dept. of Fish and Game headquarters, 1 (CSCS); Honker Gun Club, near Dutton, Van Sickle Island, 1 (CAS); 3 mi E Mare Island Bridge, adjacent to White Slough and Hwy. 37, 1 (MVZ); 2.7 mi W jct. Napa Road and Hwy. 37 (on 37), 1 (MVZ); 8 mi N Rio Vista, 80 ft, 1 (CSUF); Sears Point Road, 6 mi NW Vallejo, 65 (MVZ); Sears Point Road, 8 mi NW Vallejo, 7 (MVZ); Sears Point Road, San Pablo Bay, 47 (Rudd, 1955a); South Hampton Bay, near Solano Co. public dump, 15 (MVZ); South Hampton Bay, 13 (Rudd, 1955a); Suisun City, salt marsh adjacent to Cordelia St., 4 (MVZ); Suisun marshes, periphery of Grizzly Island, 13 (Rudd, 1955a); 3 mi NW Vallejo, 1 (UDAV); Van Sickle Island, 1 mi S Dutton, 1 (CAS); Van Sickle Island, 1 (CAS), 3 (UDAV).

Santa Catalina Shrew
Sorex ornatus willetti

1941. Sorex willetti von Bloeker, Bull. So. California Acad. Sci., 40:163. Type Locality: Avalon Canyon, Santa Catalina Island, Los Angeles Co., California.
1967. Sorex ornatus willetti, von Bloeker, Proc. Symposium Biol. California Islands, p. 246.

Distribution: Santa Catalina Shrews are known only from Santa Catalina Island, Los Angeles California (Williams, 1983). The localities for the specimens and three sight records collectively span the length of the island (Collins and Martin, 1985; Williams, 1983).

Population Status: Only a single Santa Catalina Shrew was captured in a survey during January, 1983 employing pitfalls on 22 10-trap transects distributed in all major plant communities on the island (Williams, 1983). A subsequent survey, during summer, 1985, employing pitfalls on 25 10-trap transects failed to capture any additional shrews (Collins and Martin, 1985). Williams believed that the Santa Catalina Shrew might have been on the verge of extinction. Degradation of woodland, riparian, and wetland communities by introduced ungulates, especially sheep, cattle, feral goats, and wild pigs, and further degradation of these communities by diversion of water from springs and streams to the urbanized areas on the island probably were factors contributing to the scarcity of shrews. Another important factor was probably the marginal suitability of the island communities for shrews. Santa Catalina Island contains only a few small, degraded riparian communities and wetlands. Another important element threatening shrews was the high density of feral cats on the island.

Although most of the island is being managed by the Santa Catalina Island Conservancy with the objective of preserving the native biota, the Conservancy presently derives significant income from commercial hunting of wild pigs, goats, and deer, and sale of some bison. Free roaming ungulates on the island are the major threat to its native biota and a potential source of irreconcilable conflict of management objectives. These ungulates and introduced blackbuck (Antelope cervicapra) are noticeably degrading some natural plant communities and preventing others from recovering from damage caused when densities of domestic and feral ungulates were greater. Wild pigs are causing the most apparent damage in wetlands and streamside communities and on wooded slopes with deep layers of leaf litter: areas likely to be of major importance to shrews. Additional serious threats stem from the growing human resident and transient populations on the island where potable water supplies are already overtaxed. Diversion of increasing amounts of fresh water for human use will probably result in additional degradation of the already damaged riparian systems on the island.

Habitat: Although on the mainland, Ornate Shrews are often captured in upland plant associations such as coastal sagebrush and chaparral, their precise habitat requirements are unknown, and it has not been shown that communities such as these are important to breeding populations. Over most of their range in California, Ornate Shrews are most abundant in riparian and wetland communities (Collins and Martin, 1985; Owen and

Hoffmann, 1983; Williams, 1983). The only specimen of S. o. willetti trapped was taken in a tangle of driftwood and woody roots a few feet above a creek bed; riparian vegetation was poorly developed along that portion of the creek (Williams, 1983).

Recommendations: Two recent surveys for Santa Catalina Shrews have shown the extreme rarity of this insular population, but have failed to delineate critical elements of the biotic communities that must be protected in order to ensure survival of Santa Catalina Shrews. Thus, any activities taken to help protect the population possibly could have the opposite effect. Specific actions to enhance habitat for shrews on the island should only be made after obtaining results from detailed studies of Ornate Shrews on the mainland in similar communities with a similar climate. Studies should be designed to provide information needed in determining the best course of action to enhance the chances of survival of Santa Catalina Shrews. Regardless of these studies, however, preserving wetland and riparian systems should be given high priority in management of the island. Elimination of all ungulates, starting with wild pigs, feral goats, and bison would remove the greatest sources of damage to plant communities on the island. An intensive campaign to reduce the size of the population of feral cats would alleviate some pressure on shrews, but both the practicality of such a campaign and its importance in protecting shrews is in doubt.

The possibility that insular populations of Ornate Shrews occur on Santa Cruz, Santa Rosa, San Miguel, and/or San Clemente islands should not be overlooked (von Bloeker, 1967; Walker, 1980).

Remarks: The Santa Catalina Shrew was described as a species, but later was relegated to subspecific status under Sorex ornatus (von Bloeker, 1967). It differs from mainland shrews of the ornatus group in being larger and somewhat darker in color dorsally, with lighter-colored underparts. Present data are insufficient to determine the degree of relationship between Ornate and Santa Catalina Shrews, although available evidence supports treating it as a subspecies of S. ornatus (unpubl. data). A single, subfossil cranium of Sorex was found among midden remains in a rock fissure on the coast of San Miguel Island, Santa Barbara Co. (Walker, 1980). This specimen appeared to be structurally similar to S. o. willetti, according to Walker (1980).

Anecdotal accounts of sight records of Santa Catalina Shrews by residents of the island are: Middle Canyon W of Thompson Dam (Williams, 1983); Bank House at Middle Ranch, Middle Canyon; and Road to west end, 0.2 mi W Isthmus Dump (Collins and Martin, 1985).

Distribution Records: LOS ANGELES CO.: Avalon Canyon, Santa Catalina Island, 1 (LACM); 0.1 mi W Cottonwood Reservoir, Cottonwood Canyon, 76 m, 1 (CM).

Salt Marsh Wandering Shrew
Sorex vagrans halicoetes

1913. Sorex halicoetes Grinnell, Univ. California Publ. Zool., 10:183.
Type Locality: salt marsh near Palo Alto, Santa Clara Co., California.

1928. Sorex vagrans halicoetes, Jackson, N. Amer. Fauna, 51:108.

Distribution: Sorex v. halicoetes is limited to the salt marshes of the south arm of San Francisco Bay (Findley, 1955).

Populations Status: Johnston and Rudd (1957) reported fluctuations in relative numbers between 1951 and 1955, based upon numbers of active nests found. They determined that Salt Marsh Wandering Shrews represented about 10% of the small mammal community of the marshes and were less abundant than Mus musculus, Reithrodontomys raviventris, Rattus norvegicus, and Microtus californicus.

Most of the once-extensive salt marshes of San Francisco Bay have been lost by human developments. The extent of remaining habitat for these shrews is small. Because they use only a limited area within the marshes, there is less habitat for them than for Salt Marsh Harvest Mice. Therefore, S. v. halicoetes may be under greater threats of extinction than the Endangered Salt Marsh Harvest Mice. Ford (1986) found 16 live Salt Marsh Wandering Shrews in a population survey of marshes in San Francisco Bay during 1985. He recommended federal Endangered Species status for S. v. halicoetes.

Habitat: Johnston and Rudd (1957) provided a detailed sketch of the habitat of Salt Marsh Wandering Shrews. The shrews frequented areas in tidal marshes that provide dense cover, abundant food (primarily invertebrates), suitable nesting sites, and fairly continuous ground moisture. Their center of activity was in the "medium high marsh," about 6 to 8 ft above sea level, and in lower-lying marsh not regularly inundated. Suitable sites were characterized by abundant driftwood and other debris scattered among Salicornia. The Salicornia was usually 1 to 2 ft tall. The detritus preserved moisture and offered refuge in dry periods to amphipods, isopods, and other invertebrates, and resting sites for shrews. Nesting material consisted of plant parts, primarily Spartina duff. The higher-lying marsh, 8 to 9 ft in elevation, was too dry and offered only minimal cover — few or no shrews occupied this zone. The lower zone, dominated by Spartina, was subjected to daily tidal floods and had cover too sparse for shrews.

Recommendations: Any planned developments or activities that would modify marsh vegetation and degree of inundation with the range of the Salt Marsh Wandering Shrew should be reviewed to determine impact on this species. The feasibility of modification of extant marshes to enhance suitability for Salt Marsh Wandering Shrews, Salt Marsh Harvest Mice, and other jeopardized species should be investigated.

Remarks: The taxonomy of the Sorex vagrans species group has had a complex and confusing history and additional changes in scientific names will probably be required when relationships among populations are finally resolved (Findley, 1955; Hennings and Hoffmann, 1977; Rudd, 1955a). There appears to be no controversy about the taxonomic status of the halicoetes population, however. Brown (1974) found that the karyotype of one Salt Marsh Wandering Shrew was similar to those of three specimens of S. v. vagrans from the northern part of the San Francisco Bay region. These karyotypes were most similar to S. vagrans from areas farther north in California and Oregon. Eight specimens identified as S. v. halicoetes in

the collection of the California Academy of Sciences, captured from Inverness, Marin Co., are, in my opinion, S. v. sonomae.

Rudd (1955b) compared ages, sexes, and weights of S. v. vagrans, S. v. paludivagus, S. ornatus californicus, and S. o. sinuosus. Methods of distinguishing Salt Marsh Wandering Shrews from Ornate Shrews were given in Hennings and Hoffmann (1977) and Junge and Hoffmann (1981). The report by Ford (1986) was completed too late to include details here, but is the most complete account of the distribution and current population status of S. v. halicoetes.

Distribution Records: ALAMEDA CO.: 1 mi N bay Farm Island, Melrose Marsh, 1 (MVZ); Berkeley, 1 (USNM); Dumbarton Point, 1 (KU); Elmhurst, 4 (MVZ); Hayward, 1 (MVZ); Hayward Landing, end of Russell City Road, 6 (MVZ); Melrose, 1 (MVZ); 1 mi NW Newark, 1 (MVZ); Oakland airport, 1 (MVZ); S side Oakland Airport, 12 (MVZ); West Berkeley, 1 (USNM). CONTRA COSTA CO.: Giant (Atlas Powder Co. salt marsh), 1 (MVZ); 3 mi NE Oakley, E side Grizzly Island, 1 (MVZ); mouth San Pablo Creek, 1 (MVZ); San Pablo Creek Salt Marsh, 29 (MVZ); San Pablo Marsh, Richmond (Johnston and Rudd, 1957); salt marsh, 3 mi N Richmond, 1 (CM); salt marsh, 4 mi N Richmond, 1 (CM). SAN FRANCISCO CO.: Lake Merced, 1 (CAS); San Francisco, 4 (CAS), 1 (MVZ), Presidio, San Francisco, 1 (CAS). SAN MATEO CO.: no specific locality, 1 (MVZ); Belmont, 1 (MVZ), 2 (USNM); 0.9 mi NE Coloma, 17 (CAS); 0.5 mi S Chinese Cemetery, Coloma, 1 (CAS); Coloma, 1 (CAS); W approach Dumbarton Bridge, 3 (MVZ); Juncitas, 1 (SDSNH); Menlo Park, 1 (SDSNH); Pacifica, 0.25 mi E Westview, 1 (CAS); Palo Alto, 2 (LACM); adjacent to Palo Alto Yacht Harbor, 1 (UDAV); San Mateo, 2 (USNM); Redwood City, 1 (LACM), 3 (MVZ), 23 (SDSNH); Woodside, 1 (SDSNH). SANTA CLARA CO.: 1.75 mi NE Alviso, 79 (MVZ); Los Esteros Road, 0.5 mi NE Alviso (salt marsh), 20 (MVZ); 1 mi SSW Alviso (salt marsh), 3 (MVZ); county line between Santa Clara and San Mateo counties, on bay between Palo Alto and Redwood City, 2 (CM); Palo Alto, 7 (MVZ), 3 (USNM).

Arizona Myotis

Myotis lucifugus occultus

1909. Myotis occultus Hollister, Proc. Biol. Soc. Washington, 22:43.

Type Locality: west side Colorado River, 10 mi above Needles, San Bernardino Co., California.

1967. Myotis lucifugus occultus, Findley and Jones, J. Mamm., 48:443.

Distribution: Arizona Myotis occur from southeastern California and Sonora, Mexico, to western Chihuahua, Mexico, and northward in Arizona and western New Mexico (Fenton and Barclay, 1980; Hall, 1981). In California, the Arizona Myotis occurs only along the Colorado River lowlands and in the adjacent desert mountain ranges.

Populations Status: Populations of M. lucifugus have drastically declined in numbers in many parts of its range. Fenton and Barclay (1980) attributed declines, in part, to the use of pesticides, control measures in nursery colonies, collecting of bats by researchers, and disturbance of hibernating individuals. They underemphasized the importance in disturbances of hibernating bats, noting that it causes bats to lose weight, thus decreasing their chances of survival. Judging from incidental accounts,

Arizona *Myotis* were formerly common along the Colorado River. More recent observations suggest that this population has declined drastically (K. Stager, P. Leitner, pers. comm.). Arizona *Myotis*, like many other bats, may be sensitive to disturbances in their maternity roosts too. Many females fail to return to maternity colonies in years subsequent to disturbances by humans. They may abandon a colony prematurely, just after the young have learned to fly, but before than have learned to capture insects. This could lower recruitment into the population. Stream channelization and loss of the riparian vegetation may also be factors in the decline of *M. l. occultus* in California. Pesticide use in agricultural areas along the lower Colorado River and elsewhere could be a contributing factor in the decline (Fenton and Barclay, 1980; Geluso et al., 1976).

Habitat: Both Hollister (1909) and Grinnell (1914) shot Arizona *Myotis* flying among Cottonwood trees on the floodplain of the Colorado River. Others were collected by Grinnell "over water in a back eddy of the river." Stager (1943) found one Arizona *Myotis* about 100 ft in from the entrance of a large copper mine in the Riverside Mountains, in the northeastern corner of Riverside County. He also collected individuals from a maternity colony of about 800 bats, located on the underside of a bridge near Blythe. Although *M. l. occultus* is known only from the low desert along the Colorado River in California, it is most commonly associated with pine forests at elevations from 6000 to 9000 ft in other parts of its range (Barbour and Davis, 1969).

In most areas, roosts of Arizona *Myotis* have been found beneath bridges and in attics of buildings (Barbour and Davis, 1969). Arizona *Myotis* probably also use hollows in trees and protected crevices in rocks for roosts. Stager's (1943) record is the only known occurrence in a mine or cave.

Arizona *Myotis* may migrate out of California to spend the autumn and winter elsewhere, or they may make more local migrations to suitable hibernacula. The earliest and latest records of occurrence in California are 30 April and 16 August, respectively (Stager, 1943).

Recommendations: Highest priority should be given to locating populations, especially maternity colonies, and obtaining estimates of colony size. The most critical need is to establish a data base on population size so that future trends can be more reliably monitored. Where Arizona *Myotis* may pose a public health problem or a nuisance, exclusion or non-lethal aversion devices should be the only control methods allowed (Barclay et al., 1980; Constantine, 1979).

Remarks: Earlier, I (Williams, 1979) recognized *occultus* as a species despite evidence presented by Findley and Jones (1967) and Barbour and Davis (1970) indicating interbreeding in an area in New Mexico and southern Colorado between *M. lucifugus* and *occultus*. My decision was based on the results of a phenetic analysis of the genus *Myotis* (Findley, 1972) that suggested that *occultus* and *M. l. carissima* (the taxon with which *occultus* was thought to interbreed) were best placed in different species groups. Clearly, genetic studies are needed to resolve these conflicting findings. In the meantime, however, it seems best to follow

Findley and Jones (1967) in treating occultus as a subspecies of M. lucifugus.

Distribution Records: IMPERIAL CO.: Potholes, 1 (SDSNH); 4 mi S Potholes, Colorado River, 1 (MVZ); 5 mi NE Yuma, 1 (KU), 4 (MVZ). RIVERSIDE CO.: Blythe, 6 (CM), 59 (LACM), 1 (MVZ); Ft. Yuma, 3 (CAS); Ripley, 5 mi S Blythe, 3 (LACM); Riverside Mountains, 1 (LACM). SAN BERNARDINO CO.: 10 mi N Needles, 2 (USNM).

Arizona Cave Myotis
Myotis velifer velifer

1890. Vespertilio velifer J. A. Allen, Bull. Amer. Mus. Nat. Hist., 3:177. Type Locality: Santa Cruz del Valle, Guadalajara, Jalisco, Mexico.

1897. Myotis velifer, Miller, N. Amer. Fauna, 13:56.

Distribution: M. velifer velifer is found from extreme southeastern California eastward to western New Mexico and southward to Guatemala. In California, it is known only from the lowlands of the Colorado River and adjacent desert mountain ranges (Vaughan, 1959).

Population Status: Vaughan (1959) found large colonies, each containing approximately 1000 individuals, in several mine tunnels in the Riverside Mountains of Riverside and San Bernardino counties. More recent observations in the area (P. Brown, in litt.), suggest a significant decline in population size. Mines previously occupied now have few bats. The extent of decline and its causes are speculative. Loss of riparian habitat for foraging could be a principal factor, together with human disturbances of colonies. Renewed mining activities and casual exploration of caves and mines by rock collectors and sight-seers may be major sources of disturbances. Use of pesticides might have contributed to the decline by reducing abundance of insects and by poisoning bats.

Habitat: Cave Myotis are habitual cave dwellers and are highly colonial. They inhabit arid zones in the southwestern United States. During the season of reproduction, in spring and summer, they form large colonies in warm caves and mines and less often in buildings and other structures (Barbour and Davis, 1969). In California, they have been found in an old storehouse (Grinnell, 1914) and in mine tunnels (Stager, 1939; Vaughan, 1959). In large portions of their range they are typically associated with Brazilian Free-tailed Bats (Tadarida brasiliensis). Vaughan (1959) noted that Cave Myotis used a variety of temporary roosts: buildings, caves, and mine tunnels.

Vaughan (1959) found that in the vicinity of the Riverside Mountains, Cave Myotis foraged primarily over the floodplain of the Colorado River. He found that they maintained regular foraging paths "over low vegetation, along the files of dense vegetation that line the oxbows and main channel of the river, between the scattered thick patches of vegetation that dot the floodplain, or above bodias of water." He noted that the dense, linear stands of Mesquite, Tamarisk, and Catclaw Acacia bordering still water of oxbow ponds seemed to constitute optimal foraging habitat. Most foraging bats were observed between about 6 and 15 ft above the ground,

primarily close to vegetation. Kunz (1974) found that most individuals from large colonies in south-central Kansas dispersed nightly for considerable distances to feed. Insects of a variety of orders were consumed; beetles (Coleoptera) comprised the single largest class (Kunz, 1974).

In parts of their geographic range, especially in Kansas, Oklahoma, and Texas, Cave Myotis hibernate in winter (Twente, 1955). M. v. incautus may be quite different in its life history from M. v. velifer, however (Hayward, 1970). Stager (1939) did not find Cave Myotis in California during winter and early spring. He believed that they were only in California from May to October. They probably migrate into Mexico, but this has not been established.

Recommendations: Information pertaining to location and size of extant colonies is needed. Most colonies will probably be located in caves and mines, but buildings may contain some colonies. Data on population size are essential for assessing future trends and making management decisions. Colonies of Cave Myotis located in mines that are to be reactivated will likely abandon the sites as disturbances increase in frequency. Because the bats will most likely leave a roost in autumn, the best time to bat-proof structures is during the winter months, November to March (Constantine, 1979).

Agency biologists working in the southeastern California desert area must be able to identify Myotis velifer. They should be familiar with the situation outlined here, and be aware of the sensitivity of colonies to disturbances. They should be instructed in methods of estimating population size and techniques of non-lethal control of bats in human-made structures (Barclay et al., 1980; Constantine, 1979). Public health, law enforcement, and agricultural officials should refer all reports of bats and all requests for information on eradication of bats to the Department of Health Services, Veterinary Unit in Berkeley.

Remarks: Dr. Patricia Brown (in litt.) has monitored a population of M. velifer in a mine in the Whipple Mountains since 1968. This population declined in size by over 50% between about 1960 and 1980. The decline was at least partly the result of vandals entering the mine and killing several bats. A gradual decrease in numbers has continued since that incident, however.

Hayward (1970) determined that M. v. brevis Vaughan, 1954, was not recognizably distinct from M. v. velifer. Hall (1981) did not cite Hayward's (1970) paper.

Distribution Records: IMPERIAL CO.: 4 mi S Potholes, 1 (MVZ); 5 mi NE Yuma, 5 (MVZ). RIVERSIDE CO.: Alice Mine, Riverside Mountains, 56 (LACM); Dollar Mine, 5.5 mi S, 0.6 mi E Vidal, 1 (CSLB); Mountaineer Mine, 5.5 mi S, 0.6 mi E Vidal, 750 ft, 1 (MVZ); Mule Mountains (P. Brown, in litt.); Riverside Mountains, 35 mi N Blythe, 81 (Vaughan, 1959); Riverside Mountains, NE corner of county, 1 (MVZ); Riverside Mountains, 6 mi S Vidal, 8 (MVZ); Riverside Mountains, 7 mi S Vidal, 10 (MVZ). SAN BERNARDINO CO.: Needles, 3 (MVZ); W side river, above Needles, 2 (USNM); Whipple Mountains (P. Brown, in litt.).

Riparian Brush Rabbit
Sylvilagus bachmani riparius

1935. Sylvilagus bachmani riparius Orr, Proc. Biol. Soc. Washington, 48:29.
Type Locality: 2 mi NE Vernalis, Stanislaus Co., California.

Distribution: Orr (1940) collected specimens from a single locality along the west side of the San Joaquin River in northern Stanislaus County. He also observed, but did not collect, Riparian Brush Rabbits in adjacent San Joaquin County. Orr (1940) believed that the range of S. b. riparius extended along the San Joaquin River from Stanislaus County to the Delta region. The only presently known population is found on the lower Stanislaus River in Caswell State Park; there are probably other, tiny colonies between Caswell State Park and the confluence of the Stanislaus and San Joaquin rivers (Glenn Basey, in litt.).

Population Status: Only one moderate-sized population is known to be extant within Caswell State Park, San Joaquin County (G. Basey, in litt.). This population, which numbers perhaps less than 100 individuals at the start of the breeding season, was adversely affected by clearing and burning of brush in the Park in winter of 1984-85. Further development of recreation facilities in the Park and continuing brush clearing for fuel control pose significant threats to this population. Elsewhere between Caswell State Park and the San Joaquin River, Basey (in litt.) found only inconclusive evidence of tiny, scattered populations. Use of most of the property in the floodplain of the lower Stanislaus River is restricted by wildlife easements obtained as mitigation for loss of wildlife habitat as a result of construction of New Melones Dam. The Army Corps of Engineers is the administering agency for the easements. In his surveys, Basey (in litt.) found these wildlife areas were being used for rifle ranges, livestock grazing, off-road vehicle recreation, and other activities. Although Basey's studies are still in progress, activities such as these probably compound the threats to remaining populations of Riparian Brush Rabbits.

The Army Corps of Engineers is preparing to clear much of the brush and trees from within the lower San Joaquin River floodplain, between an area below Friant Dam, Fresno Co., and the delta in San Joaquin Co. (U.S. Fish and Wildlife Service, in litt.). Although no extant populations of Riparian Brush Rabbits have been found yet along the San Joaquin River, these activities pose a substantial threat to any remaining populations there and will virtually preclude reestablishment of populations in the future.

The major threat to remaining populations may stem from annual flooding. All land bordering the diked floodplains of the lower San Joaquin and Stanislaus rivers is cultivated or otherwise developed. In most areas, much or all of the woody vegetation has been removed for control of stream flow and to enhance growth of herbaceous plants for livestock grazing. In times of severe flooding, such as in the winters of 1979-80, 1982-83, and 1985-86, nearly all habitat available to Riparian Brush Rabbits is inundated. Animals living in the floodplain are forced to shelter on dikes or in areas lacking adequate cover, exposing them to increased predation and cold, wet weather. A single, severe episode of flooding, only slightly worse than was witnessed during March, 1986, could possibly

cause the extinction of remaining populations.

The Riparian Brush Rabbit is currently designated a Resident Small Game species and may be hunted. Although the effect of hunting on populations of Brush Rabbits, in general, are probably insignificant, hunting might easily extirpate most of the small, scattered populations of Riparian Brush Rabbits outside of Caswell State Park.

Habitat: In general, brush rabbits are associated with chaparral or other types of dense brush (Chapman, 1974). Riparian Brush Rabbits occupy dense thickets of Wild Rose (Rosa sp.), Willows (Salix spp.), and Blackberries (Rubus sp.) growing along the banks of the river. Orr (1940) never observed Riparian Brush Rabbits in loose brush or in open fields. Studies by Glenn Basey (in litt.) indicated that, in summer when herbaceous plants were largest and provided densest cover, Riparian Brush Rabbits used weedy fields and clearings adjacent to patches of shrubs. These areas of herbaceous vegetation were not entered in autumn and winter when the plants were dead and cover was minimal or absent. Basey (in litt.) found that patches of herbaceous growth at the immediate edge (within less than a meter) of shrubs were important sources of food.

Distribution Records: SAN JOAQUIN CO.: Caswell State Park, 2 (CSCS); San Joaquin River, extreme southern part of county (Orr, 1935). STANISLAUS CO.: Kincaid's Ranch, 2 mi NE Vernalis, W side San Joaquin River, 2 (CAS), 3 (MVZ).

Point Arena Mountain Beaver
Aplodontia rufa nigra

1914. Aplodontia nigra Taylor, Univ. California Publ. Zool., 12:297.

Type Locality: Point Arena, Mendocino Co., California.

1918. Aplodontia rufa nigra, Taylor, Univ. California Publ. Zool., 17:479.

Distribution: Aplodontia rufa nigra is known only from the vicinity of Point Arena, Mendocino County. According to Taylor (1918), it originally occupied a total area of about 24 square miles. Camp (1918) stated that known colonies extended from the town of Point Arena to Alder Creek, 7.5 miles north of town.

Population Status: An investigation of the status of the Point Arena Mountain Beaver by Dale Steele is presently in progress (U.S. Fish and Wildlife Serv., in litt.). Some populations are threatened by housing developments and others are small and apparently vulnerable to any event that would alter the character of their habitat. The restricted distribution of this population and the fact that Mountain Beavers are often heavily persecuted by humans gives additional cause for concern. Logging may benefit Mountain Beavers in that logging opens up the forest and stimulates growth of deciduous trees and herbaceous plants. Urbanization generally results in the decline or local extirpation of Mountain Beavers. Home developments are likely in the range of the Point Arena Mountain Beaver.

Habitat: Specific information on the Point Arena Mountain Beaver was given by Camp (1918). Only north-facing slopes of ridges and gullies were found to be inhabited. In general, Mountain Beavers inhabit wooded regions along the Pacific Coast with abundant moisture and herbaceous plants for food. Soils must be sufficiently soft for burrowing. Mountain Beavers are generally most numerous on the slopes of ridges and gullies. They are usually associated with deciduous thickets with a tangle of undergrowth of both herbaceous and woody vegetation (Scheffer, 1929). The brushy successional stages of most coniferous communities (excepting the more arid, pine forests) provide the best habitat. Often, Mountain Beavers locate their burrows in areas of seepage springs. Some running water within their burrow systems may be required. Point Arena Mountain Beavers mostly occupy thickets of thimbleberries on north-facing slopes.

Mountain Beavers eat a great variety of herbaceous and woody plants (Scheffer, 1929). Although Mountain Beavers prefer succulent stems of herbaceous plants, little vegetation within their reach seems unacceptable for food or use in construction of nests. Generally, only the bark of woody plants is eaten, and most woody material is consumed in winter when herbaceous plants are unavailable. Mountain beavers cut a great deal of herbaceous material and leave it scattered around to dry. Much of this material spoils and is never eaten.

Recommendations: When available, the results of the field survey by Dale Steele, for the U.S. Fish and Wildlife Service, should be reviewed to determine if additional protection for this population is needed.

Remarks: This nearly black population of Mountain Beavers is apparently isolated from all others by unsuitable terrain (Hall, 1981; Taylor, 1918).

Distribution Records: MENDOCINO CO.: Point Arena, 3 (CM), 6 (MVZ); Point Arena, Christensen Ranch, 2 (MVZ); 5 mi N Point Arena, 1 (UDAV).

Los Angeles Pocket Mouse
Perognathus longimembris brevinasus

1900. Perognathus panamintinus brevinasus Osgood, N. Amer. Fauna, 18:30.

Type Locality: San Bernardino, San Bernardino Co., California.

1928. Perognathus longimembris brevinasus, Huey, Trans. San Diego Soc. Nat. Hist., 5:88.

Distribution: The geographic range of Los Angeles Pocket Mice is restricted to lower elevation grasslands and Coastal Sage associations in the Los Angeles Basin, from approximately Burbank and San Fernando on the northwest to San Bernardino on the northeast, and Cabazon, Hemet, and Aguanga on the east and southeast. Their geographic limits on the southwest are not clear, but probably lie somewhere near the Hollywood Hills.

Population Status: Data on the population status of P. l. brevinasus are not available. Urbanization and cultivation of the majority of the land within the interior valleys of the Los Angeles Basin have made a large percentage of its historic range uninhabitable. Stephens (1906) noted that Los Angeles Pocket Mice were usually rare, but were infrequently

abundant, probably following years of much greater than average precipitation.

Small populations probably still exist in isolated parts of the historic range of P. l. brevinasus. The extent of available habitat cannot be estimated without a better understanding of its habitat requirements.

Habitat: Nothing specific has been recorded about the habitat requirements of P. l. brevinasus. Grinnell (1933) stated that it inhabited open ground with soils composed of fine sands. Stephens (1906) remarked that he thought that Los Angeles Pocket Mice did not often dig burrows. He said that they hid under weeds and dead leaves instead. This would be unusual for any species of Perognathus should it prove to be true.

Recommendations: Field notes of persons who surveyed the available habitat of Stephens' Kangaroo Rat may include some data on recent occurrence and abundance of P. l. brevinasus; information should be sought from them. Efforts should be made to determine the habitat associations and current distribution of this subspecies.

Remarks: Huey (1939) stated that specimens from Cabazon were not typical of P. l. brevinasus. The specimens from White Water Ranch may represent P. l. bangsi. I believe that specimens from near Ranchita (2 mi E, Culp Valley) and Warner Pass, San Diego Co., stated to be P. l. brevinasus by Bond (1977), are P. l. internationalis. Huey (1939) assigned the specimens from "Warner's Pass" to P. l. internationalis, but did not mention those from near Ranchita.

The Perognathus longimembris species group is in need of taxonomic revision. The characteristics diagnostic of P. l. brevinasus, especially the short rostrum, are nearly unique among the subspecies of P. longimembris. Osgood (1900) remarked that this taxon possibly represented a distinct species. If this is the case, P. l. brevinasus is probably conspecific with P. longimembris pacificus, which has a contiguous range along the coast and which also has a short rostrum.

Distribution Records: LOS ANGELES CO.: Burbank, 1 (USNM); Garney, San Fernando Valley, 1 (MVZ; see also Grinnell and Swarth, 1913); Hyperion (= El Segundo), 1 (LACM); San Fernando, 1 (MVZ). SAN BERNARDINO CO.: Cajon Wash, 9 (LACM); N of Etiwanda, 1 (LACM); Ferndale (Osgood, 1900); Reche Canyon, 1250 ft, 4 mi SE Colton, 1 (MVZ); mouth Reche Canyon, near Colton, 1 (MVZ), 44 (USNM); 4.75 mi N San Bernardino, 1600 ft, 3 (MVZ); 5 mi NW San Bernardino, 32 (SDSNH); Slover Mountain, near Colton, 1 (MVZ). SAN DIEGO CO.: 2.5 mi N Oak Grove, 7 (SDSNH). RIVERSIDE CO.: Aguanga, 3 (SDSNH); 0.25 mi ENE Aguanga, 2050 ft, 1 (MVZ); 1 mi SE Aguanga, 2150 ft, 3 (MVZ); Banning, base San Jacinto Mountains, 2 (MVZ), 2 (USNM); 2 mi E, 0.5 mi S Banning, 2100 ft, 1 (MVZ); 2 mi E, 3 mi N Beaumont, 3000 ft, 1 (MVZ); Cabazon, 70 (SDSNH); near Cabazon, base San Jacinto Mountains, 19 (MVZ); 2 mi NE Cabazon, 2 (CSLB); 0.25 mi E Cabazon, 1800 ft, 2 (MVZ); 1 mi S Cabazon, 3 (LACM); 2 mi S Cabazon, 7 (LACM); 3 mi S Cabazon, 2 (SDSNH); 1 mi N, 2 mi W Cabazon, 2200 ft (MVZ); Dos Palmas Spring, Santa Rosa Mountains, 3500 ft, 4 (MVZ); Eden Hot Springs, 1500 ft, 1 (MVZ); Hemet, 1 (USNM); Menifie, 27 (LACM); Vallevista, San Jacinto Valley, 1800 ft, 8 (MVZ); White Water Ranch, 2 (SDSNH); Winchester, 3 (SDSNH).

Pacific Pocket Mouse
Perognathus longimembris pacificus

1898. Perognathus pacificus Mearns, Bull. Amer. Mus. Nat. Hist., 10:299.
Type Locality: Mexican boundary monument No. 258, shore of Pacific Ocean, San Diego Co., California.
1932. Perognathus longimembris pacificus, von Bloeker, Proc. Biol. Soc. Washington, 45:128.

Distribution: P. l. pacificus inhabits the narrow coastal plains from the vicinity of the Mexican border, northward to El Segundo, Los Angeles Co., California.

Population Status: The present status of P. l. pacificus is unknown. Field work on the Irvine Ranch, San Joaquin Hills, Orange County (M'Closkey, 1972; Meserve, 1976) showed these mice to be scarce. This area is now urbanized. This subspecies may not be endangered, but habitat loss due to highways, urbanization, and off-road vehicle activities has likely been extensive. Probably all populations north of the San Joaquin Hills are extinct. This may also be the case from San Diego south, although some small areas near the Tiajuana River may still be inhabited.

Habitat: The types of soil and plant communities required by Pacific Pocket Mice are not known. Several authors noted that these Pocket Mice were found only on soils of fine, alluvial sands near the ocean (Bailey, 1939; Grinnell, 1933; Mearns, 1898; von Bloeker, 1931). M'Closkey (1972) and Meserve (1976) found Pacific Pocket Mice to be rare in a Coastal Sage-scrub community in a dry, rocky and gravelly site in the San Joaquin Hills of Orange Co. M'Closkey (1972) remarked that P. l. pacificus had an unpredictable pattern of residence there. Only open spaces in an otherwise dense, weedy area were occupied near San Diego (von Bloeker, 1931).

Principal plant species at several sites inhabited by P. l. pacificus were Telephone Weed, Foxtail, Saltgrass, Ice Plant, Star Thistle, and Arrow Weed (von Bloeker, 1930). Pacific Pocket Mice apparently eat mostly seeds of grasses and forbs (Meserve, 1976; von Bloeker, 1931), although other plant materials are consumed in smaller quantities (Meserve, 1976).

Recommendations: Information on areas of present occurrence and estimates of population densities are needed. Sites with favorable habitat may be rare, and these may serve as the only reservoirs from which individuals disperse to areas of lower quality habitat. A live-trapping program designed to provide data on distribution and abundance should be carried out. All persons undertaking field work on small mammals in the area should be encouraged to gather needed information on Pacific Pocket Mice. Public agencies administering land within the range of P. l. pacificus should be informed of the need for information and of the sensitivity of Pacific Pocket Mice to further loss of habitat. The Camp Pendleton Marine Corps Base may be the only area where habitat for P. l. pacificus can be protected relatively easily.

Remarks: Some of the localities, listed below, in San Diego County probably refer to the same place (e.g., 4 mi N Oceanside; sand dunes near Oceanside; mouth of Santa Margarita River). Specimens listed from

Tiajuana Valley by Huey (1939) are probably the same ones that von Bloeker reported on from "near the type locality."

The systematic relationships of the P. longimembris group needs to be reviewed, especially the relationships among P. l. pacificus, brevinasus, bangsi, internationalis and bombycinus of southern California. These taxa, and others in Baja California, possibly represent a species distinct from P. longimembris from the Mojave Desert and the Great Basin. P. l. cantwelli is a synonym of P. l. pacificus (Huey, 1939).

Distribution Records: LOS ANGELES CO.: Clifton, 100 ft, 1 (MVZ); Del Rey, 6 (LACM); Del Ray Hills, near Loyola, 2 (LACM); El Segundo, 8 (SDSNH); 1 mi N El Segundo, 8 (SDSNH); 0.5 mi NW El Segundo, 1 (MVZ); Hyperion [= El Segundo], 50 ft, 6 (MVZ); Palisades del Rey (von Bloeker, 1932); Pays Del Rey, 6 (LACM); Wilmington, 3 (MVZ). ORANGE CO.: Dana Point, 5 mi W Capistrano Beach, 10 (LACM); Irvine Ranch, between Buck Gully and San Joaquin Reservoir, San Joaquin Hills (M'Closkey, 1972; Meserve, 1976); near San Juan Capistrano Point (Grinnell, 1933); Star Ranch, N of San Juan Capistrano Beach (V. Bleich, pers. comm.). SAN DIEGO CO.: Oceanside, 3 (LACM), 6 (MVZ), 38 (SDSNH); 4 mi N Oceanside, 8 (LACM), 7 (SDSNH); sand dunes near Oceanside (Bailey, 1939); shore of Pacific Ocean, near U.S.-Mexican boundary monument #258, 11 (MVZ), 3 (USNM); San Onofre, 1 (SDSNH); 2 mi E San Onofre (von Bloeker, 1930); mouth of Santa Margarita River, near Oceanside, 1 (USNM); near mouth Tia Juana River, 4 (SDSNH); Tia Juana Valley, 79 (SDSNH); 2 mi N U.S.-Mexican boundary monument #258, 17 (LACM).

Tipton Kangaroo Rat
Dipodomys nitratoides nitratoides

1894. Dipodomys merriami nitratoides Merriam, Proc. Biol. Soc. Washington, 9:113. Type Locality: Tipton, San Joaquin Valley, Tulare Co., California.
1921. Dipodomys nitratoides nitratoides, Grinnell, J. Mamm., 2:96.

Distribution: The historic distribution of Tipton Kangaroo Rats included most of the San Joaquin Valley floor in the Tulare Basin, from approximately Lemoore and Hanford in Kings Co. on the north, to Visalia, Tipton, Delano and Bakersfield on the east, and to the edge of the alkaline-sink plant communities on the west. Present distribution is limited to a few remaining areas of uncultivated ground, mostly with alkaline soils (Williams, 1985). The western boundary was defined by Williams (1985) as being approximately coincident with the route of the California Aqueduct. D. n. nitratoides apparently interbred with the Short-nosed Kangaroo Rat (D. n. brevinasus) along the southern and western edges of the valley floor, but the geographic ranges of the two subspecies are no longer in contact (Hafner, 1979; Williams, 1985).

Population Status: Hafner (1979) determined that populations of Tipton Kangaroo Rats were extant on parts of the Kern and Pixley National Wildlife Refuges and in several small areas still uncultivated in 1978. The only large block of habitat was located in the area east and north of Buttonwillow, Kern County. Williams (1985) did not find Tipton Kangaroo Rats on the Kern National Wildlife Refuge in 1985, and speculated that

they may have been extirpated by floods that inundated even the dikes on the refuge during Winter 1982-83. Williams (1985) estimated that the historical geographic range of the Tipton Kangaroo Rat encompassed approximately 695,174 hectares (1,716,480 ac.). By July, 1985, the area inhabited had been reduced, primarily by cultivation, to about 25,665 ha. (63,367 ac.), only about 3.7% of the historical acreage. The loss of habitat was expected to continue until there is none privately owned, perhaps within the next four or five years. Only 2486 ha. (6137 ac.) of federally administered land was found to have historically supported populations; Tipton kangaroo rats may have been extirpated from 1053 ha. of this total between 1982 and 1985. Of all local, state and federal government-administered lands, only about 2606 ha. (6434), divided among five separate parcels, had populations of low- to moderate-densities of Tipton kangaroo rats that were relatively secure from loss of habitat to cultivation or extirpation due to flooding. These areas probably were not large enough to support populations sufficient in numbers to prevent continuing loss of genetic diversity and subsequent extinction. Other potential threats to small, isolated, remnant populations included diseases, predation and poisoning by rodenticides (Williams, 1985).

Habitat: Tipton Kangaroo Rats are limited to arid-land communities occupying the valley floor of the Tulare Basin in level or nearly level terrain. They occupy alluvial fan and floodplain soils ranging from fine sands to clay-sized particles (because of the high alkalinity of these soils, some of the finer-textured soils tend to be powdery when dry rather than hard-packed). Generally, woody shrubs of one or more species are sparsely scattered over occupied terrain with scant-to-moderate ground cover of grasses and forbs. Woody shrubs commonly associated with Tipton Kangaroo Rats are: *Atriplex spinifera*, *A. polycarpa*, *A. phyllostegia*, *A. lentiformis*, *Allentolfea occidentalis*, *Haplopappus acradeniua*, and *Prosopis juliflora*. A conspicuous semiwoody species is *Suaeda fruticosa* (Williams, 1985).

In areas with vernal pools and alkaline playas, Tipton Kangaroo Rats place their burrows in any elevated terrain available, such as where wind-blown soil particles have accumulated around some obstruction or on slight ridges, usually no more than 0.5 to 1.0 meter above the playa beds. Tipton Kangaroo Rats sometimes colonize areas that are flooded in winter and spring. Favored areas include iodine bush shrublands which are flooded seasonally and where alkaline water lies close to the surface of the soil, year around. Presumably, these individuals are either drowned or escape to higher ground when the floods return (Williams, 1985).

Recommendations: The most important need is for preservation of relatively large blocks of habitat on the valley floor in the Tulare Basin where this species still lives. Most remaining uncultivated parcels of habitat may be too small to support populations of Tipton Kangaroo Rats indefinitely (Williams, 1985). Williams (1985) recommended that federal Endangered Species status be sought for *D. n. nitratoides*. Review of the status of the Tipton Kangaroo Rat for state Endangered Species designation is called for.

Remarks: Records of distribution from along the western edge of the San Joaquín Valley listed by Hafner (1979) and in the draft version of this report have been excluded below. These specimens came from areas with

habitat typical of D. n. brevinasus; it was not clear from Hafner's report if the specimens were D. n. nitratoidea or D. n. brevinasus. Williams (1985) reviewed the status of these specimens and determined they were best assigned to brevinasus. The specimens listed below from Tulare Lake (USNM) had no precise locality information. They could have come from either Kings or Tulare counties. They are listed under Kings County because others in the U.S. National Museum were collected in that county. Williams (1985) reported that extant populations of Tipton Kangaroo Rats probably occurred on at least 154 separate parcels in 54 separate blocks of uncultivated land in June, 1985; these localities are not listed below.

The taxonomy of the subspecies of D. nitratoidea was reviewed by Hoffmann (1975) and Hafner (1979).

Distribution Records: KERN CO.: Adobe Station, 4 (USNM); Bakersfield, 1 (MVZ); 8 mi NE Bakersfield, 15 (MVZ); 12 mi SW Bakersfield, 1 (MVZ); 5 mi W Bakersfield, 1 (MVZ); 19 mi SE Bakersfield, 4 (CSUF); 20 mi S, 8 mi W Bakersfield, 1 (MVZ); 3 mi N Buena Vista Lake, 5 (MVZ); Buena Vista dry Lake bottom, 15 mi NE Taft, 4 (CSLB); east side levee, 298 ft, Buena Vista Lake, 4 (MVZ); S of Buena Vista Lake Reservoir, near Taft, 1 (USNM); Buttonwillow, 15 (USNM); 4.6 mi E Buttonwillow (M. Hafner); 9.6 mi E Buttonwillow (M. Hafner); 15 mi S Corcoran, 19 (MVZ); 0.5 mi N, 1 mi E Corners [Conners?], 6 (LACM); Delano, 16 (USNM); 1 mi S, 5.4 mi W Delano (M. S. Hafner); 1.4 mi S, 8.3 mi E Edison (M. S. Hafner); Famoso, 1 (USNM); 2.5 mi S, 6.3 mi E Famoso (M. S. Hafner); Kern National Wildlife Refuge, 18 mi W Delano, 2 (LACM); 2.5 mi N, 6.2 mi E Lost Hills (M. S. Hafner); 7 mi N, 5.3 mi E Lost Hills (M. S. Hafner); 7 mi N, 6.3 mi E Lost Hills (M. S. Hafner); 5.2 mi N, 1.5 mi W Mettler (M. S. Hafner); 7 mi W Old River (M. S. Hafner); 1 mi N Pond, 1 (MVZ); 4. mi S, 0.5 mi E Shafter (M. S. Hafner); 1.5 mi W Tupman, 2 (LACM); 1.2 mi S, 1.5 mi E Tupman (M. S. Hafner). KINGS CO.: 15 mi S Corcoran (Grinnell, 1931); 3.5 mi S, 2 mi W Lemoore (M. S. Hafner); Tulare Lake, 13 (USNM); W side Tulare Lake, 1 (USNM); Lemoore Naval Air Station (T. O'Farrell, pers. comm.). TULARE CO.: Alila [= Earlimart], 16 (USNM); 1.5 mi NE Angiola, 3 (CSUF); 2 mi NE Angiola, 39 (CSUF); 1.3 mi N, 5 mi W Delano (M. S. Hafner); Earlimart, 7 (LACM); 1 mi N Earlimart, 2 (MVZ); 2 mi W Earlimart, 5 (MVZ); 3.5 mi S, 5 mi W Pixley (M. S. Hafner); Tipton, 266 ft, 43 (MVZ); 2 mi NE Tipton, 1 (CSUF); 7 mi NE Tipton, 1 (MVZ); 3.5 mi S, 8 mi W Tipton (M. S. Hafner); 10 mi SW Tipton, 3 (CSUF); 12 mi SW Tipton, 2 (CSUF).

Colorado River Cotton Rat
Sigmodon arizonae plenus

1928. Sigmodon hispidus plenus Goldman, Proc. Biol. Soc. Washington, 41:205. Type Locality: Parker, 3500 ft, Yuma Co., Arizona.
1970. Sigmodon arizonae plenus, Zimmerman, Publ. Mus., Michigan State Univ., Biol. Ser., 4:435.

Distribution: Sigmodon arizonae plenus is found in California in marshy and dense, grassy areas along the Colorado River floodplain from the Nevada border to about the level of Bard. Goldman (1928) listed only three localities for S. arizonae in California: Needles; Colorado River opposite Parker, Arizona; and 15 mi SW of Ehrenberg, Arizona. The distribution was apparently spotty, rather than continuous.

Population Status: This population is known to be extant only in one area in California (Brad Blood, in litt.). In 1965, Bradley (1966) collected along the Colorado River in Nevada, but caught no Cotton Rats. The marsh where he and Hall (1946) had caught Cotton Rats had dried up and was largely devoid of Cattails. Bradley (1966) surmised that changes in vegetation resulted from absence of flooding due to channeling of the river and restriction of river flow while filling Lake Powell. He suggested that S. arizonae was extinct in Nevada.

Habitat: Goldman (1928) noted that this subspecies appeared to be restricted to "isolated sections of alluvial bottom along the Colorado River." The climate is too hot and arid to support Cotton Rats anywhere except immediately adjacent to the river. Within this habitat, Cotton Rats inhabit areas supporting Sedges, Rushes, Cane, and other grass-like plants. Hall (1946) collected Cotton Rats from a small marsh in Nevada supporting Cattails and Bermuda Grass and ringed by Mesquite. The marsh was 0.5 mi N of the California border, along the Colorado River. Bradley (1966) collected in the same area in 1961 and found no Cotton Rats, and none were found in nearby areas with "riparian vegetation."

Recommendations: Extant populations in California should be investigated further to determine their status. Efforts to preserve existing habitat for this species should be initiated. The feasibility of securing additional habitat along the Colorado River should be investigated.

Remarks: Brad Blood and David Huckaby of California State University, Long Beach, investigated the status of S. arizonae in California. Localities listed below without numbers of specimens refer to specimens that Brad Blood (in litt.) identified as S. arizonae.

Zimmerman (1970) showed that Sigmodon hispidus and Sigmodon arizonae differed greatly in chromosome number and structure, and were distinguishable in skeletal structure. S. arizonae plenus has two more chromosomes than S. s. arizonae. Severinghaus and Hoffmeister (1978) reconfirmed the structural distinctness of the two species and discussed methods for identification of skulls.

Distribution Records: IMPERIAL CO.: near Bard, 7 mi NE Ft. Yuma, 1 (MVZ); 2 mi above Laguna Dam, 3 (MVZ); Palo Verde, 3 (MVZ); 0.5 mi S Palo Verde (B. Blood - CSLB). RIVERSIDE CO.: Blythe, 1.5 mi W Colorado River, 8 (MVZ); 3 mi NE Blythe (B. Blood - CSLB); 15 mi SW Ehrenberg, 3 (USNM); Neighbors Road (B. Blood - LACM); opposite Riverside Mountains, Colorado River (B. Blood - LACM). SAN BERNARDINO CO.: 2 mi E Earp, 4 (CSLB); Colorado River, opposite Parker, Arizona, 25 (MVZ), 1 (USNM); Colorado River, 33 mi N Blythe, off Highway 62, via Earp, 2 (CSLB); Needles, 1 (USNM); 4 mi NE Parker, Arizona, on Colorado River, 2 (CSLB).

Yuma Mountain Lion
Felis concolor browni

1903. Felis aztecus browni Merriam, Proc. Biol. Soc. Washington, 16:73.

Type Locality: Colorado River, 12 mi below Yuma, Arizona.

1929. Felis concolor browni, Nelson and Goldman, J. Mamm., 10:347.

Distribution: Yuma Mountain Lions have been recorded as occurring at low elevations in the Colorado River Valley of southeastern California, southwestern Arizona, and adjacent areas in Sonora and Baja California (Currier, 1983; Young and Goldman, 1946). Halloran (1946) reported on a specimen which was trapped on the Kofa Game Range, 50 mi NE Yuma, Yuma Co., Arizona. The area was described as rough, desert terrain with an elevation of about 1000 ft. F. c. browni probably occupies the desert areas of southeastern California, perhaps ranging as far north as the Amargosa Mountains of California and the McCullough Range of southern Nevada. Its range extended westward into the Imperial Valley. Grinnell (1933) listed an occurrence at Calexico. Weaver noted occurrence of Mountain Lions from a few areas of the desert ranges of southeastern California: New York Mountains (Weaver et al., 1969); Little San Bernardino Mountains (Weaver and Hall, 1971); near Picacho State Recreation Area (Weaver and Mensch, 1969). Leslie and Douglas (1979) reported sight records of Mountain Lions on the east side of the River Mountains, near Lake Mead, Nevada. Halloran (1946) mentioned a few reports of sightings from the Imperial National Wildlife Refuge during the 1940's.

Population Status: No current information is available. Bounties on only two Mountain Lions from Imperial County were collected between 1907 and 1950 (McClellan, 1954), suggesting that at least in that county, mountain lions were very rare. Because these bounty records did not specify area within counties, it is not known if the animals from Riverside and San Bernardino counties were Yuma Mountain Lions. Most of the riparian floodplain forest of the lower Colorado River and the woody growth along desert washes have diminished or disappeared in this century.

Habitat: Grinnell (1933) stated that Yuma Mountain Lions lived mostly in the dense vegetation of the bottomland along the Colorado River, and also noted their presence in adjacent, rocky uplands. The habitat requirements of F. c. browni are essentially unknown. Mountain Lions in adjacent regions prefer brush and timber in rocky terrain (McLean, 1954). Most of the desert ranges of southeastern California are too arid to support more than sparse brushlands or Juniper woodlands. Adequate numbers of deer for food are another usual requirement (Currier, 1983). Weaver (in litt.) thought that Burro Deer (Odocoileus hemionus eremicus), principally inhabitants of bottomlands and arroyos vegetated with Willows, Mesquite, Acacia, Ironwood, and Palo Verde, were the staple food of Yuma Mountain Lions. Merriam (1903) remarked that the unusually small teeth and "weak" rostrum of F. c. browni indicated smaller species of prey than the deer typically preyed upon by adjacent populations of Mountain Lions. Burrow Deer are larger in size than adjacent populations of Mule Deer (Cowan, 1936). The tiny-sized Coue's White-tailed Deer, which was perhaps the most abundant deer species along the Colorado River in prehistoric times, may have been the major prey species for F. c. browni. Yuma Mountain Lions probably occasionally prey upon Mountain Sheep, Burros, rabbits and hares, various rodents, and calves, in addition to Burro Deer.

Recommendations: Field surveys for Mountain Lions in the eastern halves of Imperial, San Bernardino, and Riverside counties should be conducted to determine their current status. Information on the principal food of Yuma Mountain Lions is needed to determine current and future prospects for survival and to develop a plan to ensure the recovery of F. c. browni.

The geographic range of F. c. browni in California should be more clearly defined. The racial characters of this subspecies are apparent externally (Young and Goldman, 1946; Grinnell, 1914; Merriam, 1903); thus, examination of live-captured individuals should be sufficient to confirm racial identity. Systematic review of extant specimens from the California desert area should be carried out.

Mountain Lions in the California desert area should continue to be completely protected. Any individuals preying on livestock should be captured alive, if possible, and relocated, rather than killed.

Protection of riparian communities along the Colorado River should be undertaken as soon as possible. The Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. Department of Defense should be informed of the need for information about Yuma Mountain Lions on lands they administer within the potential range of F. c. browni.

Remarks: According to Goldman (Young and Goldman, 1946), F. concolor browni is medium-sized, very pale-colored, and has short, sparse pelage. Goldman noted that this population intergraded "along the mountain barrier west of the California desert area."

See the Distribution section for circumstantial records of occurrence.

Distribution Records: IMPERIAL CO.: Colorado River, 20 mi N Picacho, 1 (MVZ); Calexico (Grinnell et al., 1937).

SECOND PRIORITY LIST

Southern California Salt Marsh Shrew

Sorex ornatus salicornicus

1932. Sorex ornatus salicornicus von Bloeker, Proc. Biol. Soc. Washington, 45:131. Type Locality: Playa del Rey, Los Angeles County, California.

Distribution: Southern California Salt Marsh Shrews are confined to the coastal marshes in Los Angeles, Orange, and Ventura counties. Known occurrence extends from Point Mugo, Ventura County on the north to the salt marshes around Anaheim Bay and Newport Beach in Orange County, on the south.

Population Status: Nothing is known about the status of the Southern California Salt Marsh Shrew. Loss of habitat to human developments along the coast has been significant, and populations probably have declined as a result. Lack of refuge sites above the marshes to escape from flooding during seasonal high tides and periodic storms may be the most crucial factor threatening extant populations.

Habitat: Nothing has been recorded concerning habitat requirements of the Southern California Salt Marsh Shrew, other than that individuals were captured in coastal marshes (von Bloeker, 1932). In general, Ornate Shrews are insectivorous; the populations living in salt marshes probably subsist primarily on amphipods, isopods, insects, and other invertebrates. They probably require fairly dense ground cover, nesting sites above mean high tide and free from inundation, and fairly moist surroundings, based on studies of other shrews in similar habitats elsewhere (Johnston and Rudd, 1957).

Recommendations: Information is needed on the current status, habitat requirements, and extent of available habitat. Threats to these populations need to be identified and steps taken to ensure the survival of Southern California Salt Marsh Shrews. Pitfalls used as livetraps are effective for capturing shrews, but pitfalls are nearly impossible to keep in the ground in tidelands. Other affective methods of surveying populations are searching for nests (Johnston and Rudd, 1957) and shrews sheltering under debris (Ford, 1986), and, to a lesser extent, use of Sherman live traps. Surveys could be carried out in conjunction with studies of Reithrodontomys megalotis limicola, another Species of Special Concern sharing these saltmarsh communities.

Remarks: These communities are also used by the Light-footed Clapper Rail (Rallus longirostris levipea) and some potential habitat for Southern California Salt Marsh Shrews is currently in Department of Fish and Game "ecological reserves" (Upper Newport Bay and Bolsa Chica). Shrews have not been reported from marshes in Bolsa Bay, but they should be expected to occur there. Specimens in the San Diego Society of Natural History collection from Big Bear Lake and Lytle Creek, San Bernardino Co., identified as Sorex ornatus salicornicus, are S. o. ornatus.

Distribution Records: LOS ANGELES CO.: Nigger Slough, 1 (von Bloeker, 1932); Playa del Rey, 2 (LACM), 1 (UCLA), 1 (SDSNH), 5 (von Bloeker, 1932). ORANGE CO.: S side Newport Bay, 1 mi above Coast Highway, 2 (MVZ). VENTURA CO.: Point Mugu, 1 (LACM).

California Leaf-nosed Bat
Macrotus californicus

1859. Macrotus californicus Baird, Proc. Acad. Nat. Sci., Philadelphia, 10:116. Type Locality: Old Fort Yuma, Imperial Co., California.

Distribution: California Leaf-nosed Bats occur from southern Nevada, southern California and Western Arizona southward through Baja California Sur and Sonora, Mexico (Hall, 1981). In California, they occupy the low-lying desert areas of southern California, including the coastal basins.

Population Status: Macrotus californicus has disappeared from most areas of the coastal basins from Los Angeles to San Diego. Elsewhere in southern California, populations have declined, but appear to have stabilized (P. Brown, in litt.).

Loss of foraging habitat in the coastal basins is probably a principal factor in the decline of populations. Elsewhere, disturbances of roosts may be the primary cause of decline. Grinnell (1918) discussed an episode which suggests that maternity colonies are sensitive to disturbance; one colony apparently abandoned a cave after biologists had visited and collected bats. Judging from the description of depth of guano, the cave had been used for a long time. Wintering bats are probably even more sensitive to disturbances, as sites suitable for overwintering colonies are probably few. Disturbances cause extra activity and elevated metabolism, resulting in extra expenditure of energy at a time when energy economy may be critical to successful overwintering.

Habitat: In California, Leaf-nosed Bats are found in lowland desert associations. They appear to be limited to areas with suitable day-roosts, which must provide shelter from excessive heat and aridity. Howell (1920a) stated that California Leaf-nosed Bats were common in the desert only in caves and old mines, especially along the old shore line of the Salton Sea bed, near sea level. Ha remarked that the sexes roosted together only during the mating season. Barbour and Davis (1969) indicated that copulation occurred from September to November.

Vaughan (1959) studied M. californicus in the Riverside Mountains near the Colorado River. There, Leaf-nosed Bats occupied day-roosts only in caves and deserted mine tunnels. He found a day-roost in a cabin near the Colorado River, however. Leaf-nosed Bats roosted in groups of several to 100 or more. Most groups were encountered within 30 to 80 ft from the entrances of tunnels, and seemed not to require darkness. Vaughan believed that day-roosts of M. californicus must be enclosed and have overhead protection from the weather. Favored sites were large enough for bats to enter by flying because these bats cannot crawl. They also provided considerable ceiling surface and flying space (individuals are not in contact while hanging).

Temperatures in day-roosts are warm, but considerably cooler than ambient day-time temperatures outside the roost (84 vs 110 deg. F, respectively, Vaughan, 1959). California Leaf-nosed Bats occupy a great variety of night roosts, where they rest and consume captured prey. The only common feature Vaughan (1959) could detect of night-time roosts was adequate overhead protection -- old adobes, deserted wooden buildings, cellars, porches and a wide variety of caves and mine tunnels were used.

Leaf-nosed Bats apparently are entirely insectivorous in California. Food includes a diversity of flightless and flying arthropods (Barbour and Davis, 1969; Vaughan, 1959). Vaughan noted that Leaf-nosed Bats hovered frequently and flew low and slowly over the ground while foraging. Generally, they flew within 3 feet of the ground over dry washes and nearby flats. They also foraged close to vegetation. Vaughan surmised that they picked insects off of the vegetation and the substrate while hovering. California Leaf-nosed Bats may travel up to a mile from their day-roosts while foraging, but Vaughan suggested that their foraging range was small, perhaps within a few hundred yards of the roost on frequent occasions.

Some California Leaf-nosed Bats may migrate out of the state (probably to Mexico) during winter; P. Brown (in litt.) stated that many are resident. They do not hibernate. Stephens (1906) failed to find bats of this species in winter, but could always locate them in spring and summer. Grinnell (1918) reported that March and September were the earliest and latest dates, respectively, for M. californicus in California. She noted, however, that one specimen in the Museum of Vertebrate Zoology was collected on 31 December in a mine near Palo Verde, and recounted information on presence of Leaf-nosed Bats on 20 February.

Recommendations: Reliable quantitative data are greatly needed on population size, distribution, and currently used maternity and overwintering roosts, if the latter are found in California. Trends cannot be unequivocally established until these baseline data are gathered. United States Geological Survey maps are a good source of information for locating abandoned mines. The old shore line of the Gulf of California around the perimeter of the Salton Sink contains many shallow grottos and caves, as does that along the Colorado River lowlands. Careful search, while avoiding excessive disturbances, should reveal colonies. Colony size can be estimated by counting emerging bats (usually, Leaf-nosed Bats emerge about 1 to 1.5 hours after sunset).

Protection of nursery colonies from disturbances by humans is extremely important. The means of accomplishment would depend upon the situation. The entrances to tunnels could probably be sealed off to prevent access by humans but permit entry by bats (Leaf-nosed Bats must be able to enter by flying). Some important roosting areas might more simply be closed to access by vehicles. This method, however, is unlikely to reduce sufficiently the level of disturbances in many areas, and is impractical in many others.

A carefully designed campaign to inform the public of the usefulness of bats and their sensitivity to disturbances may be helpful. Department of Fish and Game personnel in Southern California should be informed about the need for preservation of this and other species of bats. Agency

personnel in field positions should be trained to recognize M. californicus, as well as all other species, and should receive instructions on methods of estimating colony size and control of bats in man-made structures (see Barclay et al., 1980; Constantine, 1979). They should be informed of the sensitivity of colonies to disturbances, and use only approved methods of observation and control, when necessary. Persons in agencies such as public health, law enforcement, and agriculture should be similarly informed.

Remarks: Grinnell (1918) listed the localities, Santa Margarita Ranch and River, as being in San Diego County, whereas Riverside County was listed on the specimen tags. She also listed the localities, Indian Wells and Mecca, as being in Imperial County, but they are actually located in Riverside County.

The systematic status of Macrotus californicus has been a subject of disagreement among researchers. Anderson and Nelson (1965) believed that the evidence they examined demonstrated that californicus was a subspecies of M. waterhousii. Davis and Baker (1974) interpreted additional morphometric and karyotypic evidence as showing specific distinctness of these taxa. Hall (1981) treated californicus as a subspecies of waterhousii because of "inconsistencies" in the literature. I believe the evidence favors specific recognition.

Distribution Records: IMPERIAL CO.: Clapp Mine, 15 mi NE Yuma, 5 (MVZ); Ft. Yuma, 18 (CAS), 28 (KU), 14 (MVZ), 2 (PM), 1 (UDAV), 1 (USNM), 1 (TCWC); 6 mi SW Ft. Yuma, 10 (KU); Palo Verde, 4 (MVZ), 1 (SDSNH); 24 mi S Palo Verde, 1 (MVZ); Picacho Mine, 16.5 mi N Ft. Yuma, 1 (MVZ); Potholes, 25 (CM), 3 (SDSNH); 1 mi N Potholes, 1 (SDSNH); 2 mi N Potholes, 200 ft, 34 (MVZ); 3 mi N Potholes, 4 (KU); Senator Mine, 10 mi N Potholes, 11 (SDSNH); Tumco Mine, 5 mi N, 2 mi E Ogilby, 9 (UDAV), 6 (MVZ). LOS ANGELES CO.: Iverson Ranch, Santa Susanna Pass, Chatsworth, 1 (MVZ); 2 mi N Owensmouth (Howell, 1920). RIVERSIDE CO.: Alice Mine, 7 mi S Vidal, 2 (MVZ); Indian Wells, 2 (MVZ), 4 (USNM); Mecca, 2 (MVZ); Mountaineer Mine, 5.5 mi S, 0.6 mi E Vidal, 2 (CSLB); Mountaineer Mine, 5.6 mi S, 0.3 mi E Vidal, 14 (MVZ); Mountaineer Mine, T2S, R24E, 5 (MVZ); Neighbors, 11 (LACH); Riverside Mountains, 35 mi N Blythe, 22 (KU); Riverside Mountains, 7 mi S Vidal, 86 (MVZ); Santa Margarita River, 17 (CAS); W of State Highway 95, 9 (UDAV); Torres [Toro], 61 (MVZ); cave near Torres [Toro], 2 (KU); 5 mi E Vidal, 1 (UDAV); 5.3 mi S Vidal, 7 (CAS). SAN BERNARDINO CO.: 2 mi N Colorado River, 0.2 mi W Nevada boundary, 1000 ft, 2 (MVZ). SAN DIEGO CO.: Anza Borrego State Park, 2 (SDSNH); Artery Mine, Dulzura, 1 (SDSNH); De Luz, 8 (CAS); 2 (USNM); Donahue Mines, near Dulzura, 2 (LACH); Pauma Valley, 2 (SDSNH); 10 mi NW Ripley, 2 (KU); Vallecito, 38 (MVZ), 4 (SDSNH), 20 (USNM).

Townsend's Big-eared Bat
Plecotus townsendii

1837. Plecotus townsendii Cooper, Ann. Llyc. Nat. Hist. New York, 4:73.
Type Locality: Columbia River [Fort Vancouver, Clark Co., Washington].

Distribution: Townsend's Big-eared Bats occur throughout California,

although details of their distribution are scanty. There are two subspecies within California: P. t. townsendii occupies the humid, coastal regions of northern and central California and P. t. pallescens occurs in the remainder of the state (Hall, 1981).

Populations Status: Little specific information is available on populations trends, although a marked decline in numbers appears to have occurred over the last 40 years. Pearson et al. (1952) postulated that there was an increase in numbers prior to the 1950's due to increased roosting sites available in human-made structures. In recent years, populations of Townsend's Big-eared Bats seem to have declined in numbers in most areas of the United States (Barbour and Davis, 1969; Humphrey and Kunz, 1976). Patricia Brown (in litt.) noted that populations of P. t. pallescens in the desert area of southeastern California were declining. She stated that they no longer occupied any of the roosts used 30 years previously (about 1950). Graham (1966) found no extant colonies in California's limestone caves, and speculated that all had been abandoned due to human activities. My impression, based on numbers found and turned in to the Biology Department at California State University, Stanislaus, by local residents, is that P. t. pallescens was common in central California into the 1960's, but by the early 1970's was rarely seen. I have captured only one individual during 14 years of netting bats in central California, and none have been turned in to me by others.

Habitat: Townsend's Big-eared Bats live in a variety of communities, including coastal conifer and broad-leaf forests, oak and conifer woodlands, arid grasslands and deserts, and high-elevation forests and meadows. Throughout most of its geographic range, it is most common in mesic sites (Kunz and Martin, 1982). Known roosting sites in California include limestone caves, lava tubes, mine tunnels, buildings, and other human-made structures (Dalquest, 1947; Graham, 1966; Pearson et al., 1952). Habitat for Townsend's Big-eared Bats must include appropriate roosting, maternity, and hibernacula sites free from disturbances by humans. A single visit by humans can cause the bats to abandon a roost. Females typically roost in large maternity colonies which are highly susceptible to disturbances by humans (Barbour and Davis, 1969). Males usually roost singly or in small groups and are probably not affected as much as females by disturbances. Both sexes hibernate in buildings, caves, and mine tunnels, either singly (males) or in small groups (P. Brown, in litt.; Pearson et al., 1952).

Recommendations: Data documenting population status and size and location of maternity colonies and hibernacula are needed most. Great care must be observed in gathering such information; roosts should not be entered. Public land-administering agencies should give special consideration to protecting roosts located on public lands from human disturbances.

Remarks: Early in the investigations, I decided information was insufficient to determine a priority listing for Plecotus townsendii, but that it was probably jeopardized to some degree. Unfortunately, this decision also meant that I quit collecting detailed information on distribution records. Since development of the draft List of Concern, I have decided that this species warranted higher priority than the "sensitive" category to which it was assigned. Thus, no documentation of distribution records are included.

Pocketed Free-tailed Bat
Tadarida femorosacca

1889. Nyctinomus femorosaccus Merriam, N. Amer. Fauna, 2:23. Type Locality: Agua Caliente [Palm Springs], Riverside Co., California.
 1924. Tadarida femorosacca, Miller, Bull. U.S. Natl. Mus., 128:86.

Distribution: Pocketed Free-tailed Bats have a spotty distribution, ranging from southern California through the Baja California Peninsula, and southward through southwestern Arizona to at least Michoacan and Tamaulipas, Mexico (Hall and Kelson, 1959). In California, they are known only from a few records in the arid lowland of the southern part of the state. Pocketed Free-tailed Bats are probably resident within the state.

Population Status: There is little current information on the status of T. femorosacca in California. According to P. Brown (in litt.), the roost described by Krutzsch (1944a) is no longer occupied. The paucity of records suggests that T. femorosacca has always been rare, or at least rarely encountered, in California. Because T. femorosacca can easily be confused with the widespread and common T. brasiliensis, it may be more common than records suggest. I listed it here in an attempt to stimulate gathering of information about its status in California.

Habitat: Pocketed Free-tailed Bats are characteristically associated with rocky, desert areas with relatively high cliffs. They generally use crevices in rocks as day-roosts, although they sometimes are found in man-made structures. Krutzsch (1944a) found a colony of 50 to 60 individuals in a crevice in the side of a cliff on a southwestern-facing slope in San Diego Co. T. femorosacca drops from the roost in order to gain speed for flight.

Recommendations: The principal need at this time is for reliable data on the distribution and population status of T. femorosacca. Biologists and public health personnel who routinely work with bats should be alerted to the need for information on T. femorosacca and briefed about methods of distinguishing species of Tadarida.

Remarks: There is no controversy about the status of this species. It is similar only to T. brasiliensis in the United States (see Barbour and Davis, 1969).

Distribution Records: IMPERIAL CO: Mouth of Colorado River (Grinnell, 1933). RIVERSIDE CO.: Agua Caliente [Palm Springs], 1 (USNM); Barker Dam Reservoir, Joshua Tree National Monument (P. Brown, in litt.); Palm Canyon, near Palm Springs, 1 (FMNH), 1 (MVZ). SAN DIEGO CO.: Palm Canyon, Borrego Valley, 1 (MVZ); 2 mi SE Suncrest store, Suncrest (Krutzsch, 1944b).

California Mastiff Bat
Eumops parotis californicus

1890. Molossus californicus Merriam N. Amer. Fauna, 4:31. Type Locality: Alhambra, Los Angeles County, California.
 1932. Eumops parotis californicus, Sanborn, J. Mamm., 13:351.

Distribution: Mastiff Bats occur from central California, southward to central Mexico. In California, they have been recorded from Butte County southward in the western lowlands through the southern California coastal basins and the western portions of the southeastern desert region (Sanborn, 1932). Vaughan (1959) observed mastiff bats at Hetch Hetchy Reservoir in the central Sierra Nevada and there are also records of this species from Yosemite Valley. All others are from lower-lying regions. E. perotis is resident within the state, although some bats probably migrate from the colder areas to winter in the southern lowlands (Krutzsch, 1955).

Population Status: Available records indicate that Mastiff Bats were widespread in the San Joaquin Valley, Salinas Valley, and Coastal lowlands from the San Francisco Bay area southward to San Diego. Incidental information suggests that populations of E. perotis have undergone significant declines in recent years (P. Brown, in litt.; P. Leitner, pers. comm.). Historically known roosts in central California are no longer occupied (unpubl. data). Reasons for their decline are only conjecture. Extensive loss of habitat due to urbanization of coastal basins, marsh drainage, and cultivation of major foraging areas are likely factors in the decline. Widespread use of insecticides may have also reduced insect abundance and also poisoned some bats.

Habitat: Mastiff Bats are resident at low elevations in the coastal basins of southern California. They appear to favor rugged, rocky areas where suitable crevices are available for day-roosts. Characteristically, day-roosts are located in large cracks in exfoliating slabs of granite or sandstone. The crevices must open downward, be at least 5 cm wide and 30 cm deep, and narrow to at least 2.5 cm at their upper end (Vaughan, 1959). The crevices typically open high on a cliff and are at least 2 m above the substrate (Krutzsch, 1955; Vaughan, 1959). Mastiff Bats have great difficulty taking flight, and must drop at least 2 to 3 m for launching. Mastiff Bats also frequently roost in buildings, provided these have sheltering spaces with conditions similar to those described above. Howell (1920b) speculated that prior to construction of buildings, Mastiff Bats roosted in cracks in rocks and in hollow trees.

Vaughan (1959) observed Mastiff Bats and estimated that they foraged as much as 2000 ft above the ground. He noted that in some places they regularly foraged at 100 to 200 ft over the substrate. They probably forage for considerable distances from their roosting sites. For example, colonies roosting in suitable sites in the Diablo and Tumbler ranges, flanking the San Joaquin Valley, likely foraged over the valley floor where insects were more abundant.

Mastiff Bats become torpid on a circadian cycle during the winter months (Leitner, 1966).

Recommendations: Data on the nature and extent of changes in population densities are needed. Historic roosting sites, especially those in areas unlikely to be disturbed by humans, should be surveyed to determine current numbers. Efforts to locate occupied roosts and to estimate numbers should be undertaken. Pesticide loads in captured bats, those found dead, and layered accumulations of guano should be determined.

Colonies which must be controlled because of health hazards or for other reasons should not be poisoned. Efforts to exclude such colonies from structures should be made only at times least likely to result in increased mortality (i.e., not in winter or when young, non-volant bats are present; Constantine, 1979).

Persons in public agencies who handle questions or problems dealing with bats should be informed of the need for information on E. perotis and of its sensitivity to disturbances. Sources of information on methods of non-lethal control of bats should be brought to the attention of such agencies (e.g., Barclay et al., 1980; Constantine, 1979).

Remarks: Eumops perotis is structurally distinct from all other species of Eumops. Eumops perotis californicus is the only subspecies occurring in North America. A second, disjunct population, E. p. perotis, is found in South America, as far south as Argentina (Eger, 1977).

Distribution Records: California (no specific locality), 1 (USNM).
ALAMEDA CO.: Hayward, 1 (USNM). BUTTE CO.: Oroville (Eger, 1977).
FRESNO CO.: Fresno, 2 (CAS), 1 (MVZ); Little Table Mountain, 1 (CSUF); Mendota (von Bloeker, 1943); Trimmer, 1 (MVZ). IMPERIAL CO.: 24 mi S Palo Verde, 1 (MVZ). KERN CO.: near Bakersfield (Krutzsch, 1955); Buena Vista Lake, 5 mi NE Taft, 1 (CSLB); Buttonwillow, 1 (CAS); 1 mi SW Democrat Springs, 1950 ft, Kern River, 19 (MVZ); 10 mi N McKittrick, 1 (CAS); Summer, 1 (MVZ); 10 mi NW Taft, 1 (CSLB), 1 (LSU), 1 (ROM); 10 mi W Taft, 4 (CSLB); Twisselman Ranch, near McKittrick (Krutzsch, 1955). LAKE CO.: Arabella Lake (Storer, 1926); Middleton (Storer, 1926). LOS ANGELES CO.: Alhambra, 1 (AMNH), 1 (LACM), 1 (UI), 2 (USNM); Azusa, 1 (AMNH), 2 (CAS), 17 (LACM), 2 (LSU), 1 (MCZ), 1 (MVZ), 1 (SDSNH), 4 (USNM); Citrus College, Azusa, 1 (CSLB); Claremont (Vaughan, 1959); Covina, 1 (AMNH), 5 (CSLB), 4 (FMNH), 6 (LACM), 5 (MVZ), 4 (UI), 12 (USNM); Gardena (von Bloeker, 1932b); Glendora, 2 (CSLB); Los Angeles, 1 (AMNH), 16 (LACM), 1 (LSU), 1 (MVZ), 16 (USNM); Palms, 2 (SDSNH); Pasadena, 6 (MVZ); Pomona, 1 (KU), 1 (SDSNH), 7 (USNM); Santa Monica, 3 (SDSNH); Santa Monica Mountains, crest at east end (Vaughan, 1959); Sierra Madra, 9 (MVZ).
MARIPOSA CO.: Mariposa, 1 (ANSP); Yosemite Valley (Vaughan, 1959).
MONTEREY CO.: Camphora, 2 mi N Soledad, 1 (MVZ). ORANGE CO.: Santa Ana, 1 (ROM). RIVERSIDE CO.: 4 mi SW Lakeview, 2 (KU); Mecca, Colorado Desert, 1 (MVZ); near Perris (Vaughan, 1959); 6 mi W Riveraide (Vaughan, 1959). SAN BENITO CO.: Silver Creek, 7 mi ESE Panoche, 900 ft, 18 (MVZ; Dalquest, 1946). SAN BERNARDINO CO.: Colton, 1 (KU), 7 (MVZ), 1 (PM), 1 (TCWC), 2 (UDAV), 1 (UI); Slover Mountain, Colton, 1 (MVZ); 1 mi N, 6 mi W Lucerne Valley (Vaughan, 1959). SAN DIEGO CO.: 1.5 mi N Barrett Junction, 7 (MVZ); Barrett Dam (Krutzsch, 1943); Bow Willow Ranger Station, Anza Borrego Desert, 1 (SDSNH); Dos Cabasas, 1 (USNM); Dulzura, 4 (FMNH), 19 (SDSNH); El Cajon (Vaughan, 1959); Lake Hodges, near Escondido, 1 (MVZ); Otay, 1 (CAS); San Diego, 2 (SDSNH); southeast of Suncrest (Krutzsch, 1945); Yaqui Wall, 1 (SDSNH). TULARE CO.: Porterville (Constantine and Humphrey, 1979); Traver, 1 (CAS). TUOLUMNE CO.: Hatch Hetchy Reservoir (Vaughan, 1959).

Salinas Pocket Mouse
Perognathus inornatus psammophilus

1937. Perognathus longimembra psammophilus von Bloeker, Proc. Biol. Soc. Washington, 50:153. Type Locality: west side Arroyo Seco Wash, 150 ft, 4 mi S Soledad, Monterey Co., California.

Distribution: As defined herein (see Remarks), the known distribution of P. i. psammophilus extends from near Soledad southward to Hog Canyon in the Salinas Valley, Monterey Co. The relationships of populations on the Carrizo Plains (von Bloeker, 1937), Cuyama Valley, and upper Salinas River watershed are uncertain (see Remarks).

Populations Status: Most natural communities in the Salinas Valley have been cultivated or otherwise developed. Extant populations of Salinas Pocket Mice have not been located in that area in recent years. Areas where they may still be found are privately owned and access to search for Salinas Pocket Mice is difficult to acquire.

Habitat: According to von Bloeker (1937), Salinas Pocket Mice occur on fine-textured, sandy soils. They may also occur on a variety of other substrates in annual grassland and desert shrub communities, especially where plant cover is not dense and soils are friable.

Recommendations: The most pressing need is for information on the location and status of extant populations. Efforts to locate populations and to preserve suitable habitat in the Salinas Valley should be given relatively high priority. The systematic relationships of P. i. psammophilus, P. i. inornatus, and P. i. neglectus should be resolved prior to any proposals for protecting the Salinas Pocket Mouse.

Remarks: All of the specimens available to von Bloeker (1937) when he described P. longimembra psammophilus were subadults. He also described P. inornatus sillimani from the same locality (Arroyo Seco) at the same time (1937). All of the specimens of P. i. sillimani that von Bloeker (1937) reported on and used in his diagnosis were adults. Although von Bloeker (1937) compared both subspecies with other subspecies of their respective species, he did not compare the two new subspecies with each other. I examined all of the extant specimens of both taxa and found no evidence suggesting that there was more than one species represented. The two subspecies are based upon different age groups drawn from the same population. Neither group of specimens closely resembles P. longimembra, which, in my opinion, does not occur anywhere in the central California lowlands, despite indications to the contrary in Hail (1981) and other publications (see below). I consider psammophilus to be a subspecies of P. inornatus, and P. i. sillimani to be a junior synonym of P. i. psammophilus. The latter decision is based upon the superior page position of the description of psammophilus (von Bloeker, 1937).

Available data show that populations of P. inornatus living on the Carrizo Plain, San Luis Obispo Co., are closely similar in structure and karyotype to those of P. i. neglectus from along the western margin of the San Joaquin Valley (Williams, 1978, and unpubl. data). On the bases of different karyotypes (50 vs 56 chromosomes) and body proportions, P. i. neglectus and P. i. inornatus are probably different species. P.

longimembris does not occur in central California. Mice from within the San Joaquin, Sacramento, and Salinas valleys, identified by others as P. longimembris, are all referable to one or the other group of P. inornatus (unpubl. data).

Specimens listed here are from within the geographic range of P. i. sillimani as defined by von Bloeker (1937), but which I consider to be indistinguishable from P. i. neglectus. Their relationship with P. i. psammophilus is unresolved; it is possible that psammophilus will be found to be a synonym of neglectus. SAN LUIS OBISPO CO.: 5.5 mi SW Caneros Spring, 1 (CAS); Carrizo Plains, W end Salt Lake, 1 (USNM); Carrizo Plains, 8 mi E [SE] Simmler, 3 (USNM); 8.75 mi SE Cholame, 2200 ft, 1 (CAS); Cuyama Valley, 3 mi E Cuyama Ranch, 3 (USNM); Elk Horn Plain, 1 (CM); Indian Creek, 1500 ft, 13 mi S Shandon, 1 (MVZ); Salinas Valley, 2 mi S San Miguel, 7 (MVZ); San Diego Joe's, 2700 ft, 6 (MVZ); San Diego Joe's, 1 mi S, 7 mi E Simmler, 2700 ft, 7 (MVZ); Santiago Springs, 1 (MVZ), 4 (USNM); Santiago Springs, 1.5 mi S, 8 mi E Simmler, 10 (MVZ); 4 mi S, 5 mi E Shandon, 1175 ft, 4 (MVZ); 7 mi SE Simmler, 5 (MVZ); Soda Lake, 1 (CSLB). VENTURA CO.: Quatal Canyon, 6 mi E Venucopa, 1 ((MVZ).

Localities (above) listed as San Diego Joe's and Santiago Springs refer to the same place. This has led to considerable confusion because Santiago Creek is in Kern County on the San Joaquin Valley side of the Temblor Range and San Diego Joe's was located along San Diego Creek on the western slope of the Temblor Range. Also, the locality referred to as San Diego Joe's or Santiago Springs is around 2500 ft.

Distribution Records: MONTEREY CO.: Arroyo Seco, W side, 4 mi S Soledad, 150 ft, 8 (LACM), 30 (MVZ); Arroyo Seco River, 10 mi S Paradise Springs, 1 (USNM); Hog Canyon, 1 (LACM); Metz, Salinas Valley, 200 ft, 1 (MVZ); mouth Wild Horse Canyon, 500 ft (von Bloeker, 1937).

White-eared Pocket Mouse
Perognathus alticola alticola

1894. Perognathus alticolus Rhoads, Proc. Acad. Nat. Sci. Philadelphia, 45:412. Type Locality: Squirrel Inn, 5500 ft near Little Bear Valley, San Bernardino Mountains, San Bernardino Co., California.
1900. Perognathus alticola, Osgood, N. Amer. Fauna, 18:39.

Distribution: Perognathus alticola alticola is known only from the western portion of the San Bernardino Mountains in the vicinity of Strawberry Peak, at altitudes extending from about 5400 ft to 5800 ft. Grinnell (1908) reported that an immature Perognathus, partly eaten, was found in a trap set in Sagebrush at the north base of Sugarloaf Peak, at 7500 ft. This was likely a White-eared Pocket Mouse.

Population Status: Stephens (1906) remarked that White-eared Pocket Mice were uncommon, and that considerable trapping had yielded only six specimens. A few additional specimens were collected in the years prior to the 1940's. I am not aware of any specimens collected later than 1934. Jim Sulentic (1983) searched extensively for White-eared Pocket Mice, starting in June of 1979 and using pitfalls and livetraps. To date, no White-eared Pocket Mice have been taken.

Habitat: Only scant information has been recorded. Grinnell (1933) stated that members of this population inhabited the Transition life-zone, living on the "dry floor of open Pine forest where Bracken Fern grows." White-eared Pocket Mice are likely to be found among Sagebrush and other shrubs in open, Ponderosa Pine forests and Pinyon-Juniper woodlands and in Sagebrush covered areas on the northern slopes and Big Bear Basin of the San Bernardino Mountains.

Recommendations: The U.S. Forest Service should be informed of the need for information on White-eared Pocket Mice, as it is the principal land-administering agency within the area. Efforts to locate extant populations should be intensified, including searches in the San Gabriel Mountains. If and when such populations are located, action designed to ensure their security should be taken.

Remarks: Jim Sulentic and David Huckaby at California State University, Long Beach are principal authorities on the current population status of this taxon. White-eared Pocket Mice will probably be found to be most common on the northern slopes of the San Bernardino and San Gabriel Mountains.

Rhoad's (1894) specific epithet, alticolus, apparently referred to the mountain home of this species (altus, high; cola, inhabiting). However, the root, col, is a prefix to be used before r and meaning with or together. Osgood (1900) amended the spelling without comment. As Rhoads (1894) made no reference to what the name was supposed to mean or how it was derived, one can only guess about his intent. I suspect, therefore, that Osgood's amendment was inappropriate, but as this spelling (alticola) is well-entrenched in the literature, its continued use will best preserve nomenclatural stability. I raise this issue here because two prominent works on California's mammals (Grinnell, 1933; Ingles, 1965) used Rhoads' spelling. Rhoads' paper was dated 1893, but was published in 1894. The White-eared Pocket Mouse is an apparently isolated allospecies of the Perognathus parvus group (Williams, 1978).

Distribution Records: SAN BERNARDINO CO.: San Bernardino Mountains, 3 (USNM), 1 (ANSP), 1 (SDSNH); Squirrel Inn, San Bernardino Mountains, 5500 ft, 2 (LACM), 3 (MVZ), 6 (SDSNH); 0.5 mi E Strawberry Peak, San Bernardino Mountains, 2 (SDSNH); 1 mi E Strawberry Peak, San Bernardino Mountains, 5750 ft, 5 (MVZ), 3 (SDSNH); 2 mi E Strawberry Peak, 5750, ft, 13 (MVZ); Strawberry Peak, 5000 to 5700 ft, 21 (LACM).

Southern Marsh Harvest Mouse
Reithrodontomys megalotis limicola

1932. Reithrodontomys megalotis limicola von Bloeker, Proc. Biol. Soc. Washington, 45:133.

Distribution: Southern Marsh Harvest Mice are known to occur only in coastal salt marshes in Ventura, Los Angeles, Orange, and Santa Barbara counties, California.

Population Status: No current data are available. The urbanization of the areas within this mouse's range has been extensive. Stream

channelization and development of coastal areas have resulted in habitat loss. These developments and urbanization could have fragmented remaining habitat and isolated populations too small to endure. Some of the marshes are currently protected as ecological reserves, however.

Habitat: Southern Marsh Harvest Mice are strictly confined to marshy areas, generally coastal salt marshes dominated by Salicornia. Adjacent weedy areas and marshes in brackish sites may also be inhabited (von Bloeker, 1932a).

Recommendations: The immediate need is for data on distribution and population status. A live-trapping program should be undertaken.

Remarks: Specimens identified as R. m. limicola from Dominguez Hills and Palo Verde Hills, Los Angeles County (CSLB), are probably referable to R. megalotis longicaudus. According to von Bloeker's (1932a) description, R. m. limicola is easily distinguished from adjacent subspecies of Harvest Mice.

Distribution Records: LOS ANGELES CO.: Del Rey Marsh, 3 (LACM), 1 (USNM); 0.5 mi NW El Segundo, 1 (MVZ); Hyperion, 2 (LACM); Marina Del Rey, salt marsh N of Culver Blvd., 1 (CSLB); Nigger Slough, Gardena, 5 (LACM); Playa del Rey, salt marsh, 46 (LACM); 1 mi N Playa del Rey, salt marsh, 1 (LACM); Torrance, Avalon Blvd. and Dominguez Channel, 1 (CSLB). ORANGE CO.: Anaheim Bay, 8 (LACM); Los Altos, E of Ammo. Dump, 1 (CSLB); Newport Beach, 2 mi NE Highway 101, 2 (CSLB); San Gabriel River Blvd., 1 (CSLB). SANTA BARBARA CO.: Carpinteria, salt marsh, 5 (LACM). VENTURA CO.: Point Mugu, 16 (LACM).

Riparian Woodrat
Neotoma fuscipes riparia

1938. Neotoma fuscipes riparia Hooper, Univ. California Publ. Zool., 42:223. Type Locality: Kincaid's Ranch, 2 mi NE Vernalis, Stanislaus Co., California.

Distribution: Riparian Woodrats are known only from an area along the San Joaquin, Stanislaus, and Tuolumne rivers in Stanislaus and San Joaquin counties (Hooper, 1938; unpubl. data). Hall and Kelson (1959) assigned a specimen from El Nido, Merced Co., to this subspecies on geographical grounds (see Remarks).

Population Status: Trapping programs along the Tuolumne (C. Johnson, unpubl. ms.) and Stanislaus (G. Basey, unpubl. ms.) rivers have resulted in a few captures only in Caswell State Park. The current status of this population is unknown. Regulation of stream flow, stream channelization, cultivation of the floodplains, and brush and tree removal have diminished available riparian habitat. Removal of undergrowth and large trees with dead and hollow limbs in parks has reduced habitat further. If current trends continue, additional habitat loss can be expected. During floods, there are few or no refuges for Woodrats, as nearly all land bordering the rivers is cultivated. A population is still extant in the general area of the type locality (unpubl. data), but its demographic features are unknown.

Habitat: Dusky-footed Woodrats are found only in areas supporting brush. Generally, they occur in areas with mixtures of trees and brush. They require suitable nesting sites such as cavities in trees, snags, or logs; spaces in talus; or lodges built of downed woody material. These houses or lodges are usually a conspicuous feature of areas inhabited by N. fuscipes.

Nothing specific has been recorded about the habitat of Riparian Woodrats. Basey (unpubl. ms.) captured a few Riparian Woodrats in traps set in runways of Riparian Brush Rabbits. Students at California State Univ., Stanislaus, have noted that these Woodrats occasionally use nest boxes placed in trees for Wood Ducks along the lower San Joaquin and Tuolumne rivers. Apparently, Woodrats also eat the eggs of the Wood Ducks. The San Joaquin Valley is generally devoid of suitable habitat for Woodrats, except along rivers where trees and brush were found. Thus, this population is confined to riparian habitat.

Recommendations: A survey of riparian areas along all of the principal tributaries of the San Joaquin River should be undertaken to determine distribution and abundance of N. f. riparia. The status and relationships of the Woodrats in Corral Hollow should be clarified. Appropriate wildlife organizations and county fish and wildlife committees involved in placing and monitoring Wood Duck nesting boxes should be alerted to the need for information about Riparian Woodrats.

Remarks: There is no habitat for N. fuscipes in the area around El Nido today, because of agricultural developments. The specimen probably came from somewhere along the San Joaquin River west or south of El Nido. A specimen from 10 mi SW Los Banos (Merced Co.; CSUF) is either N. f. perplexa or N. lepida (I do not recall looking at the specimen when the data were obtained from the museum records).

Distribution Records: MERCED CO.: El Nido (Hall and Kelson, 1959). SAN JOAQUIN CO.: Corral Hollow, 1 (MVZ); Corral Hollow Creek, 4 mi E Alameda Co. line, 1 (MVZ); San Joaquin River, 3 mi NE Vernalis, 3 (MVZ). STANISLAUS CO.: Kincaid's Ranch, 2 mi NE Vernalis, 2 (MVZ).

White-footed Vole
Arborimus albipes

1901. Phenacomys albipes Merriam, Proc. Biol. Soc. Washington, 14:125.
Type Locality: Redwoods, near Arcata, Humboldt Bay, Humboldt Co., California.
1979. Arborimus albipes, Williams, Ann. Carnegie Mus., 48:426.

Distribution: White-footed Voles occur in the humid coastal forest region from the Columbia River, Oregon, southward to Humboldt County, California. They are known from near sea level to as high as 3500 ft (Maser and Johnson, 1967). The localities in California are all from low-lying areas.

Population Status: No data are available to allow determination of the population status of A. albipes. White-footed Voles have been captured infrequently, and must be considered rare. Because nearly all known

localities of capture have been associated with small streams in forested areas, White-footed Voles may be sensitive to logging and other alterations of riparian habitats.

Habitat: Maser and Johnson (1967) reviewed habitat notes associated with each specimen known to them. White-footed Voles have been taken in a variety of situations, but generally seemed to be associated with small streams in forested areas. Available evidence indicates that these voles are terrestrial, unlike A. longicaudus. Their structural features, however, suggest that they are more scansorial than typical voles (Johnson and Maser, 1982). They probably climb shrubs and downed woody material in the understory, and perhaps even trees.

All records of capture are from areas in the humid coastal forest region. Captures were mostly in forested sites, but one was taken in a logged area (two years after logging), and one was captured in a grassy spot on a partly logged ridge top (Maser and Johnson, 1967). Very small clearings, created by fallen timber and supporting herbaceous growth, may be important habitat for this species. Thickets of Alders and other riparian communities along small streams (Maser et al., 1980) may also be essential habitat.

Howell (1928) found only roots of herbaceous plants in three stomachs of White-footed Voles, whereas Maser and Johnson (1967) found green plant material in several stomachs.

Recommendations: Arborimus albipes should be given special consideration in forest management plans within its range. There is little public land within its known range in California. White-footed Voles occur in the Redwood National Park's northern section in Del Norte and Humboldt counties; special effort should be made to determine their distribution and habitat needs there.

White-footed Voles will probably be found farther inland at higher elevations on State and U.S. National Forest lands. Intensive searches should be conducted to determine the limits of their distribution in California, habitat needs, and population status. Pitfall trapping may prove more successful for capture of White-footed Voles than conventional snap-traps.

Remarks: Taylor (1915) described Arborimus as a subgenus of Phenacomys. Johnson (1973) presented and discussed evidence which indicated that Tree Voles (Arborimus) were divergent from Heather Voles (Phenacomys); he elevated Arborimus to generic rank. Unfortunately, Johnson (1973) did not state whether albipes was an Arborimus or a Phenacomys. Based upon the obviously close similarity of albipes to A. longicaudus (Howell, 1920c, 1926; Taylor, 1915), Williams (1979) treated albipes as a member of the genus Arborimus. Johnson and Maser (1982) discussed characteristics diagnostic for Arborimus and Phenacomys and formally transferred albipes to the genus Arborimus.

Distribution Records: DEL NORTE CO.: Wilson Creek, N of Klamath [city], 1 (CM). HUMBOLDT CO.: Arcate, Humboldt Bay, 1 (USNM); 5.5 mi E Bayside, 1 (MVZ); 3 mi N Orick, 1 (UCLA); Trinidad, 1 (HSU), 1 (MVZ), 2 (SDSNH); N of Trinidad, 1 (MVZ), 3 (USNM).

Point Reyes Jumping Mouse
Zapus trinotatus orarius

1899. Zapus orarius Preble, N. Amer. Fauna, 15:29. Type Locality: Point Reyes, Marin County, California.
1944. Zapus trinotatus orarius, Hooper, Misc. Publ. Mus. Zool., Univ. Michigan, 59:67.

Distribution: Zapus trinotatus orarius is apparently confined to a small area on the Point Reyes Peninsula, Marin County, California (Kruttsch, 1954).

Population Status: No data are available on the current status of Point Reyes Jumping Mice. The habitat for this population is not extensive. Post-Pleistocene changes in climate may continue to modify habitat unfavorably for this species in the Point Reyes area. Grazing by Cattle may have been a factor contributing to adverse conditions for Jumping Mice at Point Reyes, but this problem has been resolved. The impact of introduced Axis and Fallow deer is unknown. The principal causes for concern are the small range and relictual nature of the population, and the fact that these mice are seemingly scarce.

Habitat: Howell (1920d) listed the habitat of this population as bunch grass marshes on the uplands of Point Reyes. Kruttsch (1954) stated that Point Reyes Jumping Mice occur in moist areas that are safe from continuous inundation. Farther north, Pacific Jumping Mice are characteristic of the Pacific coastal coniferous forests. They seem to prefer riparian Alder communities and treeless openings with tall, dense herbaceous growth of grasses and forbs (Maser et al., 1981). Wet, marshy sites are often said to be preferred, although Pacific Jumping Mice also occur occasionally in closed forests with little understory, in dry meadows, and more often in thickets of deciduous, woody vegetation along streams and seepage areas.

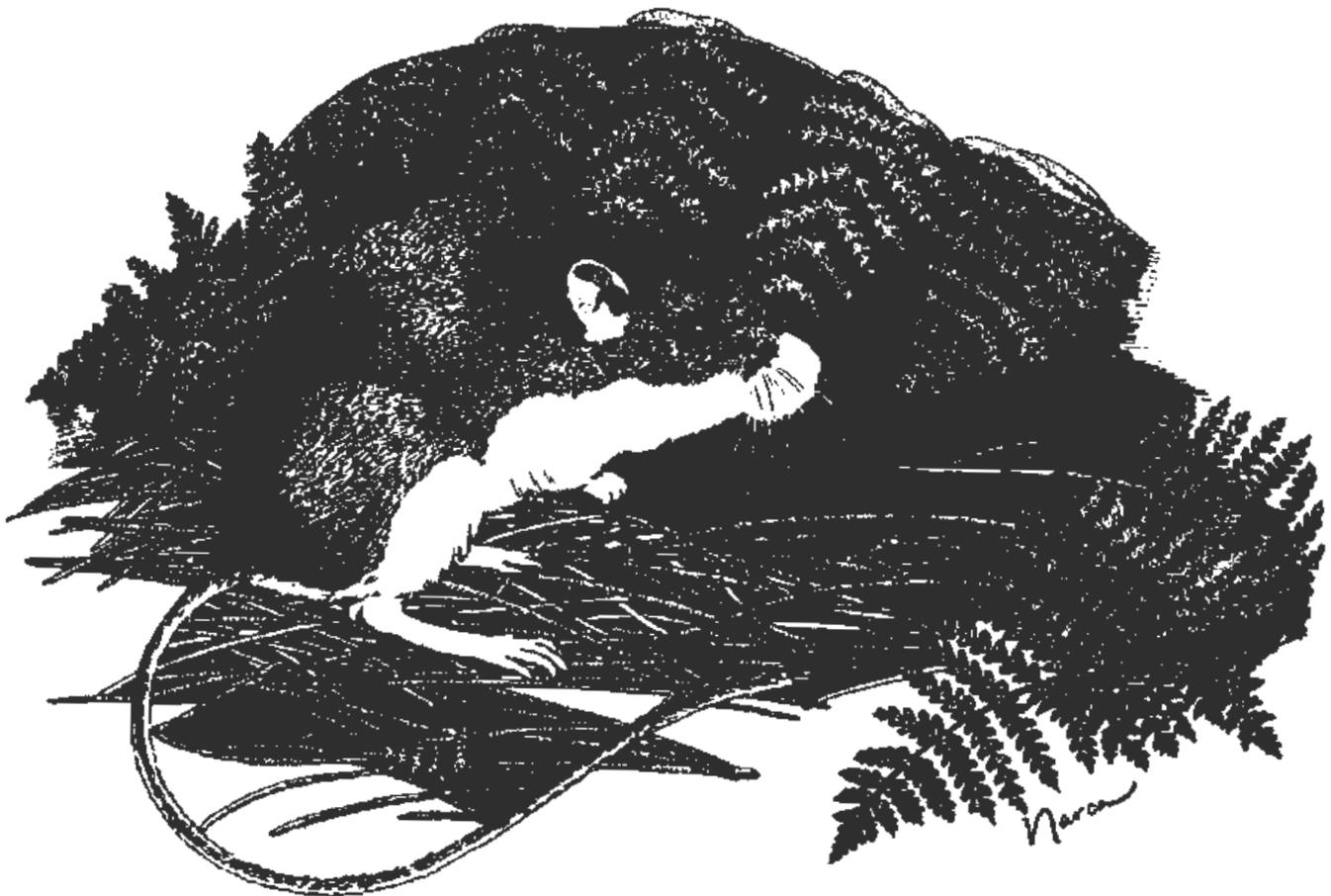
Zapus trinotatus eats seeds of herbaceous plants, especially grasses and grass-like monocots. Stems of plants are frequently cut to obtain ripening seed-heads. Fruits and insects are also eaten (Kruttsch, 1954; Jones, et al., 1978).

Recommendations: A live-trapping program employing pitfalls is the best method of sampling for Jumping Mice. Conventional livetraps rarely capture Jumping Mice in comparison to pitfalls (Williams and Braun, 1983). The Point Reyes area should be thoroughly inventoried for Jumping Mice, and their habitat associations, specific requirements, and population status established.

Remarks: Point Reyes Jumping Mice are the southernmost population of Pacific Jumping Mice. The structural characters of this population are distinctive, and no evidence exists of intergradation with Jumping Mouse populations farther north along the California coast (Howell, 1920d). Hooper (1944) arranged orarius as a subspecies of trinotatus, suggesting that intergrades could be expected from geographically intermediate areas. Kruttsch (1954) concurred with Hooper's (1944) arrangement, but noted that "Interbreeding in the wild between Z. t. orarius and Z. t. eureka probably does not take place, because these subspecies are

separated by terrain not suited to Jumping Mice."

Distribution Records: MARIN CO.: Elk, Tennessee Valley (barn on Lewis Dairy — from owl pellet), 1 (USNM); W end Elk Valley, 10 ft, 1 (MVZ); Fort Berry, 1 (CAS); Fort Cronkhite, 1 (CAS); 3 mi W Inverness, 300 ft, 16 (MVZ); Point Reyes, 1 (USNM); 5 mi NNE point Reyes Lighthouse, 12 (MVZ); 6 mi NE Point Reyes, 1 (MVZ); West Portal, Fort Berry, 2 (MVZ); 6 mi SSE Tomales Bay, 1 (CAS).



THIRD PRIORITY LIST

Big Free-tailed Bat
Tadarida macrotis

1839. Nyctinomus macrotis Gray, Ann. Mag. Nat. Hist., 4:5. Type
Locality: Cuba.
1962. Tadarida macrotis, Miller, Bull. U.S. Natl. Mus., 28:86.

Distribution: Big Free-tailed Bats are found from northern South America and the Caribbean Islands northward to the western United States. Populations in the southwestern U.S. appear to be widely scattered. Known breeding localities in the U.S. are found in parts of Arizona, New Mexico, and Texas. In California, T. macrotis is known only from a few low-lying arid areas of southern California and a single specimen from Berkeley, Alameda Co. (see Remarks). According to Barbour and Davis (1969), records of accidental occurrence (stray, migratory individuals) are known from widely scattered localities in western North America, including British Columbia and Iowa.

Population Status: Very little is known of Tadarida macrotis in California. Possibly it does not occur regularly within the state. The nature of the records, however, suggests that Big Free-tailed Bats breed somewhere within the state -- most likely in the rugged, wooded, mountainous areas of southern California. At least one of the specimens from California was a young bat (Hall, 1946), collected on 11 August. Huey (1932, 1954a) reported on two Big Free-tailed Bats from San Diego, one collected on 1 February; the second, when found, was mummified. The specimen from Berkeley was taken on 18 December (unpubl. data).

Tadarida macrotis may not be under any threats within California. Its rarity, however, gives cause for concern about its present status. Listing it here may stimulate efforts by others to clarify its status.

Habitat: Big Free-tailed Bats inhabit relatively rocky areas in the arid southwestern U.S. They apparently roost primarily in crevices in cliffs (Barbour and Davis, 1969). Findley et al. (1975) described maternity colonies situated in a crevice in the roof of a large sandstone rock shelter and under slabs of lava on a perpendicular cliff. They found Big Free-tailed Bats up to 8000 ft, but they were most common in communities below 6000 ft in New Mexico. In New Mexico, at least, females apparently inhabit forested areas during the reproductive season in the summer. Big Free-tailed Bats appear to be migratory in most of the U.S. Winter records, however, include specimens from San Diego, California, and Yuma, Arizona (Barbour and Davis, 1969).

Recommendations: An attempt to gather current information on the distribution and populations status of the Big Free-tailed Bat should be undertaken. Biologists and public health personnel who routinely receive information from the public about bats or who conduct research on bats should be alerted to the need for information on this species. They should be provided with a description to aid identification of this species. Students and faculty members at colleges and universities in southern California should be encouraged to undertake studies of the

occurrence and habitat associations of bats in various parts of southern California.

Remarks: Tadarida macrotis has been listed as T. molossa in much of the literature. A note in the card catalog of the Museum of Vertebrate Zoology, Univ. California, Berkeley, questioned the specimen from Berkeley on the basis that the tag was attached to the jar rather than the specimen. Everything else appeared to be in order and the jar seemed not to have been opened or otherwise disturbed, according to the notation. All things considered, the record should be accepted as accurate.

Distribution Records: California (no precise locality, but presumably along the Colorado River near Nevada), 1 (USNM). ALAMEDA CO.: Berkeley, Univ. California Campus, 1 (MVZ). SAN DIEGO CO.: San Diego, 2 (SDSNH); Mission Beach, San Diego (August and Dingman, 1973).

Pygmy Rabbit
Brachylagus idahoensis

1891. Lepus idahoensis Merriam, N. Amer. Fauna, 5:76. Type Locality: Pahsimeroi Valley, near Goldburg, Custer Co., Idaho.
1904. Brachylagus idahoensis, Lyon, Smithsonian Misc. Coll., 45:411.

Distribution: Pygmy rabbits are found only in the Great Basin and contiguous areas in Sagebrush-dominated communities. They occur from southeastern Washington southward to about Inyo Co., California, and eastward to western Utah and southeastern Idaho. In California, they occur in eastern Modoc, Lassen, and Mono counties and probably in northern Inyo County. Their occurrence is very spotty throughout their geographic range (Green and Flinders, 1980).

Population Status: Pygmy Rabbits have a limited and spotty distribution, being strictly confined to suitable stands of Sagebrush (primarily Artemisia tridentata) and Rabbitbrush (Chrysothamnus spp.). Although Pygmy Rabbits may seem common where found, they are not numerous over their geographic range.

The current population status of Pygmy Rabbits in California is unknown, but their numbers have probably declined in the past several years. Loss of habitat to cultivation is less of a factor than loss of habitat by overgrazing. Even though overgrazing favors growth of woody shrubs such as Sagebrush over perennial grasses, cattle often congregate in tall stands of Sagebrush, seeking shade in summer, protection from wind, and relief from insects. Frequently, cattle trample and otherwise open up the understory from ground level up to 1 to 1.5 m, reducing food and shelter for Pygmy Rabbits. Brush clearing on rangelands and range fires also reduce available habitat for Pygmy Rabbits. In Oregon, Weise and Verts (1984) found evidence of a marked decrease in occupancy of sites between 1981 and 1983. They suggested that Pygmy Rabbit populations are susceptible to rapid declines and local extirpations. The fragmentation of Sagebrush communities poses a potential threat to extant populations because of this susceptibility.

Habitat: Pygmy Rabbits are associated only with dense stands of tall Sagebrush and rabbitbrush. Soils must be friable for burrowing. Weiss and Verts (1984) found that Pygmy Rabbits were associated with areas with greater shrub cover, shrub height, soil strength, and soil depth in comparison to adjacent, unoccupied sites. There was no significant association with percent basal area of perennial grasses, density of annual grasses, density of forbs, or cryptogam cover. Burrows of Pygmy Rabbits are usually placed on slopes (Green and Flinders, 1980). Food consists principally of Big Sagebrush (A. tridentata) in winter (up to 99% of the diet), whereas grasses form a significant portion of the diet in summer. White et al. (1982) found differential use of populations of Big Sagebrush, but were unable to associate this with known variations in the chemical composition of A. tridentata populations. Captives, however, showed no significant preference as food for one type of Sagebrush subspecies over others. Weiss and Verts (1984) determined that occupancy of sites by Pygmy Rabbits in Oregon was not dependent upon the presence of particular subspecies of Sagebrush.

Recommendations: Detailed information on distribution, habitat associations, abundance, and numbers of Pygmy Rabbits killed by hunters in California are needed. Management of habitat for Pygmy Rabbits is probably the most important element in ensuring their survival. Land and resource management agencies in California should be encouraged to develop needed information on Pygmy Rabbit populations and to consider habitat for Pygmy Rabbits in land and resource management.

Remarks: The Pygmy Rabbit is designated as a Resident Small Game species in California. There is an open season for hunting from 1 July through January, with a daily bag limit of five. Although the effect of hunting on Pygmy Rabbit populations is not known, hunters probably do not kill many because Pygmy Rabbits are quite secretive and rarely venture from dense brush; they usually retreat to their burrows when threatened.

Brachylagus is structurally and behaviorally distinct from all species of Sylvilagus and apparently of an ancient lineage separate from that of Sylvilagus. It was first treated as a species of Sylvilagus by Grinnell et al. (1930) for reasons that have little or no bearing on its phyletic relationships. Since then, most authors have treated it as a species of Sylvilagus (e.g., Hall, 1981). Green and Flinders (1980) reviewed the taxonomic history of B. idahoensis.

Distribution Records: LASSEN CO.: 7 mi E Ravendale, 5000 ft, 19 (MVZ); 3 mi S Ravendale, 5300 ft, 1 (MVZ); vicinity of Red Rock Post Office, 5300 ft (Grinnell et al., 1930). MODOC CO.: Goose Lake, 2 (USNM). MONO CO.: Bodie, 8374 ft, 2 (CAS), 8 (MVZ); north of Crowley Lake (Jones, 1957); Mono Dunes (Harris, 1982); Mono Flats, 7000 ft, 3 (CAS); Mono Lake, near Mono Mills, 4 (CSUF); Mono Lake, Black Point (Harris, 1982); Mono Lake County Park (Harris, 1982).

Oregon Snowshoe Hare
Lepus americanus klamathensis

1899. Lepus klamathensis Merriam, N. Amer. Fauna, 16:100. Type Locality: head of Wood River, near Fort Klamath, Klamath County,

Oregon.

1936. Lepus americanus klamathensis, Bailey, N. Amer. Fauna, 55:95.

Distribution: Lepus americanus klamathensis is found in the Cascade Mountains from Mt. Hood, Oregon, southward to Mt. Shasta and the Trinity Mountains of California (Bailey, 1936; Orr, 1940). In California, it is known from the vicinity of Mt. Shasta, the Trinity Mountains, and from the Warner Mountains. The Warner Mountain population is probably isolated from all others by expanses of unsuitable habitat.

Population Status: Apparently, Oregon Snowshoe Hares never have been common in California within historic times, judging from early accounts (e.g., Merriam, 1899) and from the small number of specimens in museums (Orr, 1940). Mossman (1979) considered determination of their present abundance within California to be important. Mailliard (1927) failed to find L. americanus in the Warner Mountains; the species is apparently known from a single specimen from that mountain range. I saw no evidence of L. americanus in the Warner Mountains during 3 days of field work in 1983.

Populations of Snowshoe Hares undergo periodic fluctuations in numbers, so field researchers may have simply searched when populations were low. The evidence, however, favors an interpretation of rarity.

The Snowshoe Hare is a game species in California (Resident Small Game), and may be hunted from 1 July through January, with a bag limit of five per day. Many hunters probably fail, however, to distinguish Snowshoe Hares from other hares (Black-Tailed and White-Tailed) which have no season or bag limits in California. The effect of hunting on populations of L. americanus in California is unknown.

No definite decline in numbers has been established. The apparent rarity of these hares and the potential for habitat loss due to logging and usurpation of riparian habitat by humans require that the population status of L. a. klamathensis be determined.

Habitat: Snowshoe Hares are primarily found in riparian areas with thickets of deciduous trees such as Alders and Willows, and in dense thickets of young conifers, particularly firs. Dense patches of Ceanothus and Arctostaphylos are sometimes inhabited. In California, Snowshoe Hares are found mainly above the Yellow Pine zone, in Canadian and Hudsonian associations (Orr, 1940). Merriam (1899) reported that Snowshoe Hares formerly were common in marshy places along streams near Fort Klamath, Oregon. He did not obtain specimens, however, during field work at Mt. Shasta. Mossman (1979) indicated that Snowshoe Hares only inhabit areas in northern California which have snow in the winter.

Recommendations: The highest priority should be given to determining the status of the Warner Mountain population, an apparently isolated and unique population. Detailed assessments of population numbers in all areas of the range of L. a. klamathensis should be made. Habitat needs of L. americanus klamathensis should be considered in managing State and U.S. National Forest lands within its range.

Remarks: Orr (1940) regarded the Washington Snowshoe Hare as specifically

distinct from L. americanus, and treated klamathensis as a subspecies of L. washingtoni (but see Dalquest, 1942).

Distribution Records: MODOC CO.: vicinity of Fort Bidwell, 6000 ft, 1 (MVZ). SHASTA CO.: McCloud River, 12 mi E McCloud Post Office, 1 (MVZ); south fork Salmon River (Grinnell, 1933). SISKIYOU CO.: T. H. Benson Estate, Butte Creek, 5000 ft, 1 (MVZ); Gottville, 1 (USNM); McCloud, 1 (MVZ); N of Mt. Shasta (city), 1 (UDAV). TRINITY CO.: head of Bear Creek, 2 (MVZ); Rush Creek, 12 mi from Weaverville, about 3000 ft, 1 (MVZ).

Sierra Nevada Snowshoe Hare
Lepus americanus tahoensis

1933. Lepus washingtoni tahoensis Orr, J. Mamm., 14:45. Type Locality: 0.5 mi S Tahoe Tavern, Placer Co., California.
1942. [Lepus americanus] tahoensis, Dalquest, J. Mamm., 23:176.

Distribution: Sierra Nevada Snowshoe Hares range along the mid-elevations of the Sierra Nevada from the vicinity of Mt. Lassen southward to Mono and Tulare counties (unpubl.). They are known from Nevada only in the vicinity of Lake Tahoe (Hall and Kelson, 1959). They occupy altitudes above 4800 ft in the north of their range and 5000 ft in the south. Upper elevational limits are unknown; these hares generally occur below 8000 ft.

Population Status: Judging from circumstantial evidence, Sierra Nevada Snowshoe Hares are more abundant than Oregon Snowshoe Hares, but still are relatively uncommon. There is no evidence of a population decline, but L. americanus is vulnerable to widespread habitat alterations due to some logging activities and use of meadows for agriculture, grazing, and other activities. Furthermore, this is a Resident Small Game species which is hunted from 1 July through January. Many hunters likely fail to distinguish L. americanus from white-tailed hares (Lepus townsendii), which have no season or bag limits in California. The effect of hunting on L. a. tahoensis populations is unknown, but is unlikely to be much of a factor.

Habitat: The habitat of Sierra Nevada Snowshoe Hares is similar to that of L. a. klamathensis. They live only in boreal zones, typically inhabiting riparian communities with thickets of deciduous trees and shrubs such as Willows and Alders. They also frequent dense thickets of young conifers and chaparral composed of Ceanothus and Arctostaphylos (Orr, 1940). In the Lake Tahoe region in summer, Orr, (1940) noted signs of Snowshoe Hares only near brush adjacent to both meadows and riparian deciduous vegetation. He found no evidence of Snowshoe Hares on ridgetops or brush-covered upper slopes. In the Mt. Lassen region, Grinnell et al. (1930) found that Snowshoe Hares were uncommon, being infrequently encountered among thickets of Snow-brush and young firs, and in or near thickets of Alders and Willows situated in meadows. In winter, Grinnell et al. (1930) found tracks of Snowshoe Hares to be more numerous in and near thickets of Snow-brush, Willows and small conifers than on more open ridges.

Recommendations: The principal need is for reliable data on distribution

and abundance of L. a. tahoensis. Special consideration of habitat needs of L. americanus in managing public lands in California is needed.

Remarks: Lepus americanus tahoensis differs from L. a. klamathensis in its darker coloration, other, minor details of coloration, and in skull proportions. There is no controversy about its status.

Distribution Records: ALPINE CO.: Pacific Valley, half way between Woodfords and Big Trees, 1 (MVZ). EL DORADO CO.: no precise locality, 1 (MCV); Echo Lake, 1 (MVZ). LASSEN CO.: Warner Creek (Grinnell, 1933). MONO CO.: 4 mi N, 1 mi E Mammoth, 1 (MSU). NEVADA CO.: Sagehen Creek, 4 mi NW Hobart Mine, 1 (MVZ); Spruce, 1 (MVZ); 10 mi W Truckee, 1 (MVZ); Truckee, 1 (MVZ). PLACER CO.: Cisco, 1 (MVZ); Donner, 1 (USNM); near S shore Donner Lake, 6000 ft, 1 (MVZ); Donner Summit, 7000 ft, 1 (MVZ); Lake Tahoe, Rubicon subdivision between Emerald Bay and Meeks Bay, 3 (CAS); near Tahoe City, 19 (MVZ); 0.5 mi S Tahoe Tavern, 1 (MVZ). FLUMAS CO.: Willow Lake, 5600 ft, 1 (MVZ). SIERRA CO.: east side Yuba Pass, 6000 ft, 1 (MVZ). TEHEMA CO.: 7 mi E junction highways 32 and 36, 1 (CSUC); Mineral, 4800 ft, 1 (MVZ); Summit Creek, 5200 ft, 2 mi E Mineral, 2 (MVZ). TUOLUMNE CO.: Niagra Creek, 5600 ft (Orr, 1940); between Pine Crest and Belle Meadows, 1 (MVZ); 1 mi NW Strawberry, 6000 ft, 1 (CAS).

Western White-tailed Hare
Lepus townsendii townsendii

1839. Lepus townsendii Bachman, J. Acad. Nat. Sci. Philadelphia, 8(1):90.
Type Locality: Port Walla Walla, Walla Walla Co., Washington.

Distribution: Western White-tailed Hares are found from the Okanogan Valley of southern British Columbia southward east of the Cascade Crest to the southern Sierra Nevada of California, and eastward to extreme western Montana and western Colorado (Hall, 1981). In California, White-tailed Hares principally occupy open forests and sagebrush-grassland associations in the Great Basin Province. They occur also at high elevations along the main crest of the Sierra Nevada and rarely to as low as 6000 ft on the western slope. I observed white-tailed hares near Markwood Meadow at about 6000 ft, and on Tamarack Ridge at about 7500 ft in Fresno Co., approximately 30 mi west of the Sierra Nevada crest. The southernmost published locality known is Mt. Silliman, Tulare County in Sequoia National Park (Fry, 1924).

Population Status: Little current information is available for California. Airola (1980) stated that this species had not been seen in Lassen County in the last 20 years. Evidence suggests that populations of L. townsendii have declined drastically, especially at lower elevations in the sagebrush-grassland associations of the Great Basin province (Grayson, 1977). Competition with domestic livestock is probably a principal factor in the drastic population declines throughout its range, including California (Dalquest, 1948; Mossman, 1979). Loss of habitat to cultivation and other developments are probably also important factors in the decline. Hunting could be a factor, but is probably less important than habitat loss.

Dalquest (1948) noted that early explorers and settlers found White-tailed

Hares in abundance in eastern Washington. At the same time, Black-tailed Hares apparently were absent from the state prior to 1870 (Couch, 1927). With grazing by livestock the bunchgrass habitat was rapidly reduced, the Black-tailed Hares expanded their range explosively northward, and the White-tailed Hares survived only at the upper elevational limits of their habitat in the yellow pine/sagebrush-grassland ecotone. Today, White-tailed Hares are extinct over the greater part of their historic range on the Columbia Plateau. In California, they are nowhere common. Grinnell et al. (1930) found scant evidence of White-tailed Hares in the area from east of Lassen Peak to the Nevada border. Grinnell and Storer (1924) remarked that even in the center of their range in the Yosemite region they were much less common than the Black-tailed Hares of lower country. Howell (1924) failed to find White-tailed Hares in the Mammoth region, although he saw evidence of their presence. Orr (1940) declared that White-tailed Hares were one of the rarer members of the genus Lepus in California, noting that they were by no means abundant anywhere.

Currently, this is a Resident Small Game species in California with no closed season or daily bag limits.

Habitat: White-tailed Hares occupy a variety of habitats, including Sagebrush-covered slopes on the eastern Sierra Nevada, grasslands and meadows to timberline or above, and forests of Lodgepole Pine, Yellow Pine, Western Juniper, Dwarf Juniper, Red Fir, and mixed conifers. In the Sierra Nevada, White-tailed Hares apparently migrate to higher areas in summer and descend to lower regions in winter, particularly the Sagebrush-covered eastern slopes of the Sierra Nevada (Merriam, 1904; Orr, 1940).

Orr (1940) found signs of White-tailed Hares to be most abundant on exposed, flat-topped ridges above 8500 ft in El Dorado Co. Farther north in Oregon and Washington, White-tailed Hares were formerly most numerous on the bunchgrass prairies and the Sagebrush-bunchgrass associations near the Yellow-Pine zone (Bailey, 1936; Dalquest, 1948). Grinnell and Storer (1924) stated that in the Yosemite region, White-tailed Hares "generally keep to open places where they can see unobstructedly for long distances. Around Tuolumne Meadows, flat-topped hills bearing moderately open stands of trees together with some brush were often occupied."

Lepus townsendii apparently requires thickets of young or stunted conifers, or deciduous, woody plants for day-time cover. It feeds primarily at night in meadows during summer. Winter staples probably include bark of Willows, Alders and other woody plants

Recommendations: Population surveys throughout the range of L. townsendii in California should be carried out. Habitat needs of White-tailed Hares should be considered in management decisions on state and federal lands within their geographic range.

Remarks: Orr (1940) regarded the population in California formerly known as L. t. sierrae, as inseparable from L. t. townsendii.

Distribution Records: ALPINE CO.: Carson Valley, 5270 ft, 1 (MVZ); Hope Valley, 7800 ft, 1 (SDSNH), 1 (USNM); Woodfords, 1 (MVZ). EL DORADO CO.: 1 mi NW Dick's Peak, 9000 ft (Orr, 1940); Veima Lakes region (Orr, 1940).

FRESNO CO.: Badger Flat, E of Huntington Lake, 1 (CSUF); near Dinky Creek Ranger Station, about 6000 ft (DFW); Markwood Meadow, 1 (CSUF); Tamarack Ridge at Highway 168, about 7500 ft (DFW). INYO CO.: above Bishop, 1 (LACM); W slope Mt. Langley, 13800 ft (Grinnell). LASSEN CO.: Red Rock, 3 (MVZ), 2 (SDSNH); 7 mi W Termo (Grinnell, 1933). MARIPOSA CO.: E base Half Dome, 7500 ft (Grinnell and Storer, 1924). MODOC CO.: Eagleville, 1 (CAS); Goose Lake (Mailliard, 1927); Parker Creek, Warner Mountains, 6300 ft, 1 (MVZ); 3 mi S Pine Creek, 1 (MVZ); 2 mi E Pitt River Ranger Station, 1 (CAS); Steele Meadows, 4700 ft, 1 (MVZ); Warner Mountains, 2 (CAS). MONO CO.: 9 mi W Benton, 8300 ft, 1 (MVZ); Bodie, 8374 ft, 1 (MVZ); Bridgeport, 6473 ft, on U.S. Highway 395, 1 (MVZ); 8 mi SW Bridgeport, 7000 ft, 1 (CSLB); Cabin Creek, 10500 ft, White Mountains, 1 (MVZ); 10 mi N Crowley Lake, 7000 ft on U. S. Highway 395, 1 (MVZ); Farrington, 1 (MVZ); Glass Mtn., 11000 ft, 1 (MVZ); Lake Mary, 9000 ft, 1 (CAS); Log Cabin Rd. (Harris, 1982); Long Valley, Mammoth region (Howell, 1924); slopes of Mono Craters (Grinnell and Storer, 1924); Mono Lake, 1 (MVZ), 8 (USNM); Mono Mills (Grinnell and Storer, 1924); Mono Pass (Harris, 1982); Mt. Dana (Harris, 1982); 2.5 mi N Mt. Patterson, Sweetwater Mountains, 10000 ft, 1 (MVZ); 1.75 mi W Mt. Patterson, Sweetwater Mountains, 10500 ft, 1 (MVZ); 1 mi WNW Mt. Patterson, Sweetwater Mountains, 10800 ft, 1 (MVZ); Saddlebag Lake (Harris, 1982); Slate Creek Valley (Harris, 1982); 2 mi W mouth Sweetwater Canyon, Sweetwater Mountains, 10000 ft, 1 (MVZ); 4 mi SE Lower Twin Lake, 8000 ft (Summer Meadows, A. Farrington's Ranch), 2 (MVZ); Walker Lake (Harris 1982); Mt. Warren (Harris, 1982); near Williams Butte, 1 (MVZ); White Mountains, 12700 ft, 1 (CAS); White Mountain Research Station, White Mountains, 12000 ft, 1 (MVZ). PLACER CO.: Tahoe City, Lake Tahoe, 1 (MVZ). PLUMAS CO.: Willow Lake, 5600 ft (Grinnell, 1933). SHASTA CO.: vicinity of Fort Cook, near Burgettville, 1 (USNM). TULARE CO.: Big Cottonweel Meadows, Mt. Whitney, 1 (FMNH); SW end Lake South America, 11900 ft (Orr, 1940); Mineral King (Fry, 1924; Monache Meadows (Grinnell, 1933); N spur Mt. Silliman, 10400 ft (Fry, 1924). TUOLUMNE CO.: near Dana Creek, 2 mi W Mono Pass (Merriam, 1904); east base Half Dome, 7500 ft (Grinnell and Storer, 1924); Tuolumne Meadows, 8600 ft, Yosemite National Park, 1 (MVZ).

Point Reyes Mountain Beaver

Aplodontia rufa phaea

1899. Aplodontia phaea Merriam, Proc. Biol. Soc. Washington, 13:19.
 1918. Aplodontia rufa phaea, Taylor, Univ. California Publ. Zool.,
 17:480.

Distribution: According to Taylor (1918), A. r. phaea inhabited an area of approximately 110 square miles in the Point Reyes area of Marin County. Apparently, most colonies were located on north facing slopes of hills and gullies (Camp, 1918).

Population Status: The status of A. r. phaea is unknown. Much of the region within its general range is unsuited to Mountain Beavers. The actual inhabited area was only a fraction of the 110 square miles encompassed by the margins of its range (Camp, 1918). The restricted distribution of A. R. phaea gives cause for concern. Much of the area within its range, however, is included in the National Park system, giving cause for optimism about the fate of this population.

Habitat: The general remarks about the habitat of Aplodontia rufa in the account of A. r. nigra applies also to this subspecies. Grinnell (1933) noted that A. r. phaea was found on hillsides in seepage areas overgrown with Sword Ferns and Thimbleberries, and that all localities of known occurrence were below 1000 ft in elevation. Camp (1918) found colonies on a north facing bluff among treeless hills west of Inverness.

Recommendations: Surveys of the distribution and habitat associations of Point Reyes Mountain Beavers should be undertaken. The National Park Service and other public agencies responsible for land management within the range of Point Reyes Mountain Beavers should be informed of the need for information on this species. The impact on its population of all potential developments within its range should be determined. Also, the effects of introduced cervids (Axis and Fallow deer) on habitat for Mountain Beavers should be assessed.

Remarks: Aplodontia rufa phaea is isolated from all other populations of Mountain Beavers by uninhabited terrain (Hall and Kelson, 1959). They are smaller in body sizes than all other populations, and are the lightest colored of those found along the Pacific Coast.

Distribution Records: MARIN CO.: Bear Valley Ranch, 2 (MVZ); Heim's Ranch, 5 mi W Inverness, 48 (MVZ); 3 mi W Inverness, 1 (MVZ); near highway, 4 mi W Inverness, 2 (UDAV); 6 mi W Inverness, 7 (MVZ); Lagunitas, 1 (CAS), 2 (MVZ); Limantour Bay, 1 (CAS); Marshall Ranch, 8 (MVZ); Murphy Ranch, about 4 mi WSW Inverness, 10 (MVZ); 4 mi S Olema, 4 (MVZ); 2 mi W Olema, 1000 ft, Mt. Wittenberg, 1 (MVZ); Point Reyes, 1 (CM), 15 (USNM); Point Reyes, 4 mi W Inverness, 2 (CM); 3 mi NE Point Reyes (city), 1 (CM); Wildcat Canyon, Tevis Ranch, 9 mi W Olema, 2 (MVZ).

Tehachapi Pocket Mouse
Perognathus alticola inexpectatus

1926. Perognathus alticola inexpectatus Huey, Proc. Biol. Soc. Washington, 39:121. Type Locality: 14 mi W Lebec, 6000 ft, Kern Co., California.

Distribution: Tehachapi Pocket Mice are known from a few scattered localities from Tehachapi Pass on the northeast to the area of Mt. Pinos on the southwest, and around Elizabeth, Hughes, and Quail Lakes on the southeast. Known localities are between about 3500 and 6000 ft in elevation.

Populations Status: Trapping for the Tehachapi Pocket Mouse by Sulentic (1983) produced 11 specimens from two localities on the eastern side of Tehachapi Pass in an area where a single specimen was caught in 1975 (Williams, 1978). In view of the scarcity of specimens and the general inability to find Tehachapi Pocket Mice, their populations must be small, scattered, and vulnerable to changes in habitat quality.

Habitat: The habitat of the Tehachapi Pocket Mouse is not well defined. Four specimens were captured in a fallow grain field at about 4000 ft, several years after it had been planted to grain (Sulentic, 1983; Williams, 1978). The predominate plant in the area when I collected there

was Russian Thistle (Salsola sp.). Desert shrubs and grasses dominated nearby hills. Cantwell (in Huey, 1926) collected Tehachapi Pocket Mice on a grassy flat among scattered Yellow Pine trees. Other areas where Tehachapi Pocket Mice have been collected support arid annual grassland and desert shrub communities.

Recommendations: Additional studies of habitat requirements and distribution are needed. Areas likely to support populations are the mountain slopes of the Tehachapi and San Gabriel ranges that front on the Mojave Desert.

Remarks: Perognathus alticola inexpectatus appears to be allied with P. a. alticola structurally. Sulentic (1983) believed that the Tehachapi Pocket Mouse was a distinct species from the White-eared Pocket Mouse. Populations of P. a. inexpectatus may be in contact with and intergrade with populations of P. parvus xanthonotus, which is known from an area of the Tehachapi Mountains in the vicinity of Walker Pass and adjacent canyons. Habitat for Pocket Mice of this species group appears to be nearly continuous along the desert slopes of the southern Sierra Nevada, Tehachapi Mountains, San Gabriel Mountains, and San Bernardino Mountains. The allopatric distributions of these taxa (Hall, 1981) probably is more apparent than real. Eight Tehachapi Pocket Mice, in addition to the specimens listed below, were captured in the area of Tehachapi Pass by Sulentic (1983, and unpubl.).

Distribution Records: LOS ANGELES CO.: Elizabeth Lake, 4 (LACM); Gorman, 1 (LACM); 2 mi E Gorman, 3500 ft, 3 (MVZ); 2.5 mi SE Gorman, 1 (MVZ); Lake Hughes, 1 (LACM); 2 mi W Quail Lake, 3500 ft, 1 (LACM). KERN CO.: 0.5 mi SW Cameron, 3900 ft, 4 (MVZ); 14 mi W Lebec, 6000 ft, 3 (SDSNH); Cuddy Valley, Mt. Pinos, 1 (LACM); Sand Canyon, about 8 mi E (by rd.) Tehachapi, sec. 28, T32S, R34E, 4080 ft, 3 (CSLB), 1 (MSB); Tehachapi, 2 (USNM); Tehachapi Peak, 2 (USNM).

Short-nosed Kangaroo Rat

Dipodomys nitratoides brevinasus

1920. Dipodomys merriami brevinasus Grinnell, J. Mamm., 1:179. Type Locality: Hays Station, 19 mi SW Mendota, Fresno Co., California.
1921. Dipodomys nitratoides brevinasus, Grinnell, J. Mamm., 2:96.

Distribution: Short-nosed kangaroo Rats are found on the western side of the San Joaquin Valley, from near Los Banos, Merced Co., southward west of the San Joaquin River and a line approximately coincident with the Kettleman Hills, Lost Hills, and Elk Hills to the southern end of the valley. They also occur in the Panoche Valley, San Benito Co., the Sunflower Valley, Kings Co., the Antelope Plain in Kern Co., the Carrizo Plain in San Luis Obispo Co., the Cuyama Valley in San Luis Obispo and Santa Barbara counties, and at the edge of the valley floor around the south end of the San Joaquin Valley from the vicinity of Maricopa on the West to east of Bakersfield on the east (Hall, 1981; Williams, 1985, and unpubl. data). Within this area, they are found mostly on flat and gently sloping terrain and on hill tops in desert-shrub associations, primarily Atriplex.

Population Status: Loss of habitat has been extensive throughout the range of the Short-nosed Kangaroo Rat, particularly on flatter lands in the Cuyama, San Joaquin and Panoche valleys, and on the Antelope and Carrizo plains. Cultivation of native communities has been the principal reason for loss of habitat. Relatively small, isolated populations are found on the southern Antelope Plain west of Buttonwillow and in the vicinity of Taft and Maricopa, Kern Co.; on uncultivated sites in the Kettleman Hills, and in and around oil fields near Coalinga, Fresno Co.; west of Interstate Highway 5 on unirrigated lands at the edge of the valley in Fresno Co.; and around Soda Lake on the Carrizo Plain, San Luis Obispo Co. Where they are found, they are typically common. A major cause for concern is that virtually all of the areas where Short-nosed Kangaroo Rats still are found are privately owned and have moderate to good potentials for cultivation. Only the lack of irrigation water has prevented cultivation of most areas until now. Of greater concern is the lack of lands dedicated to preserving natural communities within its range, except for the area immediately around Soda Lake on the Carrizo Plain (few Short-nosed Kangaroo Rats occur within the confines of the present preserve). Public-owned lands within the geographic range of Short-nosed Kangaroo Rats, such as those on the Carrizo and Elk Horn plains, recently have been subject to intense grazing pressures with virtually no plant litter remaining (some areas are being grazed year around), and providing little opportunity for herbaceous plants to fruit (unpubl. observ.). Preliminary field work in some of these areas during the past year found no Short-nosed Kangaroo Rats in areas where they were fairly common as recently as 1982 (Kerry Kilburn, pers. comm.; unpubl. data).

The Short-nosed Kangaroo Rat was not included on the priority List of Concern when the draft copy was assembled, primarily because it appeared to warrant lesser concern than many other species. In the ensuing five years, however, additional field work within its geographic range, focused mostly on Giant Kangaroo Rats, found that some populations once considered secure were declining or had disappeared. Some other areas where Short-nosed Kangaroo Rats were presumed to occur, based on the type of plant communities, proved not to have extant colonies. Thus, in reassessing its status, it seemed best to elevate it to the Third Priority Category to emphasize potential threats to remaining populations and to expedite the gathering of information needed to determine its status.

Habitat: Dipodomys nitratoides brevinasus occupies grassland and desert-shrub associations on friable soils. They inhabit highly alkaline soils around Soda Lake, on the Carrizo Plains, and less saline soils elsewhere. On the valley floor, around Los Banos, Merced Co., small populations live on dikes secure from winter flooding, then move into seasonally flooded iodine bush shrublands during the summer months, where at least some individuals reproduce (unpubl. data). Hawbecker (1951) reported that, in the Panoche Valley, San Benito Co., Short-nosed Kangaroo Rats were found on gentle slope and rolling, low hill-tops where some shrubs were present. He suggested that they did not "venture far out of this habitat." Light to moderate grazing by livestock probably enhances habitat for Short-nosed Kangaroo Rats.

Recommendations: The primary needs are for detailed information on distribution and populations status of Dipodomys nitratoides brevinasus,

and land use projections within areas still inhabited. The U.S. Bureau of Land Management should pay particular attention to this species in its management plans for lands in western Kern Co., and on the Carrizo and Elk Horn plains in San Luis Obispo Co. The impact on Short-nosed Kangaroo Rats and other native species by the present pattern of livestock grazing should be determined and grazing leases reviewed accordingly. The California Department of Fish and Game should review its opportunities to purchase and develop lands as a preserve for this and other jeopardized species of the San Joaquin Valley lowlands, especially in northwestern Fresno and eastern San Benito counties in the Panoche Valley area.

Remarks: Because the Short-nosed Kangaroo Rat was not on the draft List of Concern, distribution records were not obtained from most museums visited. The basic distributional area is documented in Grinnell (1922) and Hoffmann (1975). Williams (1985) discussed, in detail, the boundary between the subspecies D. n. nitratoides and brevinasus. Ten specimens identified as D. nitratoides from 3 mi E Cuyama Ranch, 2200 ft, Cuyama Valley (probably San Luis Obispo Co.) collected in 1916 (USNM collection) were not mentioned by Grinnell (1922) or Hall (1981). Hoffmann (1975) examined specimens from the Cuyama Valley, but did not identify the number or museum where those specimens were housed (I presume that they were the specimens in the U.S. National Museum). He compared them with samples of nitratoides from other localities and determined that they exhibited characteristics more diagnostic of Dipodomys merriami (fide Lidicker, 1960), but equivocated as to their identity. Any surveys for Dipodomys nitratoides brevinasus should include the Cuyama Valley and should be designed to obtain information useful in resolving the specific identity of that population, presuming it is extant.

Red Tree Vole
Arborimus longicaudus

1890. Phenacomys longicaudus True, Proc. U.S. Natl. Mus., 13:303. Type Locality: Marshfield, Coos Co., Oregon.
1973. Arborimus longicaudus, Johnson, J. Mamm., 54:239.

Distribution: Red Tree Voles are found along the Pacific coastal lowlands in Oregon and Northern California (Howell, 1926; Hall, 1981; but see Remarks). In California, they range from the Oregon border southward to Sonoma County along the coast, and in the coastal mountain ranges southward to about Mt. Sanhedrin, Mendocino Co. Marginal records on the east are Bridgeville, Humboldt Co.; South Fork Mountain, Trinity Co.; Mt. Sanhedrin, Mendocino Co.; and Occidental, Sonoma Co. (Hall, 1981; Howell, 1926). Records of elevation extend from near sea level to about 3100 ft in California (Grinnell, 1933; unpubl. data).

Population Status: Red Tree Voles have always been considered rare, although they are common locally (Taylor, 1915). Records of distribution within California suggest a spotty pattern of dispersion. Their reproductive potential is lower than typical voles (Hamilton, 1962), and presumably, populations could be jeopardized by greatly increased mortality associated with extensive logging. Clearing trees for agriculture and homesites, and logging, especially clear-cutting, within the range of Red Tree Voles have significantly reduced available habitat

and fragmented populations (Maser et al., 1981). Construction of roads and powerlines also have contributed to loss of habitat and fragmentation and isolation of populations.

The Red Tree Vole was not listed in any of the three priority categories on the draft List of Concern, but was considered a sensitive species. Information on its population status was unavailable, but it did not seem to be jeopardized. Since development of the draft list, I have reconsidered its status in light of a trip through portions of its geographic range in search of populations, made in April, 1984. Although Red Tree Voles are still locally common in the foothills of mountains on the east edge of the coastal plain in Humboldt Co., loss and fragmentation of habitat has been extensive everywhere within its range. Furthermore, these trends are likely to continue at an accelerated pace in the future. The Red Tree Vole has been elevated to the Third Priority Category to emphasize that current trends in logging may jeopardize the species and to emphasize the need for definitive information on distribution and population status.

Habitat: Red Tree Voles live only in coastal coniferous forests consisting of Douglas Fir, Grand Fir, Western Hemlock, and/or Sitka Spruce. Taylor (1915) remarked that most Red Tree Voles were found in Douglas Fir and Grand Fir trees, and that only Todd (1891) found these voles in Sitka Spruce. Maser and Storm (1970) stated that Red Tree Voles also inhabit Western Hemlock trees. They live, nest, and feed within the forest canopy. Males are partly terrestrial, but females rarely are found on the ground. Red Tree Voles feed on the needles, buds, and tender bark of twigs of Douglas Fir, Western Hemlock, and Grand Fir (Howell, 1926; Maser and Storm, 1970; Maser et al., 1981; and Taylor, 1915). They do not eat Redwood needles; hence pure stands of Redwood are not occupied (Taylor, 1915). Redwood is the principal forest type in preserves within the range of the Red Tree Vole. Generally, large trees are preferred as homes, although small trees are also inhabited, especially where larger ones are unavailable (Benson and Borrell, 1931; Howell, 1926). Condensation of water on leaves from dew and fog or frequent rains may be required as a source of drinking water (Taylor, 1915). Although many of the factors determining the occurrence of Red Tree Voles are not known, these animals probably require fairly dense, mature stands of conifer forest composed of at least some Douglas Fir or Grand Fir. Clear-cuts, forest fires, and other factors that create openings in the forest and isolate blocks of trees are detrimental to Red Tree Voles.

Large nests are constructed in trees, generally around the trunk, typically from 20 to 60 ft above ground (Benson and Borrell, 1931). Nests have been found as low as 4 ft to as high as 100 ft or more. The nests consist primarily of the resin ducts of fir needles, the only part not eaten by the voles, and fecal material. The bulk of the nest increases over the years as a series of residents occupy the site and add material.

Recommendations: The most pressing need is for detailed information on the present distribution and population status of Red Tree Voles. Known and projected developments within its present range should be assessed to determine their impact on the species. State agencies, the U.S. Forest Service, U.S. Bureau of Land Management, and the U.S. National Park Service should conduct detailed surveys for Red Tree Voles on lands they

manage. Clear-cutting in areas inhabited by Arborimus longicaudus should be avoided in preference to selective logging whenever possible.

Remarks: Until recently, the Red Tree Vole was considered to be a member of the genus Phenacomys. Johnson (1973) reviewed the structural, ecological, and behavioral characters of Arborimus and Phenacomys. Additional studies of the generic differences of Arborimus and Phenacomys were presented by Johnson and Maser (1982). According to Maser et al. (1981) and Sara George (pers. comm.), the Red Tree Vole in California is a different species than that found in most of Oregon; Murray Johnson is currently investigating the relationships of these sibling populations and their geographic distributions.

During the research for this report, I decided Arborimus longicaudus was not to be included in a priority category on the List of Concern; thus, I stopped recording distributional records during visits to museums. Therefore, the following list does not include records of specimens from all of the museums visited. Noteworthy are the collections at the California Academy of Sciences and Humboldt State University.

Distribution Records: HUMBOLDT CO.: 5 mi E Arcata, 1 (CSLB); Big Bend, Mad River, 2 (MVZ); Bridgeville, 1 ((MVZ); 4.3 mi N Bridgeville, 1 ((MVZ); 4.6 mi N Bridgeville, 2 ((MVZ); 2 mi E Bridgeville (Benson and Borrell, 1931), 1 (MVZ), 1 (PM); 4.6 mi by rd. (Hwy 36) E Bridgeville, 1 (MVZ); 1 mi W Bridgeville (Benson and Borrell, 1931); 1.5 mi W Bridgeville, 1 (MVZ); 2 mi W Bridgeville, 2 (UCLA); 3 mi N Capetown, Oil Creek, 2 (MVZ); 5.3 mi NE Capetown, Morrow Ranch, 1450 ft, 5 (MVZ); Carlotta, 5 (MCZ), 13 (MVZ), 2 (ROM), 4 (SDSNH), 3 (UCLA), 18 (USNM); Chaparral Mt., 2 (MVZ); Coyote Peak, 1 (MVZ); Cuddeback, 1 (MVZ); French Camp, 3100 ft, 1 (MVZ); 2 mi along Johnson Rd., off Bald Hill Rd., 1 (CSLB); 8.2 mi (by rd.) E Korbek, 1 (MVZ); Maple Creek, 1 mi N jct. Mad River, 4 (MVZ); 0.5 mi S (by rd.) Maple Creek, 1 (MVZ); 3.2 mi NW Petrolia, 1 (MVZ); 5.2 mi SE Petrolia, 1 (MVZ). MENDOCINO CO.: Anchor Bay, 3 (CM); 10 mi E Point Arena, Garcia River, 3 (CM); 8 mi SW Laytonville, Clark Ranch, 1 (MVZ); Mendocino City, 16 (MVZ); Mt. Sanhedrin, 1 (ANSP); 4 mi S Mt. Sanhedrin, Leerly's Ranch, 2340 ft, 1 (MVZ); 0.8 mi S Slick Rock Creek on State Hwy #1, 2 (MVZ); 3 mi W Whiskey Spring, Graveyard Rd., 800 ft, 1 (MVZ). SONOMA CO.: 1 mi N, 0.2 mi E Bridgehaven, 50 ft, 1 (MVZ); 1 mi N Camp Meeker, 1 (MVZ); 3.5 mi N Camp Meeker, 1 (MVZ); Duncan Mills, 1 (LACM); 3 mi E Duncan Mills, 1 (MVZ); 2 mi W Duncan Mills, 4 (MVZ); 3 mi W Duncan Mills, 1 (MVZ); 3.5 mi W Duncan Mills, 1 (MVZ); 7 mi N (by rd.) Fort Ross, 1 (MVZ); 1 mi E Jenner, 3 (MVZ); near Monte Rio, Bohemian Grove on Russian River, 2 (MVZ); 2 mi SE Monte Rio, 1 (CM); 2 mi S Monte Rio, 1 (MVZ); 2.3 mi S Monte Rio, 11 (MVZ); 3 mi S Monte Rio, 4 (MVZ); 4 mi S Monte Rio, 1 (MVZ); 1 mi W Monte Rio, 1 (CM); Occidental, 2 (LACM); 2 mi N Occidental, 3 (MVZ); 0.5 mi S Occidental, 2 (MVZ); 1 mi S Occidental, 1 (MVZ); 0.25 mi W jct. Sheephouse Creek and Russian River, 1 (MVZ); 0.5 mi E Stewart's Point, 1 (MVZ); 10 mi SSE Stewart's Point, 1 (MVZ). TRINITY CO.: Mad River, 2500 ft, South Fork Mtn., 1 (MVZ); Reilley's Ranch, 3000 ft, South Fork Mtn., 4 (MVZ).

Pacific Fisher
Martes pennanti pacifica

1898. Mustela canadensis pacifica Rhoads, Trans. Amer. Philos. Soc., new ser., 19:435. Type Locality: Lake Keechelus, Kittitas Co., Washington.
1912. Martes pennanti pacifica, Miller, Bull. U.S. Mus., 79:94.

Distribution: Martes pennanti was formerly widely distributed in boreal forests across Canada and the northern United States, extending south in the mountains to California and Utah in the west and Tennessee and North Carolina in the east (Powell, 1981; Strickland et al., 1982a).

Pacific Fishers are found along the Pacific Coast from north-central coastal British Columbia to northern California, in the Cascade Mountains, and the Sierra Nevada of California. They range eastward to the Blue Mountains of northeastern Oregon (Hall, 1981). In California, they occur from the Oregon border in the northwestern part of the state south to about Clear Lake, Lake County, in the Coastal Mountains and to Sonoma County along the coast. They range eastward in northern California to around Eagle Lake, Lassen County, and southward in the Sierra Nevada to at least Greenhorn Mountain, Kern County (Schempf and White, 1977). Altitude of occurrence varies from near sea level to over 11000 ft.

Population Status: Schempf and White (1977) reviewed historic and recent records of Fishers in California, including sightings on file in U.S. Forest Service offices and from California Department of Fish and Game records. Data they gathered suggested that Fishers were relatively common in the North Coast region, but were rare or uncommon in the Sierra Nevada and appeared to be decreasing. These data were unsupported by field surveys, so recent trends were unknown. Particular attention was drawn to the apparent decline of populations in the southern Sierra Nevada and possible declines in the northern Sierra Nevada. Buck et al. (1983) studied a population of Fishers in Trinity Co. to determine habitat use and possible effects of timber harvest on Fishers. They found that clearcutting and the general trend toward reduction in size and isolation of mature stands were probably detrimental to Fisher populations. They also determined that selective cutting of trees decreased the quality of habitat for Fishers.

Habitat: Fishers prefer heavy stands of mixed species of mature timber, but they range widely in forested regions (Buck et al., 1983). They are frequently encountered in second-growth forests, and sometimes in forest openings. A few records of Fishers have been found in communities such as scrub woodlands at lower elevations (Schempf and White, 1977). This does not mean, however, that Fishers can live in these habitats permanently. In California, Fishers primarily inhabit mixed conifer forests composed of Douglas Fir and associated conifers, although they also are encountered frequently in higher elevation, fir and pine forests such as Red Fir and Lodgepole Pine, and mixed evergreen/broad leaf forest.

Fishers prey on a variety of small- and medium-sized mammals, especially Chipmunks, Squirrels, Marmots, Woodrats, Porcupines, Rabbits, Hares, Martens, Foxes and other small carnivores (Powell, 1981; Strickland et al., 1982a; Yocum and McCollum, 1973). Grinnell et al. (1937) speculated

that Fishers also feed on birds such as Grouse.

Fishers are known to den in cavities near the tops of large trees, in hollow logs on the ground, in talus, and crevices in rock outcrops (Grinnell et al., 1937).

Recommendations: Field surveys are needed to establish a data base against which future trends can be assessed, and to define more accurately current status. Attention should focus on the Sierra Nevada, as evidence suggests declining populations there (Schempf and White, 1977).

Effects of various forest harvesting practices on Fisher populations should be determined over a broader area (Buck et al., 1983); and specific habitat needs such as stand density and tree size, food sources, and den sites should be determined. Snags, damaged and senescent trees with large cavities, and hollow logs are probably important for Fishers, especially where talus and rock crevices are unavailable.

Remarks: Schempf and White (1977) presented several records (mostly sightings) in addition to those listed below and referred to an unpublished paper where these records were documented. Yocum and McCollum (1973) mapped several localities in Del Norte, Humboldt and Trinity counties, but did not present descriptions of the localities. Bruce and Weick (1973) and Gould (1978) also presented data on Fishers in northwestern California and the northern Sierra Nevada, respectively.

Grinnell et al. (1937) considered *M. p. pacifica* to be inseparable from *M. p. pennanti*. Goldman (1935), however, found that the two taxa were separable. Hall and Kelson (1959) believed that evidence presented by Goldman was sufficient for subspecific status.

Distribution Records: DEL NORTE CO.: 3 localities unspecified (Yocum and McCollum, 1973). HUMBOLDT CO.: Waterman Ridge, Hawkins Bar Road (Yocum and McCollum, 1973). LAKE CO.: near Lakeport, 1 (CAS). LASSEN CO.: Eagle Lake (Grinnell et al., 1930). MARIPOSA CO.: Big Creek, near Wawona, 2 (USNM); Big Meadows, Coulterville Road, 4000 ft, 1 (MVZ); Bridalveil Creek (Cunningham, 1959); Chinquapin, 1 (MVZ); near Crane Flat, Yosemite National Park, 1 (MVZ); Fort Monroe, 1 (MVZ); Grouse Creek, 1 (MVZ); Yosemite National Park, 1 (MVZ); Yosemite Valley, 3 (MVZ), 1 (USNM); Wawona, 1 (USNM). MENDOCINO CO.: Cahto, 1 (USNM); near Covelo, 1 (USNM); Eden Valley, 1 (MVZ). SHASTA CO.: Cassel, Burney Mountain, 1 (USNM); Cassel, Rock Creek Mountains, 1 (USNM); Fort Crook, 1 (USNM). SIERRA CO.: Webber Lake Area (Gould, 1978). SISKIYOU CO.: near Cecilville, 4 (MVZ); Mount Shasta, 1 (USNM). TRINITY CO.: near Helena, 2 (MVZ); Wells Creek, E fork, 15 mi E Hay Fork, 1 (USNM); S fork Trinity River, sec. 29, T1N, R7E, 2000 ft, 1 (MVZ). TULARE CO.: Atwell's Mill, 1 (USNM); Kern River, 2 mi downstream from junction with Little Kern River, 1 (MVZ). TUOLUMNE CO.: near Hetch Hetchy Valley, 3 (MVZ); Hog Ranch Ranger Station, Yosemite National Park, 1 (MVZ); head Lyell Canyon (Grinnell and Storer, 1924); Tuolumne Big Trees, 2 (MVZ).

American Badger
Taxidea taxus

1778. Ursus taxus Schreber, Die Saugthiere. . ., 3:520. Type Locality:
Labrador and Hudson Bay, Canada.
1894. Taxidea taxus, Rhoads, Amer. Nat., 28:524.

Distribution: American Badgers occur from northern Alberta southward to central Mexico. They range from the Pacific Coast eastward through Ohio. They are absent from the humid coastal forests and from other regions with dense forests. In California, Badgers ranged throughout the state except for the humid coastal forests of northwestern California in Del Norte Co. and the northwestern portion of Humboldt Co. (Long 1973; unpubl. data).

Population Status: Badger populations have declined drastically in California within the last century (Grinnell et al., 1937; Longhurst, 1940). Grinnell et al. (1937) noted that Badgers were reduced in numbers over almost all of their range in California by 1937. At that time they were still numerous in the Central Valley, but now they survive only in low numbers in peripheral parts of the valley and adjacent lowlands to the west in eastern Monterey, San Benito and San Luis Obispo counties. In the coastal areas from Mendocino county south they have been drastically reduced in numbers. They have been extirpated from many areas in southern California. Long and Killingley (1983) regarded the status of Badgers in California as poor. Deliberate killing probably has been a major factor in the decline of Badger populations. Most people regard Badgers as detrimental to their interests and attempt to kill them. Cultivation is adverse to Badgers, as they do not survive on cultivated land.

Agricultural and urban developments have been the primary causes of decline and extirpation of populations of Badgers in California. Rodent and predator poisoning pose double threats through direct and secondary poisoning of Badgers and elimination of the food Badgers are dependent upon. Shooting and trapping of Badgers for animal "control" is another source of mortality. The U.S. Fish and Wildlife Service took 4086 Badgers in California from 1966 to 1976 (Lee, 1977). Trapping of Badgers for the fur trade probably has had little impact on populations in many areas because the fur was of low economic value. In the late 1920's to at least the late 1930's, Badger fur was in high demand and trapping increased to levels that may have decimated local populations (Grinnell et al., 1937). Again, subsequent to 1975, demand for Badger pelts has increased and increased efforts are being expended to trap Badgers.

No current data exist on the status of Badger populations in California, but they have obviously declined or disappeared in large sections of the state, particularly areas west of the Cascade-Sierra Nevada mountain axis and in coastal basins of southern California. Badgers were common in mountainous areas only in large, treeless meadows and expanses near timberline. Longhurst (1940) noted that they had nearly disappeared from Napa County by 1940.

Despite the probable continuing decrease in numbers of Badgers statewide, reports of numbers trapped for the fur market indicate substantial increases in captures in recent years (e.g. 107 Badgers reported trapped in 1975-76 and 299 in 1976-77; California Dept. of Fish and Game, unpubl. report). Most of these Badgers were taken in the northern and eastern

counties, although Fresno and San Benito counties produced 45 and 20 respectively, in 1976-77. The increase in numbers trapped most likely reflects the increased prices paid for pelts and the consequently greater effort expended in trapping Badgers. For example, 931 trapping licenses were sold in 1975-76 and 1692 in 1976-77. Less than one-half of the licences filed reports of their captures both years (207 and 751, respectively).

Habitat: In California, Badgers occupy a diversity of habitats. The principal requirements seem to be sufficient food, friable soils, and relatively open, uncultivated ground. Grasslands, savannas, and mountain meadows near timberline are preferred. Badgers prey primarily on burrowing rodents such as Gophers (Thomomys), Ground Squirrels (Spermophilus, Amnospermophilus), Marmots (Marmota), and Kangaroo Rats (Dipodomys). They are predatory specialists on these rodents, although they will eat a variety of other animals, including mice, Woodrats, reptiles, birds and their eggs, bees and other insects, etc. Grinnell et al. (1937) recounted reports of Badgers breaking open bee hives to eat both the brood and honey. They regularly dig out nests of Bumble Bees.

One report of densities of Badgers reviewed by Long gave an estimated density of one Badger per square mile. Bailey (1905) noted that one Badger spent a summer in a 20-acre field. Sargent and Warner (1972) found that a radio-collared female had a home range of 850 hectares (2091 acres): 725 hectares (1783 acres) in summer, 53 hectares (130 acres) in fall, and 2 hectares (5 acres) in winter. Messick and Hornocker (1981) found that home ranges averaged 2.4 and 1.6 sq. km for adult males and females, respectively, in Idaho.

Recommendations: Current data on Badger populations are needed throughout the state, especially from the lowlands of western California. The effects of continuing habitat loss, rodent poisoning, and trapping for the fur trade should be assessed. Mandatory reporting of take (including animals discarded) by trappers and hunters should be required. Information on home range size and density of prey required by Badgers is needed for effective management. The impact on Badgers of the use of rodenticides and trapping for the fur trade should be assessed.

Remarks: Long (1972) revised Taxidea taxus primarily on the basis of specimens in the U.S. National Museum. While his paper has contributed much to an understanding of geographic variation in this species, it has also confused the taxonomy of Badger populations in California. T. t. jeffersonii (Harlan) generally ranges in the better-watered areas of California, including coastal areas, most of the Sierra Nevada, and most of the Great Basin Province. T. t. berlandieri Baird ranges through the hotter, drier desert and grassland associations of southeastern California and the Central Valley. This makes sense from an ecogeographic point of view: larger, darker-colored Badgers from cooler, moister areas and smaller, lighter-colored Badgers from hotter, drier areas. The problem occurred with the assignment of specimens to particular subspecies. A specimen from Alila (Earlimart), Tulare County, on the floor of the southern San Joaquin Valley, was assigned to jeffersonii, while another specimen from Alila was assigned to berlandieri.

Specimens from geographically adjacent and ecologically continuous areas

(hot and arid) of the San Joaquin Valley were assigned to jeffersonii (e.g. Tulare Lake, Huron, Stanley, Alcalde, and Taft), while others from Tracy, San Joaquin County, were assigned to berlandieri. These and other taxonomic assignments by Long (1972) make no sense from a geographic or environmental perspectives. Long (1972) noted that some of these specimens exhibit intermediate characters, suggesting intergradation. This is probably the case. I can see no compelling reason, however, to assign the Central Valley population to berlandieri. In fact, Long assigned most of the specimens from this region to jeffersonii, although his range map and statements lead to the opposite conclusion. A better arrangement would be to include all specimens from the Central California lowlands in T. t. jeffersonii. For this account, however, I do not use trinomials for Badger populations. The principal concern is for populations in the lowlands of western California, west of the main Cascade-Sierra Nevada mass and the southern California coastal region. This would include some populations that Long (1972) assigned to T. t. jeffersonii and some he called T. t. berlandieri.

Distribution Records: ALAMEDA CO.: Oakland, 2 mi NE Mills College, 1 (MVZ). BUTTE CO.: 18 mi W Oroville, 1 (CSUC). CONTRA COSTA CO.: Rattlesnake Canyon, near Orinda, 1 (MVZ). EL DORADO CO.: Echo, 7500 ft, 2 (MCZ). FRESNO CO.: Alcalde, 1 (USNM); 7 mi SW Coalinga, 1 (CAS); Huron, 374 ft, 1 (USNM); 0.6 mi NE Marion Lake, 10500 ft, Kings Canyon National Park, 1 (MVZ); Panoche Creek, 550 ft, 1 (MVZ). HUMBOLDT CO.: 27 mapped localities without locality descriptions, based on sight records (C. P. Yocum, in litt.). INYO CO.: no specific locality, 1 (LACM); Furnace Creek Ranch, 1 (MVZ); 3 mi NE Jackass Spring, 1 (MVZ); 7 mi E Laws, at Silver Creek, 1 (MVZ); Wild Roae Canyon, 1 (MVZ). IMPERIAL CO.: Alamo Duck Preserve, 8 mi NW Calipatria, 1 (MVZ); Bard, 1 (UCLA); 3 mi N Bard, 2 (SDSNH); 6 mi W Bard, 1 (SDSNH); 5 mi N Laguna Dam, 1 (MVZ); Manganese Wells, Lower Colorado River, 1 (MVZ); Palo Verde, 1 (LACM), 1 (MVZ); 0.75 mi N Palo Verde, 1 (MVZ); 13 mi N Palo Verde, 1 (MVZ); 18 mi WNW Palo Verde, 1 (MVZ); 20 mi N Picacho, Colorado River, 1 (MVZ); Silabee, 1 (MVZ). KINGS CO.: Stanley, 1 (USNM). KERN CO.: Antelope Valley, near Neenach, 1 (FMNH); Bakersfield, 1 (MVZ); Buttonwillow, 1 (CAS); 3 mi S Cantil P. O., 1 (LACM); 3 mi SE Cantil, M & R Ranch, 1 (LACM); 3 mi ENE Hart's Place, 1 (LACM); 4 mi S Inyokern, 1 (LACM); 4 mi SW Inyokern, 1 (LACM); S Fork Kern River, 25 mi from Kernville, 1 (USNM); 5 mi NW Mojave, 3350 ft, 1 (MVZ); Tulare Lake, mouth of Kern River, 2 (USNM); Taft (Long, 1972); E side Walker Pass, 5000 ft, 1 (LACM); Willow Springs, 1 (AMNH). LAKE CO.: Lakeport, 1 (CAS); several miles N Upper Lake, 1 (WFBM). LASSEN CO.: Amedee, 1 (USNM); Calneva, 1 (MVZ); Hayden Hill, 1 (USNM); Karlo, 2 (MVZ); 2 mi S Madeline, 1 (HSU); Merrillville, 1 (USNM); 7 mi N Observation Peak, 5300 ft, 1 (MVZ); Poison Lake, 1 (USNM); 20 mi E Susanville, 1 (CSUC); 10 mi E Ravendale, 5400 ft, 1 (CAS); Susanville, 1 (USNM); Termo, 1 (MVZ); Willow Creek, Barran Ranch, 1 (CSUC). LOS ANGELES CO.: Covina, 1 (UCLA); Fairmont, Antelope Valley, 1 (LACM), 1 (MVZ); Los Angeles, 1 (LACM); near Lovejoy Buttes, 1 (MVZ); Tejuanga Wash, 1 (MVZ). MADERA CO.: San Joaquin Experimental Range (Newman and Duncan, 1973); head San Joaquin River, 2 (USNM). MARIN CO.: Bear Valley Ranch, Olema, 1 (MVZ); Bolinas, 1 (MVZ); 0.75 mi from beach, 1.25 mi NW Bolinas, 1 (MVZ); Fort Barry, 1 (MVZ); 3 mi W Inverness, 2 (MVZ); Millerton Gulch, 2.25 mi NE Inverness, 1 (MVZ); 7 mi N Novato, 1 (MVZ); Tomales Point, 1 (MVZ). MARIPOSA CO.: no locality specified, 1 (USNM); Wawona, 1 (USNM). MENDOCINO CO.: Clarke Ranch, 8 mi SW

Barlimart], 283 ft, 6 (USNM); Otosi, 4 (USNM); 4 mi SW Porterville, 1 (AMNH); White River, 1 (CAS); Whitney Meadows, 9800 ft, 1 (MVZ). TUOLUMNE CO.: Tuolumne Meadows, 4 (MVZ), 1 (USNM). VENTURA CO.: Mount Pinos, 1 (MVZ); Mount Pinos, 5500 ft, 1 (LACM); Saticoy, 1 (MVZ). YOLO CO.: Davis, 1 (UDAV); Woodland, 1 (UDAV).

Channel Islands Spotted Skunk
Spilogale gracilis amphiala

1929. Spilogale phenax amphialus Dickey, Proc. Biol. Soc. Washington, 42:158. Type Locality: 2.5 mi N ranch house near coast, Santa Rosa Island, Santa Barbara Co., California.
1933. Spilogale gracilis amphialus, Grinnell, Univ. California Publ. Zool., 40:105.

Distribution: Channel Islands Spotted Skunks are known to occur only on the islands of Santa Cruz, Santa Rosa and San Miguel. They are probably extinct on San Miguel Island, however (Walker, 1980).

Population Status: Nothing specific is known about the status of Spotted Skunks on the Channel Islands. Grinnell et al. (1937) noted that "quite a few" skins of these Skunks were received from Santa Cruz Island by Colburn's taxidermy shop in Los Angeles in 1918. Laughrin (1973) noted that Spotted Skunks were quite rare when he surveyed Santa Cruz Island in 1973. According to von Bloeker (1967), Spotted Skunks were once very common on Santa Cruz and Santa Rosa Islands, but by 1967 they were rarely found on either island, at least near human dwellings.

Remarks by these authors were subjective impressions; there have been no studies of population size on either island. The seeming rarity of Spotted Skunks may indicate normal population fluctuations, or reflect a real decline in numbers.

Santa Rosa and Santa Cruz are the two largest of the Channel Islands. Both are privately owned, and both have had less habitat alteration and fewer introductions of exotic mammals than most of the other islands. According to Laughrin (1973) Wapiti (Cervus elaphus), Mule Deer (Odocoileus hemionus), Wild Pigs (Sus scrofa), Cattle and Horses, occupied Santa Rosa Island in 1973 in addition to native mammals. Sheep formerly were present, but apparently have been completely removed. A list of currently extant, introduced species on Santa Cruz Island is unavailable. Von Bloeker (1967) mentioned Horses, Wild Pigs, Cattle, and Roe Deer (Capreolus capreolus) as being present, and implied that feral cats were established on both islands. Laughrin (1973) noted that Sheep also occurred on Santa Cruz Island, but fences were erected to restrict them to the north side. A hunting program to reduce their numbers was in effect at that time.

The principal reason for concern about the Channel Islands Spotted Skunk is the scanty information available suggesting a significant decline in populations. Because island biota are more prone to extinction than those of mainlands, concern is heightened. Human disturbances on the islands are probably not sufficient to cause this decline. Domestic cats and/or dogs have possibly introduced diseases to which the Skunks are

Laytonville, 1 (MVZ); Eden Valley Ranch, 18 mi above Willits, 1 (MVZ).
MERCED CO.: Los Banos, 1 (MVZ); Los Banos Game Refuge, 2 (MVZ); 10 mi S Merced, 1 (CSCS); 2 mi SW Stevinson, 1 (CSCS). MODOC CO.: 3 mi E Alturas, 1 (MVZ); 16 mi W Alturas, 1 (USNM); Cedarville, 1 (USNM); Dry Creek, 3 (MVZ); Eagleville, 1 (CAS); 5 mi NE Fort Bidwell, 1 (MVZ); 7 mi E Fort Bidwell, 1 (MVZ); Lake City, 1 (MVZ); 2 mi N Lake City, 1 (MVZ); 3 mi E Likeley, 1 (MVZ); Modoc National Forest, Bump Head Mtns., near Clear Lake, 1 (WFBM); Parker Creek, Warner Mountains, 3 (MVZ); 12 mi E Steele Meadow, 5200 ft, 1 (MVZ); Warren Peak, 1 (MVZ). MONO CO.: Sonora Pass, 9600 ft, 1 (MVZ). MONTEREY CO.: Arroyo Seco Wash, 2 mi S Soledad, 150 ft, 1 (MVZ); 10 mi S Carmel, by Road # 1, 1 (MVZ); Highway G16, at Cachagua Creek, 0.3 mi W divide, 1 (MVZ); Jamesburg, 1 (USNM); King City, 1 (UDAV); 2.5 mi E Monterey Municipal Airport, Highway 117, 1 (MVZ); 9 mi E Parkfield, 1 (MVZ); 7 mi E San Lucas, 1 (MVZ); Seaside, 1 (MVZ). NAPA CO.: Napa (Grinnell et al., 1937); 3 mi SW Napa, 1 (MVZ). PLUMAS CO.: Quincy, 1 (USNM). RIVERSIDE CO.: Banning, San Jacinto foothills, 2200 ft, 1 (MVZ); Cabuilla (=Anza), San Jacinto Mountains, 1 (MVZ); Indio, 1 (UCLA); 18 mi NW Palo Verde, 1 (MVZ); Pinto Basin, 1750 ft, 1 (MVZ); San Jacinto, 1 (CAS); Temecula, 2 (MVZ). SACRAMENTO CO.: Indian Mound, N of Hood, 1 (MVZ); Polk, 1 (USNM). SAN BENITO CO.: Hollister, 1 (CAS). SAN BERNARDINO CO.: Cedar Canyon, 5000 ft, Providence Mountains, 2 (MVZ); near Cimia, 3 (MVZ); Indian Cove, 3000 ft, 2 mi S, 6 mi W Twenty Nine Palms, 1 (MVZ); 2.5 mi SW Kelso, 2100 ft, 1 (MVZ); near Lake Arrowhead, San Bernardino Mountains, 1 (LACM); Reche Canyon, near Colton, 1 (MVZ); 2 mi ESE Rock Spring, 4700 ft, Lanfair Valley, 1 (MVZ); San Bernardino, 1 (SDSNH); Vidal, 1 (LACM). SAN DIEGO CO.: California Border, 1 (AMNH); Colorado Desert, Laguna Station, New River, 1 (USNM); near El Cajon, 2 (UCLA); El Cajon Valley, 1 (USNM); Escondido, 1 (SDSNH); Hilldale, 1 (SDSNH); Lakeside (Bond, 1977); 1 mi N La Jolla, 1 (SDSNH); La Puerta Valley, 2 (CAS), 1 (MVZ), 4 (SDSNH), 1 (USNM); Mexican Boundary at monument 258, 1 (USNM); Ramona, 1 (SDSNH); W of San Marcos, 1 (SDSNH); Santa Ysabel, 1 (USNM); Sequan District, 1 (USNM); Sweetwater Reservoir, 1 (SDSNH); Twin Oaks, 1616 ft, 2 (USNM); Witch Creek, 4 (SDSNH). SAN FRANCISCO CO.: 1666 46th Ave, San Francisco, 1 (CAS); Golden Gate Park, San Francisco, 1 (CAS). SAN JOAQUIN CO.: Corral Hollow, 1 (MVZ); Tracy, 14 (USNM). SAN LUIS OBISPO CO.: 3 mi W Red Hills, near Shandon, 1 (MVZ); 12 mi S Shandon, 2 (MVZ); 14.5 mi S Shandon, 1 (MVZ); 15 mi S Shandon, 1 (MVZ); 6 mi SE Shandon, 1 (MVZ); 7 mi SE Shandon, 1 (MVZ); 8 mi SE Shandon, 1 (MVZ); 9 mi SE Shandon, 2 (MVZ); 10 mi SE Shandon, 2 (MVZ); 17 mi SE Shandon, 1 (MVZ); 18 mi SE Shandon, 2 (MVZ); 18.5 mi SE Shandon, 1 (MVZ); 19 mi SE Shandon, 1 (MVZ); 1.5 mi W Yegues Mountain, 1 (MVZ). SAN MATEO CO.: Alpine, 1 (SDSNH); Menlo Park, 1 (CAS); near Peak Mountain, 1 (CAS); Pescadero, 1 (USNM); San Francisco Game Refuge, 2 (MVZ). SANTA BARBARA CO.: 4 mi E Cuyama Ranch, 2200 ft, 1 (USNM); 10 mi E Gaviota Pass, 1 (MVZ); Santa Anita Ranch, 7 mi W Gaviota, 2 (MVZ). SANTA CLARA CO.: San Antonio Creek, vicinity of Mountain View, 1 (CAS). SANTA CRUZ CO.: Aptos, 1 (USNM). SHASTA CO.: Burney, 1 (USNM); Dickey Ridge, near Crystal Creek, 4000 ft, 20 mi W Redding, 1 (MVZ); Fort Crook, 1 (USNM); Warner Creek, 6600 ft, 1 (MVZ). SISKIYOU CO.: Beswick, 1 (USNM); Butte Creek, 1 (CAS); 5 mi N Edgewood, 2800 ft, 1 (MVZ); Teenor, 1 (USNM). SONOMA CO.: no locality designated, 1 (CAS); Freestone, 1 (MVZ). STANISLAUS CO.: 2 mi S La Grange, 1 (CSCS). TEHEMA CO.: 10 mi NW Bluff, 1 (CSUC); South Yolla Bolly Mt., 1 (USNM); 2 mi S South Yolla Bolly Mt., 1 (MVZ). TRINITY CO.: on Highway 299, near Big Bar, T5N, R8E, sec. 22, 1 (HSU). TULARE CO.: no locality designated, 1 (USNM); Alila [=

susceptible.

Habitat: Nothing specific has been recorded of the habitat of Channel Islands Spotted Skunks. According to von Bloeker (1967), they were formerly common around human dwellings, particularly on Santa Cruz Island, but by 1967 they were rarely found near any man-made structures on either island.

In much of their range, Western Spotted Skunks (*Spilogale gracilis*) are common only in areas of rock outcrops such as hillsides and rocky canyons. Spotted Skunks often take up residence in or under buildings, where these occur. They seem generally to avoid flat expanses, cultivated fields, and grasslands where rocks or brush are unavailable for cover and dens. They sometimes use burrows of other animals for dens (Grinnell et al., 1937).

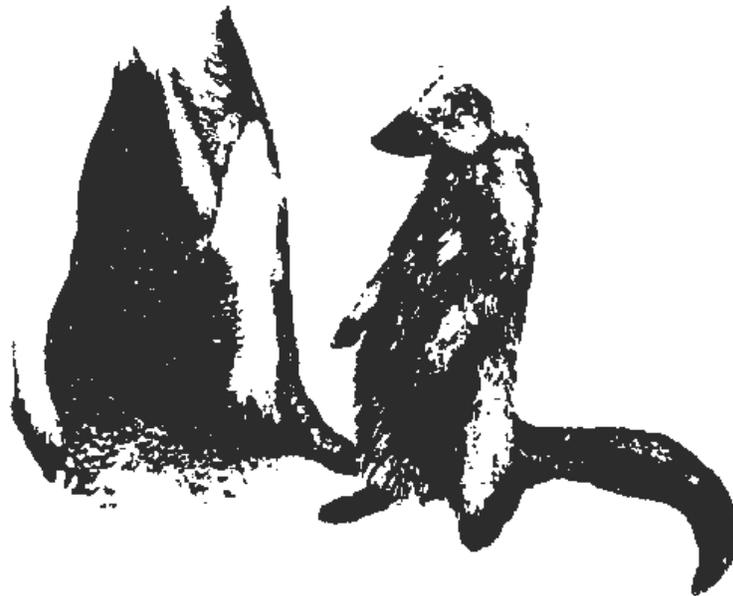
Spotted Skunks appear to be more tolerant of xeric environments than Striped Skunks, and may be found far from water. Food consists of a great variety of small animals -- arachnids, insects, mice and rats, lizards, snakes, eggs, and birds -- as well as fruits and seeds. Insects appear to be the staple, at least during months when they are abundant.

Recommendations: A survey of the islands to determine present numbers of spotted skunks and provide a data base for future monitoring is encouraged. If populations are found to be low, attempts to determine cause of the declines should be made.

Remarks: Von Bloeker (1967) did not indicate the disposition of the nine specimens mentioned in his paper. Some or all of these are probably included in the museum records listed below.

Channel Island Spotted Skunks are larger and with more black coloration (less white) than their mainland relatives. The status of this subspecies is not disputed in the literature. Walker (1980) reported on a subfossil specimen from a midden on San Miguel Island. He referred to unpublished field notes by C. D. Voy (1893), in which Voy related the capture of a small Skunk in a trap on San Miguel Island some years prior to his visit.

Distribution Records: SANTA BARBARA CO.: Santa Cruz Island, 9 (von Bloeker, 1967); Santa Cruz Island, Prisoners Harbor, 2 (MVZ); Santa Cruz Island, Stanton Ranch headquarters, 1 (MVZ); San Miguel Island (Walker, 1980); Santa Rosa Island, Becker's Bay, 16 (LACM); Santa Rosa Island, 2.5 mi N ranch house near coast (Dickey, 1929); Santa Rosa Island, Skunk Point, 1 (LACM).



OTHER CANDIDATES

The species listed in Table 5 were on the original working list or were suggested as candidate Species of Special Concern by others, species listed by the International Union for the Conservation of Nature, or designated as Sensitive by the U.S. Forest Service or the U.S. Bureau of Land Management. None are thought to face significant threats at this time, although lack of information is sufficient reason to consider some as sensitive species. Researchers and land and resource managers should endeavor to gather needed information on distribution and population status for those species indicated as sensitive.

Table 5. List of other candidate species not included on the List of Concern. Page number refers to starting page of species account. Table continues on next page.

Species	Page
Mt. Lyell Shrew (<u>Sorex lyelli</u>)	74
San Bernardino Dusky Shrew (<u>Sorex monticolus parvidens</u>)	74
Inyo Shrew (<u>Sorex tenellus</u>)	75
Monterey Vagrant Shrew (<u>Sorex vagrans paludivagus</u>)	75
Salinas Ornate Shrew (<u>Sorex ornatus salarius</u>)	75
Angel Island Mole (<u>Scapanus latimanus insularis</u>)	75
Alameda Island Mole (<u>Scapanus latimanus parvus</u>)	76
Long-tongued Bat (<u>Choeronycteris mexicana</u>)	76
Mammoth Little Brown Myotis (<u>Myotis lucifugus relictus</u>)	76
San Joaquin Myotis (<u>Myotis yumanensis oxalis</u>)	76
Spotted Bat (<u>Euderma maculatum</u>)	77
Sierra Nevada Mountain Beaver (<u>Aplodontia rufa californica</u>)	77
Kingston Mountain Chipmunk (<u>Tamias panamintinus acrus</u>)	77
Mt. Pinos Chipmunk (<u>Tamias speciosus callipeplus</u>)	78
Santa Catalina Ground Squirrel (<u>Spermophilus beecheyi nesioticus</u>)	78
San Bernardino Golden-mantled Ground Squirrel (<u>Spermophilus lateralis bernardinus</u>)	78
Palm Springs Round-tailed Ground Squirrel (<u>Spermophilus tereticaudus chlorus</u>)	79
Townsend Soft-haired Ground Squirrel (<u>Spermophilus townsendii mollis</u>)	79
Rock Squirrel (<u>Spermophilus variegatus grammurus</u>)	79
San Bernardino Flying Squirrel (<u>Glaucomys sabrinus californicus</u>)	80
Buena Vista Lake Pocket Gopher (<u>Thomomys bottae ingens</u>)	80
Honey Lake Pocket Gopher (<u>Thomomys townsendii relictus</u>)	80
San Joaquin Pocket Mouse (<u>Perognathus inornatus inornatus</u>)	81
McKittrick Pocket Mouse (<u>Perognathus inornatus neglectus</u>)	81
Arroyo Seco Pocket Mouse (<u>Perognathus inornatus sillimani</u>)	81
Yellow-eared Pocket Mouse (<u>Perognathus parvus xanthonotus</u>)	82
Sierra Valley Kangaroo Mouse (<u>Microdipodops megacephalus californicus</u>)	82
Pale Kangaroo Mouse (<u>Microdipodops pallidus pallidus</u>)	82
Point Conception Kangaroo Rat (<u>Dipodomys agilis fuscus</u>)	82
Lesser California Kangaroo rat (<u>Dipodomys californicus eximius</u>)	83
Big-eared Kangaroo Rat (<u>Dipodomys elephantinus</u>)	83
Berkeley Kangaroo Rat (<u>Dipodomys beermanni berkeleyensis</u>)	83

Table 5 (continued). List of other candidate species not included on the List of Concern. Page number refers to starting page of species account.

Species	Page #
Merced Kangaroo Rat (<u>Dipodomys heermanni dixonii</u>)	84
Argus Mountain Kangaroo Rat (<u>Dipodomys panamintinus argusensis</u>)	84
Panamint Kangaroo Rat (<u>Dipodomys panamintinus panamintinus</u>)	84
Santa Cruz Kangaroo Rat (<u>Dipodomys venustus venustus</u>)	85
Sonora Beaver (<u>Castor canadensis repentinus</u>)	85
Golden Beaver (<u>Castor canadensis subauratus</u>)	86
Santa Catalina Harvest Mouse (<u>Reithrodontomys megalotis catalinae</u>)	87
Salinas Harvest Mouse (<u>Reithrodontomys megalotis distichlis</u>)	87
Santa Cruz Harvest Mouse (<u>Reithrodontomys megalotis santacruzae</u>)	87
Anacapa Island Deer Mouse (<u>Peromyscus maniculatus anacapae</u>)	87
Santa Catalina Deer Mouse (<u>Peromyscus maniculatus catalinae</u>)	88
Western Cotton Rat (<u>Sigmodon hispidus eremicus</u>)	88
Colorado Valley Woodrat (<u>Neotoma albigula venusta</u>)	88
Monterey Vole (<u>Microtus californicus halophilus</u>)	88
Mohave River Vole (<u>Microtus californicus mohavensis</u>)	89
San Pablo Vole (<u>Microtus californicus sanpabloensis</u>)	89
South Coast Marsh Vole (<u>Microtus californicus stephensi</u>)	89
Owens Valley Vole (<u>Microtus californicus vallicola</u>)	89
San Bernardino Vole (<u>Microtus longicaudus bernardinus</u>)	90
Ringtail (<u>Bassariscus astutus</u>)	90
Humboldt Marten (<u>Martes americana humboldtensis</u>)	90
Inyo Long-tailed Weasel (<u>Mustela frenata inyoensis</u>)	91
Pallid Bobcat (<u>Felis rufus pallescens</u>)	91
Northwestern White-tailed Deer (<u>Odocoileus virginianus ochrourus</u>)	92

Mt. Lyell Shrew

Sorex lyelli was generally thought to live only in montane communities at high elevations in the central Sierra Nevada (Ingles, 1965). Review of accounts of capture of four of the five known specimens (Grinnell and Storer, 1924; Howell, 1924), together with information from recent captures, suggests that S. lyelli is widespread in high montane and cold steppe communities of the central and eastern slopes of the Sierra Nevada (Williams, 1984). Furthermore, S. lyelli is probably conspecific with S. preblei, ranging in similar habitats northward to Washington and eastward at least to northern Utah, Wyoming, and Montana (Williams, 1984, and unpubl. data). They face no threat of extinction.

San Bernardino Dusky Shrew

Published information on the distribution of Sorex monticolus parvidens included records of specimens from a desert spring at about 4200 ft, upward through mixed-conifer forest at about 7500 ft in elevation in the San Bernardino and San Gabriel mountains (Findley, 1955; Hennings and Hoffmann, 1977; Jackson, 1928). Grinnell (1908) captured only Ornate Shrews in the San Bernardino Mountains, including some from the type locality of S. m. parvidens (described by Jackson in 1921). Steve Clifton and I conducted a field study to determine the population status of the San Bernardino Dusky Shrew, trapping at 51 sites in the San Gabriel and

San Bernardino mountains (Williams, 1983). Although several shrews were captured from localities between 6000 and 9000 ft, no Dusky Shrews were found. Comparison of the shrews captured by us and San Bernardino Dusky Shrews identified by Hennings and Hoffmann (1977) with reference series of S. monticolus and S. ornatus showed that S. m. parvidens was indistinguishable from S. ornatus ornatus. Sorex monticolus parvidens is, therefore, considered a junior synonym of S. o. ornatus; these populations are not threatened (Williams, 1983).

Inyo Shrew

At the time this project was initiated, only three specimens of Sorex tenellus were known from two localities in California (Hoffmann and Owen, 1980). Their probable distribution, on the eastern slopes of the southern Sierra Nevada and in the White Mountains, suggested no cause for concern. Subsequently, discovery of Inyo Shrews in the Sweetwater Mountains (Williams, 1984) and the Mono Basin (Harris, 1982), and at a site on the western slope of the Sierra Nevada in Red Fir forest (Williams, 1984), shows that they are fairly widespread and under no threats.

Monterey Vagrant Shrew

Sorex vagrans paludivagus lives in riparian and tidal and freshwater wetlands of the San Francisco Peninsula, the Salinas River Delta, and adjacent lowlands in the Monterey Bay area (Findley, 1955; Hennings and Hoffmann, 1977). Only scanty information is available to document distribution and populations status. Although the area within the geographic range of Monterey Vagrant Shrews is under intense pressure from human developments, several wetland communities, including the type locality, Elkhorn Slough, are protected from development. S. v. paludivagus may be more vulnerable than many wetland species, particularly birds and Long-toed Salamanders which have received special management considerations in different wetlands within the region. Therefore, it should be considered sensitive.

Salinas Ornate Shrew

Sorex ornatus salarius occupies a variety of riparian, wetland, and upland terrestrial communities in the vicinity of the Salinas River Delta (Owen and Hoffmann, 1983; unpubl. data). Although the region is undergoing intense development, I could not find information documenting its current status. The relatively wide range of communities providing habitat for S. o. salarius suggests that it is probably not jeopardized.

Angel Island Mole

Scapanus latimanus insularis is confined to Angel Island, Marin Co., in the northern portion of San Francisco Bay (Hall, 1981). The island is a state park and under no threat of intensive development. Introduced Mule Deer (Odocoileus hemionus) seriously damaged vegetation on the island, resulting in considerable soil erosion, which was probably the major threat to moles. The California Department of Parks and Recreation has instituted measures to control the size of the deer population. Determining the current population status of Angel Island Moles should receive high priority in management of the island.

Alameda Island Mole

Scapanus latimanus parvus is known only from Alameda Island, Alameda, Alameda Co. (Hall, 1981). The island is intensely developed with the Alameda Naval Air Station (Nimitz Field) occupying nearly half; most of the remaining area is occupied by commercial and residential developments. Alameda Memorial State Beach Park is the most extensive state-managed property on the island. I have no current information on the population status of S. l. parvus, but development of Alameda Island warrants treating it as a sensitive species.

Long-tongued Bat

Choeronycteris mexicana seems to be a sporadic visitor to California from Mexico, appearing in San Diego County in autumn (Huey, 1954b; Olson, 1947). Records include bats taken in San Diego in September, 1946 (Olson, 1947), October and December, 1947 (Huey, 1954b), and October, 1963 (Banks and Parrish, 1965). Long-tongued Bats feed mostly on nectar and pollen of night-blooming succulents such as agave. They roost in relatively well-lighted caves and in buildings, and under shallow, cave-like overhangs and portals on buildings. No protection or management of Long-tongued Bats is required in California. Additional information on their occurrence within the state is needed, however, and this need should be brought to the attention of agency biologists and others likely to receive reports of bats.

Mammoth Little Brown Myotis

Myotis lucifugus relictus is known from the Long Valley and Owens Valley (Harris, 1974). In general, M. lucifugus is associated with large, permanent bodies of water in western North America. They often roost and form maternity colonies in the attics of buildings, under bridges, and other structures (Fenton and Barclay, 1980). M. l. relictus was suggested as a candidate species by the U.S. Fish and Wildlife Service (in litt.). I have not found evidence that it is jeopardized, although information on current population status is lacking. Major developments in the region (impoundment and diversion of rivers and streams) probably enhance habitat for the species.

San Joaquin Myotis

Myotis yumanensis oxalis occupies areas on the valley floor and foothills of the San Joaquin Basin and Delta, westward to at least Berkeley, Alameda Co. (Hall, 1981). This species was on the original working list. Within their range, San Joaquin Myotis are among the commonest bats, forming relatively large maternity colonies in attics of buildings, barns, and other structures (unpubl. observations). Populations of all bats appear to have diminished greatly in the last two decades in central California, and this trend will probably continue as more land is developed, more insecticides are used, and as barns and other structures used as roosts and sites for maternity colonies become less numerous. I do not believe the situation warrants high priority consideration now, but treatment as a sensitive species is advisable.

Spotted Bat

Euderma maculatum was listed as a rare species in the U.S. Bureau of Sports Fisheries and Wildlife Rare and Endangered Species List of 1968 (Watkins, 1977). Listing did not confer legal, protected status for the species. E. maculatum was also listed in the 1969 edition of the International Union for Conservation of Nature Red Data Book, and as a Category 2 species by the U.S. Fish and Wildlife Service (1982). Spotted Bats range widely in western North America from southern British Columbia (Woodsworth et al., 1981) to Mexico (Watkins, 1977). In California, records of Spotted Bats include the eastern and southern portions of California, the central Sierra Nevada and the foothills of the Sierra Nevada in the San Joaquin Valley. They probably occur throughout the state in suitable habitat. Most often, Spotted Bats have been found in arid desert and open pine forests in rough, rocky terrain (Easterla, 1971; Findley and Jones, 1965; Leonard and Fenton, 1983; Watkins, 1977; Woodsworth et al., 1981). Spotted bats appear to roost mainly in rock crevices (Leonard and Fenton, 1983; Watkins, 1977), and females appear to favor Ponderosa Pine forest as habitat during the reproductive season (Findley and Jones, 1965). I found no evidence that the Spotted Bat is threatened in California. A review of its distribution and population status by Fenton et al. (1983) found no significant threats that warranted seeking federal Threatened or Endangered Species status.

Sierra Nevada Mountain Beaver

Unpublished observations (Dale Steele) on a population of Aplodontia rufa californica, living near a freshwater seep along historic Lee Vining Creek, about 1 km from Mono Lake, provided the basis for inclusion of this population among the species on the draft List of Concern. It was the only local population of a more widely distributed taxon to be so included. Other populations of Sierra Nevada Mountain Beavers are found at numerous sites, particularly where there is a dense growth of small deciduous trees and shrubs, wet soil, and/or nearby water, and an abundance of herbaceous forbs, ferns, berry vines, etc. (Camp, 1918; Scheffer, 1929). Because of the unique habitat of the Mono Basin population in semidesert surroundings and because water-flow in Lee Vining Creek is usually diverted by the Los Angeles Metropolitan Water District, this population could be jeopardized. On this basis, the population was listed as a Category 2 species by the U.S. Fish and Wildlife Service (1982). Subsequently, additional information on the status of Mountain Beavers in the Mono Basin was published by Harris (1982). John Harris (pers. comm.) believes that Mountain Beavers living near Mono Lake are immigrants from higher elevations along the eastern slope of the Sierra Nevada, and that, periodically, some establish homes in suitable sites. In reconsidering its status in light of the observations by Harris (1982, and pers. comm.) and the recent litigation that has returned water to Lee Vining Creek (at least temporarily), there seems to be little justification for including this population on the List of Concern.

Kingston Mountain Chipmunk

Tamias panamintinus acrus occurs only in the Kingston Mountains in the desert area of northeastern San Bernardino Co. (Hall, 1981). This population is apparently isolated from all other populations of Tamias by

hot, low-lying desert communities (Johnson, 1943). Within the Kingston Mountains, the chipmunks live in arid pinyon-juniper woodlands, occupying nests among rocks in fissured cliffs and ledges. The U.S. Bureau of Land Management listed T. p. acrus as a Sensitive Species in its California Desert Conservation Area Plan (unpubl. documents). Johnson (1943) noted that Kingston Mountain Chipmunks were few in number and occupied a potential geographic range of less than 40 square miles. Major uses of land in the area include cattle grazing and mining (U.S. Bureau of Land Management, in litt.); neither activity poses serious threats to the population. No evidence known to me supports considering it as sensitive.

Mt. Pinos Chipmunk

Tamias speciosus callipeplus is apparently restricted in distribution to the upper slopes and summit of Mt. Abel and Mt. Frazier of the Transverse Ranges, (southwestern Tehachapi Range). Howell (1929) recorded a single specimen from Canyon de Uvas (Grapevine Canyon). Records of elevation extend from 6000 ft on north-facing slopes to 8800 ft in open, coniferous forest (A. I. Roest, in litt.; Grinnell, 1933). Lodgepole Chipmunks (T. speciosus) are generally found in open forests with a mix of shrubs and trees. They are nearly always associated with Lodgepole Pine, although Red Fir, Jeffrey Pine, and Chinquapin are also common plant associates (Johnson, 1943); Red Fir does not occur, and White Fir is probably an important associated species within the range of T. s. callipeplus. Lodgepole Chipmunks frequently take refuge in trees and rarely venture far from tree cover. No information is available to document the status of this isolated population. Dr. Aryan Roest expressed concern about its status and stated that a high level of recreational activities by humans in that area, including extensive vacation home developments might be responsible for a perceived decline in population density. The relatively wide-spread occurrence of Mt. Pinos Chipmunks on public lands and their preference for relatively open forests suggests that they are not currently threatened, but this should be established by field studies. Treatment as a sensitive species is recommended.

Santa Catalina Ground Squirrel

Spermophilus beecheyi nesioticus occurs only on Santa Catalina Island, Los Angeles Co. Although this species was on the original working list, primarily because of its insular distribution, it was shortly dropped from consideration. California Ground Squirrels are widely distributed, occurring from below sea level to high elevations in temperate, mixed conifer forests (Grinnell, 1933). They are most numerous in disturbed communities undergoing secondary succession. During field work on Santa Catalina Island in January, 1983 (Williams, 1983), I observed several Santa Catalina Ground Squirrels. The general degradation of native plant communities by introduced Bison, Feral Goats, Wild Figs, and other introduced ungulates favor this species. There is no reason to treat it as sensitive.

San Bernardino Golden-mantled Ground Squirrel

Spermophilus lateralis bernardinus is a relictual population of the Golden-mantled Ground Squirrel and is distributed from about 6500 to 11500 ft in the elevation in the San Bernardino Mountains (Grinnell, 1933). In

the western Sierra Nevada, Golden-mantled Ground Squirrels chiefly inhabit forest floors, especially in open forests with a mix of tall trees, brush, and open ground supporting herbaceous plants (White et al., 1980). This species was included on the original List of Concern primarily on the basis of my experiences with S. lateralis on the western slope of the central Sierra Nevada. During field work in the San Bernardino Mtns. (Williams, 1983, and unpubl.), Golden-mantled Ground Squirrels were observed in open pine and mixed conifer forests and in pinyon-juniper woodlands on the northern, desert slopes of the mountains. Their abundance in a broader range of plant communities in the San Bernardino Mountains lessens the importance of threats to the taxon from home and recreational developments.

Palm Springs Round-tailed Ground Squirrel

Spermophilus tereticaudus chlorus was on the draft List of Concern as a Third Priority species. Populations are restricted to areas below about 1200 ft in the Coachella Valley (Grinnell and Dixon, 1918) in Riverside Co. Here, Round-tailed Ground Squirrels occupy dry, level, sandy areas, apparently being most numerous in areas with fine sandy soils supporting abundant herbaceous growth; Mesquite (Prosopis sp.), Suaeda/Distichlis, and Creosote (Larrea) associations are also commonly used. They do not inhabit cultivated fields and lawns but they feed in such areas when the distance from their home burrows is not too great. The habitat for S. t. chlorus has been reduced substantially by urbanization, cultivation, and construction of roads, railroads, airports, and golf courses. Little public land is found in the Coachella Valley, and not all that is publicly owned supports this species. The reason for removing it from the List of Concern is because of the Coachella Valley Macropreserve agreement between the U.S. Department of the Interior, The Nature Conservancy and other organizations. S. t. chlorus should be treated as a sensitive species until information on its status is available.

Townsend Soft-haired Ground Squirrel

Spermophilus townsendii mollis occurs in two disjunct areas in eastern California: the region from the upper Owens Valley to the Mono Lake area in Mono Co.; and in the Honey Lake area in Lassen Co. (Hall, 1981). Townsend Ground Squirrels live in communities with sandy soils supporting Big Sagebrush and Rabbitbrush. Typically, they are found in loosely organized colonies. In California, they are dormant from about July to January or February (Harris, 1982). They do not live in cultivated fields. S. t. mollis was on the working list, but definitive information on its status has not been developed. Much of the land around Honey Lake is under cultivation and the species could be threatened there. There are fewer developments that would threaten the species in the southern sector of its range where extant colonies are known from the Mono Lake Basin (Harris, 1982; and unpubl. data). I found no evidence to support listing this species.

Rock Squirrel

In California, Spermophilus variegatus grammurus only occurs near the eastern border in desert mountain ranges (Clark and Providence ranges) of San Bernardino Co. (Hall, 1981). There, it lives in pinyon-juniper

associations among rocks (Ingles, 1965). I found no information to indicate that the species is threatened in California.

San Bernardino Flying Squirrel

Glaucomys sabrinus californicus is known from the San Bernardino and San Jacinto ranges, living between about 5200 and 8500 ft. There probably is a population of G. sabrinus in the San Gabriel Mountains also (Vaughan, 1954). Summer (1927) conducted an extensive trapping survey south of Big Bear Lake in the San Bernardino Range in summer, 1926. He took 22 specimens over the course of several months, all in White Fir trees. Grinnell (1933) remarked that these flying squirrels inhabited woodlands where Black Oak or White Fir trees were common. Grinnell and Swarth (1913) captured a single animal in the San Jacinto Mountains. It was taken in a Black Oak at about 6000 ft. Records of 38 specimens from the two mountain ranges, most of which were taken prior to the 1960's, were located. The San Bernardino Flying Squirrel was listed as a Third Priority species on the draft List of Concern because of high densities of homes and recreation sites in mid-elevation forests in both ranges and killing of trees by air pollution, and because authorities had remarked on the seeming scarcity of these animals (Grinnell, 1908; Grinnell and Swarth, 1913; Summer, 1927). Field work in the San Gabriel and San Bernardino mountains (Williams, 1983) convinced me that the threats from developments were of much lesser magnitude than feared earlier. G. s. californicus was deleted from the final List of Concern for these reasons. All flying squirrels are protected from taking in California, therefore having some protection from direct depredation by humans.

Buena Vista Lake Pocket Gopher

Thomomys bottae ingens is limited to areas in the vicinity of historic Buena Vista Lake, in the southern San Joaquin Valley, Kern Co. (Hall, 1981). Buena Vista Lake has been drained and is under irrigated cultivation; cotton is grown on the historic Lake Bed and on most surrounding land. Periodic field work, especially in 1985 (Williams, 1985) produced evidence of extant colonies in the South Coles Levee Oil Field and the Buena Vista Lake Recreation Area north of the lake bed, and elsewhere within its limited geographic range. Given the ability of pocket gophers to adapt to pastures and fields in perennial crops such as alfalfa and to golf courses, T. b. ingens was dropped from active consideration.

Honey Lake Pocket Gopher

Thomomys townsendii relictus occurs only in a small area in the vicinity of Honey Lake in the western part of Honey Lake Valley, Lassen Co. (Hall, 1981). Its geographic range extends from near Susanville in the northwest to near Amedee in the northeast and Doyle in the south (Thaeler, 1968). Within this area, Honey Lake Pocket Gophers are confined to deep soils of lacustrine origin. They are found in moist meadows along the western edge of the Honey Lake Valley and range into the more arid grasslands in the eastern part of the valley, where their range appears to be coincident with the distribution of saltgrass (Distichlis; Thaeler (1968)). Soil type may be the primary limiting factor for this gopher. Although much of the Honey Lake Valley is under cultivation or in irrigated pasture, Honey Lake

Pocket Gophers appear to be common and not threatened by developments in the region (J. L. Patton, pers. comm.).

San Joaquin Pocket Mouse

Perognathus inornatus inornatus occurs along the eastern side of the San Joaquin Valley and possibly in the Sacramento Valley (unpubl. data). The boundaries between the geographic ranges of P. i. inornatus, with 50 chromosomes, P. i. neglectus, with 56 chromosomes (Williams, 1978), and the population from the Sacramento Valley (a single specimen from Lake Co. had 60 chromosomes; unpubl. data) are not well documented. Taxonomic problems in this species complex have complicated the resolution of its populations status further. Typical San Joaquin Pocket Mice from the eastern edge of the San Joaquin valley have been found in areas with friable soils in grasslands and Blue Oak savannas, from near sea level to about 1500 ft in elevation. Some of the oldest and largest collections, made near the beginning of the century (unpubl. data) were from areas of wind-drifted sand, a habitat that has essentially disappeared due to cultivation and urbanization. This species was listed in the Third Priority on the draft List of Concern, based primarily on the extensive loss of habitat in the San Joaquin Valley. Reflection has resulted in removing it from the List of Concern, although it should be treated as a sensitive species until information is available to resolve its population and systematic status.

McKittrick Pocket Mouse

Perognathus inornatus neglectus occurs along the western side of the San Joaquin Valley, in the Mojave Desert, on the Carrizo Plain, and in the upper Salinas Valley (unpubl. data). Its distributional limits and relationships to P. i. inornatus, P. i. psammophilus, and the inornatus group pocket mice from the Sacramento Valley are unclear. McKittrick pocket mice have been taken on a variety of soil types in desert shrub associations supporting Atriplex spp., Ephedra californica, and annual herbaceous plants such as Bromus spp. and Erodium. Most of the available habitat for this pocket mouse is located on the sloping, western margin of the San Joaquin Valley and the adjacent, rugged hills. McKittrick pocket mice seem to be uncommon, or at least only locally common, but probably are not under serious threats now.

Arroyo Seco Pocket Mouse

Perognathus inornatus sillimani was described by von Bloeker (1937); he also described the Salinas pocket mouse (Perognathus longimembris psammophilus) at the same time. The type series of both taxa were collected from the same locality. I have examined all of the available specimens of both species. The specimens of P. i. psammophilus were all subadults and the specimens von Bloeker (1937) called P. i. sillimani were all adults. The two taxa are based upon different age groups of the same population, which is allied with the inornatus species complex, not P. longimembris. The Arroyo Seco Pocket Mouse is, therefore, a junior synonym of Perognathus inornatus psammophilus. The latter name has priority because of pgs precedence in the publication describing both taxa (see account of P. i. psammophilus).

Yellow-eared Pocket Mouse

Perognathus parvus xanthonotus is known from the southeastern slopes of the Tehachapi Mountains in the vicinities of Freeman (Walker Pass), Horse, Indian Wells, and Sage canyons in Kern Co. (unpubl. data). Yellow-eared Pocket Mice are associated primarily with arid desert shrub and Joshua Tree communities and in ecotonal areas supporting a sparse cover of Pinyon Pine trees. Altitudes recorded for specimens range from about 4000 to 5300 ft. The Yellow-eared pocket mouse was treated as a separate species from P. parvus by Hall (1981). Its karyotype and aspects of its structure are indistinguishable from most members of the parvus species group (Williams, 1978), and I see no reason to treat it as a separate species. The U.S. Bureau of Land Management designated the Yellow-eared Pocket Mouse as a Sensitive Species in the California Desert Conservation Area Plan. There are no known or projected developments that would jeopardize this taxon, despite its apparent restricted, geographic range and narrow altitudinal distribution.

Sierra Valley Kangaroo Mouse

In California, Microdipodops megacephalus californicus is known only from the type locality in the Sierra Valley, Plumas Co. (Hall, 1981). Although found on substrates of gravelly texture, they are most often associated with sandy soils. The restricted distribution of M. m. californicus was the primary reason for including it on the working list. There is no information on its current status.

Pale Kangaroo Mouse

Microdipodops pallidus pallidus occurs in California as two disjunct populations: one in the Fish Lake Valley, near Oasis, Mono Co., and one in the Deep Springs Valley, Inyo Co. Inhabited areas in California are steppe-desert associations on fine, sandy soils from about 5000 to 5500 ft in elevation (Grinnell, 1933). I found no information on the current population status of M. p. pallidus. Most of the land supporting both population is either privately owned or is public land outside specified multiple-use classes of the U.S. Bureau of Land Management California Desert Conservation Area Plan. Future developments in these areas would pose threats to the only known populations of M. pallidus in California, although I am not aware of any planned developments. During a one-day visit to the area in 1982, I found no evidence that the populations are under serious threats.

Point Conception Kangaroo Rat

Dipodomys agilis fuscus was placed on the working list because of its apparently restricted distribution. It is known only from the vicinity of Point Conception, Santa Barbara Co., in coastal chaparral communities (Boulware, 1943). Best (1983) could find no characteristics separating the more widely distributed subspecies, D. a. perplexus, from fuscus. I believe detailed studies will show the populations are in contact and do not warrant taxonomic recognition as separate subspecies. This is the primary reason for not ranking this kangaroo rat in a priority category.

Lesser California Kangaroo Rat

Dipodomys californicus eximius is found only in the vicinity of Marysville Buttes in Sutter Co. According to Grinnell and Linsdale (1929), eximius differs from the wider-ranging subspecies, D. c. saxitilis, only in its paler coloration. Neither subspecies was numerous at the time Grinnell and Linsdale (1929) investigated their status. D. c. saxitilis apparently was limited to foothill communities just above the edge of the valley floor, in sites on slopes with soils that remained "well-drained through the wet winter months" (Grinnell and Linsdale, 1929). Presumably, the Lesser California Kangaroo Rat has similar requirements. According to Blair Cauti (pers. comm.), eximius had not been collected for several years. It was included on the working list, but was dropped after review of information on its taxonomic status suggested that there was little justification for recognizing the wider-ranging D. c. saxitilis as a subspecies separate from eximius. Current information on its population status and a review of the taxonomy of D. californicus is needed. The Lesser California Kangaroo Rat should be considered vulnerable and treated as a sensitive species until its status is determined.

Big-eared Kangaroo Rat

Published information on the distribution of Dipodomys elephantinus suggests that its range is limited to the southern portion of the Gabilan Mountains in San Benito Co., in the vicinity of Pinnacles National Monument (Grinnell, 1922; Hall, 1981). The Big-eared Kangaroo Rat was included on the working list because of its small geographic range and because it was listed by the International Union for Conservation of Nature Red Data Book. Also, it was listed as a Category 2 species by the U.S. Department of the Interior (1982). I collected kangaroo rats with diagnostic characteristics of D. elephantinus in chaparral communities in Del Puerto Canyon in western Stanislaus Co., and from Clear Creek in the southern Diablo Range, San Benito Co. An additional specimen in the Collections at Fresno State University, from near the border of Fresno and San Benito counties is of this species. I found no justification for recognizing elephantinus as a species separate from D. venustus (Narrow-faced Kangaroo Rat) or to be concerned about its population status. Troy Beat (pers. comm.) is presently studying the relationships between D. venustus and elephantinus.

Berkeley Kangaroo Rat

Published records of occurrence of Dipodomys heermanni berkeleyensis are from the Berkeley Hills, Mount Diablo, and the Livermore Valley (Hall, 1981). Berkeley Kangaroo Rats probably occupy suitable habitat throughout the mountain ranges east of San Francisco Bay and west of the San Joaquin Valley. Habitat for Berkeley Kangaroo Rats, in so far as is known, consists of open, grassy hilltops (Grinnell, 1933) and open spaces in chaparral and Blue Oak/Digger Pine woodlands (unpubl. data). Habitat for Berkeley Kangaroo Rats has been reduced significantly in the hills and valleys north of Livermore, and this gives some cause for concern about its status. However, D. heermanni with characteristics attributed to D. h. berkeleyensis (Grinnell, 1922) are fairly common on the east flank of the Diablo Range in Del Puerto Canyon, Stanislaus Co., and Corral Hollow, Alameda Co. (unpubl. data). The limits of the geographic range of D. h.

berkeleyensis and its relationships to D. h. tularensis (Tulare Kangaroo Rat) need to be reviewed in order to clarify their distributional and population status.

Merced Kangaroo Rat

Dipodomys heermanni dixonii is known from eastern Merced and Stanislaus counties (Hall, 1981) in grassland and savanna communities. It was included on the working list because of its limited distribution and the rapid rate of conversion of native plant communities to irrigated fields in this portion of the San Joaquin Valley. Thousands of acres of land in eastern Stanislaus and Merced counties, considered safe from cultivation six years ago has since been converted to orchards and vineyards. No additional information on its population status has been located, but threats to its population from continuing loss of habitat seem great enough to warrant treating it as sensitive until its status is clarified.

Argus Mountain Kangaroo Rat

Dipodomys panamintinus argusensis occurs only in the Argus Mountain Range in Inyo County (Hall, 1981). Its population is isolated from others of D. panamintinus. Nothing specific is recorded of its habitat associations, but, in general, Panamint Kangaroo Rats occur in arid, mountain steppe communities vegetated with Yucca, Pinyon Pine, Juniper, and Big Sagebrush. They appear to be most common on coarse-textured soils on sloping ground (Johnson et al., 1948). This taxon was included on the working list because it was designated as a Sensitive Species in the U.S. Bureau of Land Management California Desert Conservation Area Plan. A portion of the Argus Mountains lies within the China Lake Naval Weapons Center. Nearly all of the rest of the Argus Range is public land administered by the U.S. Bureau of Land Management. This land is designated as Class L (limited use), which means use is limited to livestock grazing, mining, and other activities that are unlikely to jeopardize the population of kangaroo rats. There is no known reason for granting special consideration to this population.

Panamint Kangaroo Rat

Dipodomys panamintinus panamintinus occupies the Panamint Range in Inyo Co., between about 4600 and 7000 ft. Distributional records include several specimens from around Jackass Spring, the head of Willow Creek, 1 mi s. of Lee Pump, and South Park Meadow (Johnson et al., 1948; Hall, 1981). Habitat for D. p. panamintinus is probably similar to other populations of this species (see above). It was included on the working list because it was designated as a Sensitive Species in the U.S. Bureau of Land Management California Desert Conservation Area Plan. Panamint Kangaroo Rats were fairly common in Pinyon-Juniper communities around Jackass Spring during field work in 1974 (unpubl. data). Most of the Panamint Mountains lie within Death Valley National Monument and are inaccessible to off-road vehicles and protected from most forms of development. Other portions of the geographic range of the Panamint Kangaroo Rat are public lands designated for limited use (Class L) by the U.S. Bureau of Land Management. There is no known evidence of threats to the Panamint Kangaroo Rat.

Santa Cruz Kangaroo Rat

The geographic range of Dipodomys venustus venustus extends from the Santa Cruz Mountains eastward to Mount Hamilton in the Diablo Range, and southward to Freemont Peak in the northern end of the Cabilan Range (Grinnell, 1922; Hall, 1981). Kangaroo rats of this group are also known from the Diablo Range in western Stanislaus Co., and from the southern Diablo Range in San Benito and Fresno counties (unpubl. data; see account of the Big-eared Kangaroo Rat). Some populations of Dipodomys venustus are found on slopes with a heavy cover of chaparral (Grinnell, 1933). Haubecker (1940) found burrows of Santa Cruz Kangaroo Rats on sand, sandy loam, and loam soils, but never in soils of "heavy" texture. He trapped Santa Cruz Kangaroo Rats in two abandoned agricultural fields which had supported chaparral originally (Chamise, Black Sage, Manzanita, Buck Brush, and Coyote Brush) and conifer forest (Coast Redwood, Douglas Fir, Madrone, and Tanoak). He speculated that they also inhabited the areas with chaparral, as he trapped Santa Cruz Kangaroo Rats at the edge of chaparral. Animals I have captured in the Diablo Range were taken in chaparral (unpubl. data). In the Santa Cruz Mountains, known collecting localities have sandy soils. Available evidence suggests a severe decline in populations of Santa Cruz Kangaroo Rats in the Santa Cruz Mountains. Michael Marangio (in litt.) reported that his searches at several sites failed to uncover evidence of extant colonies. Increasing density of residential housing and the domestic and feral house cats may be factors in extirpating some populations. Quarrying of sand has probably led to extirpation of others (M. Marangio, in litt.). I have not included the Santa Cruz Kangaroo Rat on the List of Concern because I could find no threats to populations in most portions of the Diablo Range; however, measures to locate and protect populations in the Santa Cruz Mountains should be considered.

Sonora Beaver

Castor canadensis repentinus was originally found along the Colorado River in California. In 1911, upon completion of construction of irrigation and drainage canals between the Colorado River and the Imperial Valley, Sonora Beavers colonized portions of the Imperial Valley (Grinnell et al., 1937). They inhabit slow- to moderate-flowing waters of the main channels of the Colorado River and canals, sloughs, and oxbow lakes. Where the water is shallow and the banks are of rock, lodges are constructed. Elsewhere, however, beavers place nests in burrows in banks and levees. Dams are constructed where waters are shallow, but are uncommon along the Colorado River (Tappe, 1942). Sonora Beavers eat bark and twigs of Willows, Mesquite, Cottonwood, and other woody plants, and Cattails, grasses, Arrow Weed, and other herbaceous plants. The Sonora Beaver was included on the draft List of Concern in a Fourth Priority category for sensitive species, and is currently designated as a furbearer and may be trapped in California. Dixon (1922) estimated that 100 Sonora Beavers lived in the Imperial Valley in 1921. Trapping and water shortage caused a subsequent decrease in the population, and by 1940, Tappe (1942) estimated that there were only 32 left in the Imperial Valley, mostly living along the lower portion of the Alamo River. Tappe found a total of 13 Sonora Beavers in canals and sloughs in the Palo Verde Valley and 272 along the Colorado River (129 on the California side). The present status of the Sonora Beaver population is unknown. Loss of riparian habitat

along the Colorado River has been extensive since the 1940's. River channelization, phreatophyte control, and lining of canals and drains with concrete are probably the most troublesome factors affecting Sonora Beavers. No Sonora Beavers were taken by animal damage-control agents of the U.S. Fish and Wildlife Service in Imperial, Riverside, or San Bernardino counties between 1969 and 1976 (Lee, 1977). A single beaver was reported as taken by a fur trapper in Imperial Co. during the 1975-76 season (Lee, 1977). Periodic contamination of the Alamo River in the Imperial Valley by raw sewage from Mexicali, Mexico, may threaten any remaining Sonora Beavers living there. The Sonora Beaver should be considered as a sensitive species and its status determined.

Golden Beaver

Castor canadensis subauratus was originally found throughout the lower courses of the San Joaquin and Sacramento river systems, including the streams draining into Tulare and Buena Vista lakes. Altitudinal range was from sea level up to about 1000 ft. Golden Beavers probably did not occupy the upper segments of streams of the western Sierra Nevada (Grinnell, 1933), although they have been introduced there at numerous sites (in the 1940's alone, there were 172 different transplants of Golden Beavers). Golden Beavers inhabit slow- to moderate-flowing streams, ponds, and lakes. The main requirement seems to be sufficient food, which consists of roots, bulbs, grasses, Cattails, and other herbaceous plants, and bark and twigs of Willows, Cottonwoods, Alders, and other woody plants (Grinnell et al., 1937). Golden Beavers usually dig burrows in banks of streams and levees, and less frequently construct dams and lodges. The Golden Beaver was included on the draft List of Concern as a sensitive species (Fourth Priority group). Golden Beavers were nearly exterminated by unregulated harvest prior to 1911, when legislation was passed in California to protect Beavers fully. The populations responded to protection by increasing to densities to where trapping was allowed again in 1925. Controls were ineffective against illegal trapping and full protection was extended again in 1933. In 1957, beavers were classified as a furbearer and a season for harvest was designated. No bag limit on the number taken has been in effect since 1957 (Tappe, 1942; Lee, 1977). The history of the harvest of beavers in California suggests that most populations have been fairly stable over the 25 to 30 years prior to 1977 (Lee, 1977). Also apparent from fur trappers' reports is an upward trend in numbers of persons purchasing trapping licenses in the past decade and the increasing prices being paid for furs (California Dept. Fish and Game, unpubl. Licensed Fur Trappers Report, 1976-77). Pelts of beavers did not increase in average price paid, however. In any case, beavers are highly vulnerable to trapping and any market trends or socio-economic factors causing increased trapping pressure could result in a rapid population decline. Alteration of aquatic habitats, including decreased stream flow, increased pollution, channelization of streams, stream-side brush clearing, and regulation of stream flow, also could affect beaver populations adversely. The Golden Beaver should be treated as a sensitive species. Close monitoring of populations of Golden Beavers, including regular field surveys, is recommended. Decisions on trapping regulations should not be made solely on data from reports of licensed trappers, as many trappers fail to report their take (44% of the licensees in 1976-77 did not file reports), and there is no assurance that data based upon such reports are accurate.

Santa Catalina Harvest Mouse

Reithrodontomys megalotis catalinae is found only on Santa Catalina Island, Los Angeles Co. It was included on the original working List of Concern in the Third Priority category because of its insular distribution and because no information was available on its status or habitat requirements (Howell, 1914; von Bloeker, 1967). During field work on Santa Catalina Island during January, 1983 (Williams, 1983), Santa Catalina Harvest Mice were found in all plant communities and were fairly common. There are no known threats to R. m. catalinae.

Salinas Harvest Mouse

Reithrodontomys megalotis distichlis occurs in the region of Monterey Bay (Hall, 1981), in fresh and brackish water wetlands and probably in adjacent upland grasslands. It was included on the working list because of its restricted distribution and the high rate of urbanization in that area. Most of the wetland communities where these mice live are under protection. There is no evidence that they are threatened.

Santa Cruz Harvest Mouse

Santa Cruz Island, Santa Barbara Co., is home to Reithrodontomys megalotis santacruzae (Pearson, 1951). Pearson (1951) noted that Santa Cruz Harvest Mice were found only in a small, grassy area adjacent to a small, fresh-water marsh of Scirpus, Typha, and Salix. He remarked that this habitat was rare, perhaps not found elsewhere on the island, and that Santa Cruz Harvest Mice were probably limited to that one spot on the island. R. m. santacruzae was included on the draft List of Concern in the Highest Priority because of its apparent restricted habitat, Pearson's (1951) belief that the total insular population was very small, and the damage to plant communities on the island by introduced ungulates. Laughlin (1973) Pearson (1951), and von Bloeker (1967) collectively listed Cattle, Pigs, Sheep, Wapiti (Cervus elaphus), Mule Deer, and Roe Deer (Capreolus pygmaeus = C. capreolus) as introduced mammals to the island. R. m. santacruzae was removed from the final List of Concern because field studies by Bills (1969) found that Santa Cruz Island Harvest Mice were widely distributed on the island, and because the island has recently come under the management of The Nature Conservancy. The current population status of the Santa Cruz Harvest mouse is unknown, but the balance of available information suggests no reason for including it on the final List of Concern. Studies to determine its population status and the nature of any existing threats should be undertaken.

Anacapa Island Deer Mouse

Peromyscus maniculatus anacapae is found on East, Middle, and West Anacapa islands, Ventura Co. (von Bloeker, 1942). Anacapa deer mice live in all terrestrial habitats on the islands and also use the intertidal zone for foraging (Grinnell, 1933; P. W. Collins, in litt.). P. m. anacapae was included on the draft List of Concern as a sensitive species (Priority Four) on the basis of evidence furnished by Paul W. Collins (in litt.). According to Collins (in litt.; unpubl. U.S. Natl. Park Serv. Rept.), Anacapa Deer Mice were restricted to grassland habitats on the islands because of competition with black rats (Rattus rattus). He estimated that

populations were eliminated from 75% of the available habitat. The population on East Anacapa Island was affected most severely. The U.S. National Park Service (Dept. of the Interior) has administrative authority for the Anacapa Islands, which are part of the Channel Islands National Monument. The Anacapa Deer Mouse was not included in a higher-priority category because the National Park Service is aware of the situation and has presumably taken measures to reduce or eliminate black rats from the islands. P. m. anacapae should be treated as a sensitive species and its population status should be monitored.

Santa Catalina Deer Mouse

Peromyscus maniculatus catalinae is confined to Santa Catalina Island, Los Angeles Co., where it inhabits most terrestrial plant communities (von Bloeker, 1967). It was placed on the working list because of its insular distribution, the general degradation of the island by introduced ungulates, possible predation by feral cats which occur in high density on the island (Laughlin, 1973), and possible competition with introduced black rats and house mice (Mus musculus; von Bloeker, 1967). It was not assigned to a priority category on the final List of Concern because during field work on the island in January, 1983, Santa Catalina Deer Mice were found to be fairly common and under no threats (Williams, 1983).

Western Cotton Rat

According to Hall (1981), Sigmodon hispidus eremicus is confined to the region along the lower Colorado River in California. Western Cotton Rats also occur in the Imperial Valley, having immigrated there shortly after completion of the canal from the Colorado River to the Imperial Valley (Dixon, 1922). Western Cotton Rats inhabit wetlands and upland habitats with dense grass and other herbaceous plants. In times of population irruptions, they may be found far from wetlands in a variety of plant communities atypical of their usual habitat (unpubl. data). S. h. eremicus was placed on the working list because of its restricted distribution in an area known to have been significantly altered by human developments. Brad Blood (in litt.) found Colorado River Cotton Rats to be fairly common during field studies in 1979 and 1980. Although not widespread, they are probably not jeopardized.

Colorado Valley Woodrat

In California, Neotoma albigula venusta is found in the low-lying desert areas of Imperial, San Diego, and Riverside counties (Grinnell, 1933; Hall, 1981). It is closely associated with patches of Beaver-tail Cacti (Opuntia spp.) and Mesquite. N. a. venusta was included on the working list, but no evidence indicating that it was threatened was found.

Monterey Vole

According to von Bloeker (1937), who named Microtus californicus halophilus, it is confined to saltwater wetlands around Moss Landing and Seaside, Monterey Co. Although not placed on the original working list, the status of this vole has been questioned since. My impression is that California Voles (including the Monterey Vole) are common in both marshes and in adjoining upland grasslands, vineyards, and weedy fields. They

appear to range widely, especially in the winter months. Although Monterey Voles are recorded from only a restricted area, they are probably more widely distributed. Most wetlands within its range are protected.

Mohave River Vole

Microtus californicus mohavensis is known to occur only along the Mohave River in the vicinity of Victorville and Oro Grande, San Bernardino Co. (Grinnell, 1933). Although on the working list, no information on recent occurrence was found. The desert region in the vicinity of Victorville is undergoing a human population explosion that could threaten many native species. A brief visit to the area in 1983 did not provide time to search for evidence of voles, but habitat suitable for this species (weedy herbaceous growth in wet areas along the river) was noted at several sites between Hesperia and Victorville. Also, some irrigated land in pasture and alfalfa could provide additional habitat for the Mojave River Vole. M. c. mohavensis should be treated as a sensitive species until its population status is determined.

San Pablo Vole

Microtus californicus sanpabloensis is known from the salt marshes of San Pablo Creek, Contra Costa Co., on the south shore of San Pablo Bay (Hall, 1981). M. c. sanpabloensis was not included on the original working list but is included here because of subsequent questions about its status. The decision not to give this and other populations of California Voles with restricted distributions greater consideration was based upon the fact that California Voles live in a wide variety of grassland associations, especially in the wet months when there is an abundance of green, herbaceous plants. Extirpation of a small population at one site is likely to soon be offset by immigration from populations occupying other sites nearby. Field work in San Pablo and Suisun Bays on the opposite shore from where the San Pablo Vole lives, found California Voles to have withstood episodes of record flooding during the winter of 1982-83 (Williams, 1983). Foreman (fide T. Rado, pers. comm.) determined the distribution and status of M. c. sanpabloensis during 1985. On the basis of his findings, priority listing is not warranted.

South Coast Marsh Vole

Populations of Microtus californicus stephensi are recorded from tidal marshes at Point Mugo, Orange Co., and Playa del Rey and Sunset Beach, Los Angeles Co. (Hall, 1981). M. c. stephensi was not included on the original working list for the reasons stated for M. c. sanpabloensis. No information on the current status of M. c. stephensi is available. Human developments in the region may have more severely restricted voles to the extant marshes, and catastrophic episodes of flooding or epidemics may pose a greater threat of extinction to this subspecies than to California Voles elsewhere. M. c. stephensi should be treated as a sensitive species until its status is determined and threats to its population identified.

Owens Valley Vole

Microtus californicus vallicola has been recorded from several sites in the Owens Valley, Inyo Co., from near the head of Willow Creek in the

Panamint Mountains, Inyo Co., and from near Benton, Mono Co. According to Grinnell (1933), Owens Valley Voles inhabit wetlands and "lushly grassy ground." M. c. vallicola was placed on the original working list, but soon was dropped from further consideration. M. c. vallicola was listed as a Category 2 species by the U.S. Dept. of Interior (1982). Even though water diverted from the Owens Valley to the Los Angeles Basin has had significant environmental impact within the range of this subspecies, considerable habitat, including irrigated pastures and alfalfa fields still remain. There is no evidence to support listing this species in a priority category or as sensitive.

San Bernardino Vole

Microtus longicaudus bernardinus has been recorded from the higher elevations, above about 7500 ft, in the San Bernardino Mountains (Hall, 1981). According to Grinnell (1933), it inhabits streamside and wet mountain meadows. M. l. bernardinus was included on the original working list but was dropped later. Subsequently, in summer of 1982, extensive trapping for shrews, conducted by Steve Clifton and me, produced a number of voles from the San Bernardino Mountains. None were found that could be distinguished from M. californicus, a wide-spread species at lower elevations in southern California. In my opinion, M. l. bernardinus is probably a subspecies of californicus, but the taxonomic studies are incomplete. Regardless, these voles are not threatened.

Ringtail

Bassariscus astutus is found throughout most of California, from below sea level to at least 8000 ft in the Sierra Nevada (Hall, 1981). Its principal habitat requirements seem to be den sites among boulders or in hollows in trees and sufficient food in the form of rodents and other small animals. I included two of the four subspecies occurring in California (B. a. octavus, B. a. raptor) on the working list. The status of a third subspecies (B. a. willetti) was also questioned since development of the draft report. Certainly, urbanization in the Southern California coastal basins and in the San Francisco Bay area, and loss and degradation of riparian communities throughout California have depleted and extirpated some populations, but there is no evidence of threats to any of the subspecies over a broad area. Ringtails are protected from taking by state regulations.

Humboldt Marten

Martes americana humboldtensis occurs in California in the coastal conifer forests from Sonoma Co., northward into Oregon. The altitudinal range is from near sea level to over 4000 ft (Grinnell et al., 1937; unpubl. data). Grinnell et al. (1937) remarked that Humboldt Martens were sparsely distributed within this region, although the evidence they reviewed suggested that it was more widely distributed and numerous at an earlier time. According to their report, Humboldt Martens mainly used ridgetops in spruce forests and were rare in redwood forest. Trappers they interviewed believed that squirrels (Tamiasciurus douglasii), mice, and birds were the major prey of Humboldt Martens. Information on the status of the Humboldt Marten was provided by Schempf and White (1977). Although there is no evidence that it is currently threatened, a number

of studies summarized by Strickland et al. (1982) have demonstrated that clear-cutting of forests is incompatible with Martens, whereas low-intensity fires and selective logging have less impact. Mature forest is essential habitat for Humboldt Martens, providing nesting sites in snags, hunting sites, overhead cover from predators, and preferred prey species. Martens are easily trapped and overharvesting is always a potential problem where trapping pressures are high. Even a short trapping period, early in the season, may not solve the problem of overharvest. Public agencies administering lands and resources within the range of the Humboldt Marten should treat it as a sensitive species requiring special consideration in land and resource management decisions.

Inyo Long-tailed Weasel

Mustela frenata inyoensis has been recorded from a few localities in the Owens Valley, in the vicinity of Lone Pine, Independence, and Alvord, Inyo Co. (Hall, 1981). Long-tailed Weasels occur throughout all of California except the southeastern deserts, south and east of Owens Valley. They are common wherever their favored prey, pocket gophers, voles and other rodents are plentiful, even in suburban areas where sufficient open space is available (unpubl. data). The Inyo Long-tailed Weasel was not included on the original working list, but is included here because questions about its status have been raised since. There are no known developments within the range of this subspecies that would pose serious threats to its population.

Pallid Bobcat

Felis rufus pallescens is found on the Modoc Plateau and adjacent areas of the Great Basin province of northeastern California in Lassen, Modoc, Shasta, and Siskiyou counties (Gould, 1977a; Hall, 1981). Bobcats live in most terrestrial communities, but are seldom found on open, flat grasslands and deserts or in areas densely populated by humans. Areas with broken, rocky terrain and/or dense brush are associated with high densities of Bobcats, and also support high densities of small mammals and lagomorphs, their favored prey (Grinnell et al., 1937). The Pallid Bobcat was included on the draft List of Concern as a sensitive species (Priority Four), primarily because of the high price offered for its pelt and evidence reviewed by Gould (1977a). Some of the following data apply to all Bobcats in California, but they illustrate recent trends affecting Pallid Bobcats. The reported annual take of Bobcats in California by fur trappers increased from 241 in 1966-67 to 3618 in 1976-77, a 15-fold increase. Average prices paid for Bobcat pelts increased from \$18.00 in 1966-67 to \$133.50 in 1975-76 (Lee, 1978). Prices paid for prime pelts of Pallid Bobcats were much higher than this average, the highest recorded by 1977 was \$405 (Gould, 1977a). Hunters also take substantial numbers of Bobcats each year. Gould (1977b) estimated that between 9600 and 11400 Bobcats were killed by hunters statewide during 1976. The U.S. Fish and Wildlife Service killed an additional 205 Bobcats in California for predator control. Gould (1977a) documented a probable decline in numbers of Pallid Bobcats between 1971 and 1976, listing increased fur trapping as the likely cause. A 4.5-fold increase in numbers taken by trappers in Lassen, Modoc, Shasta, and Siskiyou counties occurred between 1960-61 and 1975-76 (91 and 406). This probably represents only a fraction of the total take, because, according to Gould (1977a), considerable illegal

trapping and hunting occurs, both within and outside of season. Also, many trappers do not file reports, and hunters not marketing pelts are not required to report on taking Bobcats. Zezulak (1980) studied Pallid bobcats between 1976 and 1979, radio-collaring and determining movements and size of home range for 5 adult males, 5 adult females, and 5 juveniles. He also determined litter size for females over a 2-year period. He reported that trappers filing reports took 162 Pallid bobcats near his study area between 1976 and 1979. Zezulak (1980) concluded that because 75% of the animals trapped were less than 2-years old, the population was expanding in response to "moderately heavy" human-caused mortality. Another interpretation of these data are that increased mortality due to trappers and hunters caused the reduction in the average age of bobcats in the population, without speculating as to whether the population was stable, declining, or increasing in size. In any case, evidence available to Zezulak (1980) suggested that the population was not jeopardized by the level of pressure exerted by hunters and trappers during the period of his study. Present regulations and management practices should be changed to facilitate collection of reliable estimates on take by hunter, illegal trapping, and licensed trapping by persons who fail to submit reports on captures. Treating the Pallid Bobcat as a sensitive species, requiring periodic monitoring of its population status and special consideration in land management decisions, is recommended.

Northwestern White-tailed Deer

Odocoileus virginianus ochrourus were reported from localities in Lassen, Modoc, Mono, Shasta, and Siskiyou counties (Grinnell, 1933; Hall and Kelson, 1959). Little is known of the habitat of White-tailed Deer in California. Walsingham (1873) remarked that they occurred on the plains around the Klamath marshes in Oregon and in the upper Pit River drainage of Shasta Co., California. He stated that in east-central Oregon, near Bend, they frequented thick clumps of willows and other woody shrubs bordering streams and marshes. Walsingham (1873) noted that Mule Deer were abundant on hillsides and that White-tailed Deer occupied the floodplains. Cowan (1936) wrote that over much of their former range, this subspecies of White-tailed Deer occupied riparian and floodplain communities. Bailey (1936) reviewed field notes of early explorers and other sources and concluded that members of this subspecies lived mainly in thickets of willows and other woody plants along streams. He noted that sometimes they were found in the hills and attributed this to being crowded out of more favorable areas by settlers in the valleys. Fisher (in Grinnell et al., 1937) believed that White-tailed Deer in eastern Lassen County occupied a geographic range approximately corresponding to the average winter range of Mule Deer. O. v. ochrourus was included on the working list because of its disputed status. Adams (1963) reviewed evidence of White-tailed Deer in California and disputed its occurrence within the state in historic times. Adams' (1963) conclusion was based on two factors: the habitat in California was not like the habitat for this species in Montana; and a general lack of undisputed specimens known to him. He stated that the habitat for White-tailed Deer in northeastern California was "strikingly different from that of the whitetail habitat that . . . [he] had known in northwestern Montana." To reach his conclusion he had to discount one specimen of a White-tailed Deer from California that he could not dispute and ignore the account by Walsingham (1873), an international authority on the family Cervidae, of his travels

through northern California and his observations of White-tailed deer. He also discredited the writings of a number of other prominent naturalists (e.g., Bailey, 1936; Cowan, 1936; Dixon, 1927; and N. Hollister and C. H. Merriam in Adams, 1963) supporting the occurrence of White-tailed Deer in California. That few specimens from California were located by him is true, although there is no indication that Adams (1963) attempted to locate and examine a complete skin and partial skeleton (for a whole mount) donated to the Oakland Museum (Dixon, 1927). The lack of scientific specimens is not surprising in view of the lack or scarcity of specimens from California of other large mammals, such as the Bison, California Grizzly Bear, Gray Wolf, and Mexican Jaguar (Grinnell et al., 1937; Merriam, 1919, 1926). Geographic variation in habitat requirements was apparently unfamiliar to Adams, or at least that White-tailed Deer in California might differ in their use of habitat from those in Montana was a possibility that he did not accept. Arguing against his viewpoint is an extant population of Columbian White-tailed deer, in the vicinity of Roseburg, Oregon, less than 100 miles from the northern border of California. Its habitat is quite different from the riparian habitat along the Columbia River where the other population is found (Fisher et al., 1977; Suring and Vohs, 1979). In summary, the evidence strongly supports the occurrence of Northwestern White-tailed Deer in California. They were probably extirpated from California sometime between the 1930's and 1950's, mainly because of loss of habitat.

DISCUSSION

The major developments threatening mammalian species are virtually the same as identified in jeopardizing several species of birds in California (Remsen, 1978), with the loss and degradation of riparian woodlands and wetlands at the top of the list. Of the 36 species and subspecies on the List of Concern (Table 2), 15 are limited to or depend upon riparian and wetland communities, or are thought to be so dependent (Table 3). Four of these require habitat in riparian communities along the Colorado River: the Arizona Myotis, Arizona Cave Myotis, Colorado River Cotton Rat, and Yuma Mountain Lion. Three others require habitats in riparian and wetland communities on the floor of the San Joaquin Valley: the Buena Vista Lake Shrew, Riparian Brush Rabbit, and Riparian Woodrat. The Salt-marsh Wandering Shrew and Suisun Shrew occupy tidal marshes in San Francisco and San Pablo bays, respectively. The Southern California Salt-marsh Shrew and Southern Marsh Harvest Mouse live only in the tidal marshes along the southern California Coast. The Point Reyes Mountain Beaver and Point Reyes Jumping Mouse require wetland communities in the Point Reyes region, north of San Francisco Bay, and the Point Arena Mountain Beaver occupies wetlands in the vicinity of Point Arena, Mendocino Co. Additionally, Snowshoe Hares use riparian communities extensively, and the two on the List of Concern (Oregon Snowshoe Hare, Sierra Nevada Snowshoe Hare) require habitat in these communities.

Species of concern confined to lowland desert, grassland, and savanna communities of the southern California coastal basins include the Los Angeles Pocket Mouse and Pacific Pocket Mouse (Table 3). Also of concern in that region and elsewhere in the southern lowlands of California are the American Badger, California Leaf-nosed Bat, Big Free-tailed Bat, Pocketed Free-tailed Bat, and California Mastiff Bat. Loss of habitat probably is the principal factor jeopardizing these species.

Species jeopardized by loss of grassland and desert communities in the San Joaquin Valley and contiguous areas such as the Carrizo Plain are the Tipton Kangaroo Rat, Short-Nosed Kangaroo Rat, and populations of the American Badger. Loss and degradation of native communities in the San Joaquin Valley lowlands are especially serious problems. The importance of the San Joaquin Valley to populations of the California Mastiff Bat is unestablished, but it was probably a major area for foraging Mastiff Bats. No recent records of California Mastiff Bats are known from the San Joaquin Valley, although scanty data suggest they were more common into the 1950's or 1960's. In addition to the four species mentioned here and the three species requiring riparian and wetland communities listed above, four species of mammals with Rare and Endangered Status are confined to the region (San Joaquin Antelope Squirrel, Fresno Kangaroo Rat, Giant Kangaroo Rat, and San Joaquin Kit Fox; Table 1). There are also other endemic species and subspecies of mammals of the San Joaquin Valley, all of whose populations have been seriously reduced in size. Some, including the San Joaquin Pocket Mouse (Perognathus inornatus inornatus and P. i. neglectus) and Tulare Grasshopper Mouse (Onychomys torridus tularensis) also may be in danger, but available data suggest lesser threats to these species than those listed.

Loss and fragmentation of old-growth conifer forests pose threats to two

species on the list, the Red Tree Mouse and the Pacific Fisher. Too little is known about the distribution and habitat of the White Footed Vole to state with certainty, but it too may be jeopardized by current forest harvest practices. Insufficient information is available to identify species of bats that might be similarly jeopardized, although a number of species are distributed mainly in conifer forests and may be jeopardized by widespread loss of mature and old-growth forests.

Nine species of concern are presently classified as game or furbearing species: the Riparian Brush Rabbit and Yuma Mountain Lion in the highest priority; and the Pygmy Rabbit, Oregon Snowshoe Hare, Sierra Nevada Snowshoe Hare, Western White-tailed Hare, Pacific Fisher, American Badger, and Channel Islands Spotted Skunk in the third priority. Only the Pacific Fisher is currently protected from taking. The Yuma Mountain Lion is classified as a game species, although at present there is no open hunting season on Mountain Lions in California. Regardless of whether or not other populations of Mountain Lions in California are allowed to be hunted, those of the southeastern desert areas should continue to be fully protected. Killing and trapping are likely to be major threats only for the populations of the American Badger of concern. For the American Badger, the Riparian Brush Rabbit, and species of hares on the List of Concern, data sufficient to justify the seasons and bag limits must be gathered. Determining the status of, and the impacts of hunting on, these species should be high priorities of the Department of Fish and Game.

Emphasis in the species accounts has been given to determining the population status and potential threats to individual species. State and federal legal protection should be sought for those species for which information is adequate to establish their threatened or endangered status. While these activities will focus concern on individual species and provide a measure of protection for those found to require it, they are probably not the most efficient and cost-effective way to ensure their survival.

Preservation of the mammalian species of concern listed here, species already with state or federal threatened and endangered status, and species of birds, reptiles, plants, and other taxonomic groups can be best accomplished by concentrating conservation efforts on their biotic communities rather than emphasizing single-species management. This also would provide more security to members of their communities that are not normally accorded protected status, but which may be essential to the perpetuation of their communities (e.g., lower plants, fungi, invertebrates).

An integrated, intergovernmental development/conservation approach which focuses upon preserving representative segments of each unique biotic community while other resource- and land-use goals are being formulated is needed. This would lessen the need for listing of most of these species as threatened or endangered and probably save much of the money and duplication of efforts expended on management of threatened and endangered species on a one-by-one basis.

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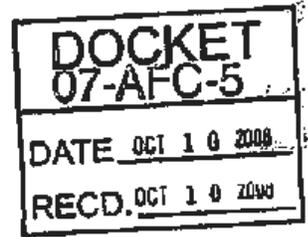
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APPENDIX

Acronyms for museums where research collections of specimens and other documentation of localities referred to in the lists of distribution records are listed below. Museum acronyms generally follow Choate and Genoways (1975).

AMNH	American Museum of Natural History, New York
ANSP	Philadelphia Academy of Natural Sciences
CAS	California Academy of Sciences, San Francisco
CM	Carnegie Museum of Natural History, Pittsburgh
CSCS	California State University, Stanislaus
CSLB	California State University, Long Beach
CSUC	California State University, Chico
CSUF	California State University, Fresno
CSUS	California State University, Sacramento
DFW	Sight records and uncataloged specimens, Daniel F. Williams
FMHN	Field Museum of Natural History, Chicago
HSU	Humboldt State University
KU	University of Kansas, Museum of Natural History
LACM	Natural History Museum of Los Angeles County
LSU	Louisiana State University
MCZ	Harvard University, Museum of Comparative Zoology
MSB	University of New Mexico, Museum of Southwestern Biology
MVZ	University of California, Berkeley, Museum of Vertebrate Zool.
PM	Paris Museum
ROM	Royal Ontario Museum, Toronto
SDSNH	San Diego Society of Natural History Museum
SFSU	San Francisco State University
TCWC	Texas A & M University, Texas Cooperative Wildlife Collections
UCLA	University of California, Los Angeles
UDAV	University of California, Davis, Museum of Zoology
UI	University of Illinois, Museum of Natural History
UMMZ	University of Michigan, Museum of Zoology
USNM	National Museum of Natural History, Washington, D.C.
WFBM	University of California Davis, Museum of Wildlife and Fisheries Biology

BEFORE THE CALIFORNIA ENERGY COMMISSION
STATE OF CALIFORNIA



In the Matter of:)
Application for Certification for the)
Ivanpah Solar Electric)
Generating System)
_____)

Docket No. 07-AFC-5

**STAFF RESPONSE TO APPLICANT'S PROPOSED SCHEDULE
AND REQUEST FOR REVISED SCHEDULING ORDER**

INTRODUCTION

On October 1, 2008, the applicant for the Ivanpah Solar Electric Generating System Project (ISEGS) filed a proposed schedule and a request for a revised scheduling order, or (alternatively) for a scheduling conference. The California Energy Commission committee responsible for this project subsequently issued an order for such a conference on October 15, 2008, and requested that parties respond to the applicant's proposed schedule by October 10, 2008.

During the past two weeks, Energy Commission staff has conferred with the staff of the U.S. Bureau of Land Management (BLM) to determine the feasibility of applicant's proposed schedule. Such collaboration is necessary because the Preliminary Staff Assessment (PSA) for this project is a "joint" document that will also serve as the Draft Environmental Impact Statement (DEIS) for BLM's right-of-way permit, the federal land permit required for ISEGS. The DEIS satisfies federal National Environmental Policy Act (NEPA) requirements for BLM's issuance of right-of-way permits. After conferring with BLM, Commission staff subsequently met with the applicant to discuss the proposed schedule.

APPLICANT'S PROPOSED SCHEDULE IS IMPRACTICAL

Prior to the outset of the ISEGS proceeding, BLM staff and Commission staff entered into a Memorandum of Understanding (MOU) regarding the joint production of the PSA/DEIS document and the Final Staff Assessment/DEIS document.¹ The goal of the MOU is to provide simultaneous and consistent state and federal environmental review.

¹ The MOU is titled "Memorandum of Understanding between the U.S. Department of the Interior, Bureau of Land Management California Desert District and the California Energy Commission Staff Concerning Joint Environmental Review for Solar Thermal Power Plant Projects." The MOU was signed by the Commission's Executive Director on August 8, 2007.

Proof of Service (Revised 7/14/06) filed with original.
Mailed from Sacramento on 10/10/08

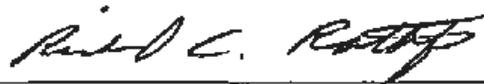
Among other things, the MOU provides that the two agencies will share in the preparation and review of the environmental analyses for solar thermal projects, and indicates that the environmental documents will serve the dual purpose of satisfying both state California Environmental Quality Act (CEQA) and federal NEPA requirements. (MOU, p. 4.) According to the MOU attachment titled "BLM & CEC Combined Processing Plan," the PSA/DEIS is to be issued during the same approximate time frame as the circulation (for federal NEPA purposes) of the DEIS. In the federal NEPA process, BLM must submit the DEIS to a "Notice of Availability" (NOA) review process by the Department of Interior before the DEIS can be noticed in the Federal Register and publicly released. The NOA review period can take several weeks before the DEIS is publicly issued and BLM's 90-day comment period on the document can begin. During the NOA review period the PSA/DEIS will be virtually complete, but not yet publicly released. Thus, there can be little further schedule progress during this period.

Applicant's proposal is to try to avoid the delay caused by the NOA review period by having Commission staff publish the PSA first (apparently captioned solely as the PSA) and initiating Staff workshops on the document during the NOA review period. However, BLM staff believe that such a shortcut is inconsistent with the MOU and with the agencies' agreement to release the PSA/DEIS as a joint document that meets federal NEPA requirements, including NOA review and Federal Register publication before its release. BLM believes that participation in workshops on what is in essence the DEIS, but before the DEIS is officially reviewed and published for federal purposes, violates federal requirements. BLM and Commission staff believe that any departure from the joint document, including during the NOA review period, is contrary to the MOU, and BLM staff further believes that such departure would require BLM to produce its own separate DEIS.

If the applicant's proposal is accepted, and BLM proceeds to divorce itself from the Commission process and produce its own DEIS without the Commission's PSA, this breakdown of the joint document collaboration will add many months to the schedule for federal approval. Thus, in an effort to gain some weeks, applicant's proposed schedule risks significant project delay from the breakdown of the state/federal agency collaboration. For these reasons, Commission staff opposes applicant's proposed schedule.

Dated: October 10, 2008

Respectfully submitted,



RICHARD C. RATLIFF
Staff Counsel IV

**BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE
STATE OF CALIFORNIA**

**APPLICATION FOR CERTIFICATION
FOR THE IVANPAH SOLAR ELECTRIC
GENERATING SYSTEM**

DOCKET NO. 07-AFC-5

**PROOF OF SERVICE
(Revised 7/14/08)**

INSTRUCTIONS: All parties shall 1) send an original signed document plus 12 copies OR 2) mail one original signed copy AND e-mail the document to the web address below, AND 3) all parties shall also send a printed OR electronic copy of the documents that shall include a proof of service declaration to each of the individuals on the proof of service:

CALIFORNIA ENERGY COMMISSION
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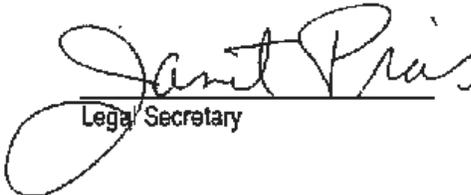
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I, Janet Preis, declare that on October 10, 2008, I deposited copies of the attached Staff Response to Applicant's Proposed Schedule and Request for Revised Scheduling Order in the United States mail at Sacramento with first-class postage thereon fully prepaid and addressed to those identified on the Proof of Service list above.

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Transmission via electronic mail was consistent with the requirements of California Code of Regulations, title 20, sections 1209, 1209.5, and 1210. All electronic copies were sent to all those identified on the Proof of Service list above.

I declare under penalty of perjury that the foregoing is true and correct.


Janet Preis
Legal Secretary



HOME FUNGAL DISEASE EDUCATION RESEARCH/SCHOLARSHIP CLINICAL TRIALS ABOUT NEWS/PRESS PARTNERS



Cocci is a fungus present in certain areas of the Western Hemisphere. You can get infected with Cocci if you live or travel to these areas. Read on to learn more about the infection or the fungus that causes it.

WHAT IS IT?

Overview

Coccidioidomycosis, (pronounced kok-SID-ee-ay-doh-my-KOH-sis), commonly called Valley Fever or Cocci, is a fungal disease caused by the *Coccidioides* (poy-deez) fungus. The Cocci fungus is endemic in the Southwest United States and the arid areas of Eastern Washington State, as shown in Figure 1. Outside of this region, this fungus is present in parts of Mexico and South and Central America. The areas where Cocci can be found seem to be expanding, potentially due to the temperature associated with climate change. Periods of drought can also increase the number of Cocci infections in the endemic region.

Figure 1. Areas where *Coccidioides* fungi can be found. Reproduced with permission from CDC and MSGERC.



Cocci is a growing problem. In 2019, there were 20,003 confirmed cases of Valley Fever reported in the United States. Most cases are diagnosed in people in Arizona or California. The number of cases is believed to be drastically underestimated because many people affected by the disease aren't diagnosed. Most people who experience Cocci will recover, but unlike symptoms associated with more common respiratory illnesses, the symptoms associated with Cocci may last six months on average, approximately 200 deaths a year are attributed to Cocci in the United States. This is also likely underreported. The economic impact of the disease is estimated to be more than 1.5 billion US dollars. For these reasons, improving awareness, diagnosis, and the management of Cocci will have a large public health impact.



Key Term:

Endemic means regularly occurring within an area or community.

What's in a Name?

You may hear Cocci referred to in several ways. For simplicity, on first mention we will use the technical term, then through the rest of the document we will use Cocci. Here are some of the other terms you may encounter that describe the disease or the fungus, along with a brief explanation of how those terms arose.

- **"Valley Fever"**—this is the term typically used to describe the fungal lung infection caused by Cocci. Sometimes it's used to describe other forms of the disease because the first cases described in the United States occurred in the San Joaquin Valley of California
- **"San Joaquin Valley Fever"**—another term that shows a geographical association
- **"Desert rheumatism"**—this name came about because Cocci is often present in the desert region. Rheumatism is added to "desert" because people get joint pain from the fungus because of their body's reaction to the fungus (inflammation)
- **"Cocci"**—this term is just a lot shorter and easier to say than *Coccidioides* or coccidioidomycosis
- **"Disseminated cocci"** or **"Disseminated Valley Fever"**—this term means that the disease has spread from the primary location (usually the lung) to other parts of the body
- **"Cocci Meningitis," "Valley Fever Meningitis,"** or **"CNS Cocci"** – these terms refer to disease that has invaded the brain or central nervous system



Science Sidebar:

Why is coccidioidomycosis such a long, difficult name? There is a reason. The people who first described Cocci saw a large structure in the tissue and thought it was a protozoan parasite similar to *Coccidia*. That's where the confusion arose and how the term *Coccidioides* (resembling *Coccidia*) arose. Later on, researchers were looking at the spherule phase of a fungal organism (more on that in the other Science Sidebar). In your reading, you may come across the term *Cocci*.

the gastrointestinal illness caused by *Coccidia*. It typically occurs in livestock. Don't get confused—these are different diseases. People with Valley Fever around chickens or other livestock.



Key Term:

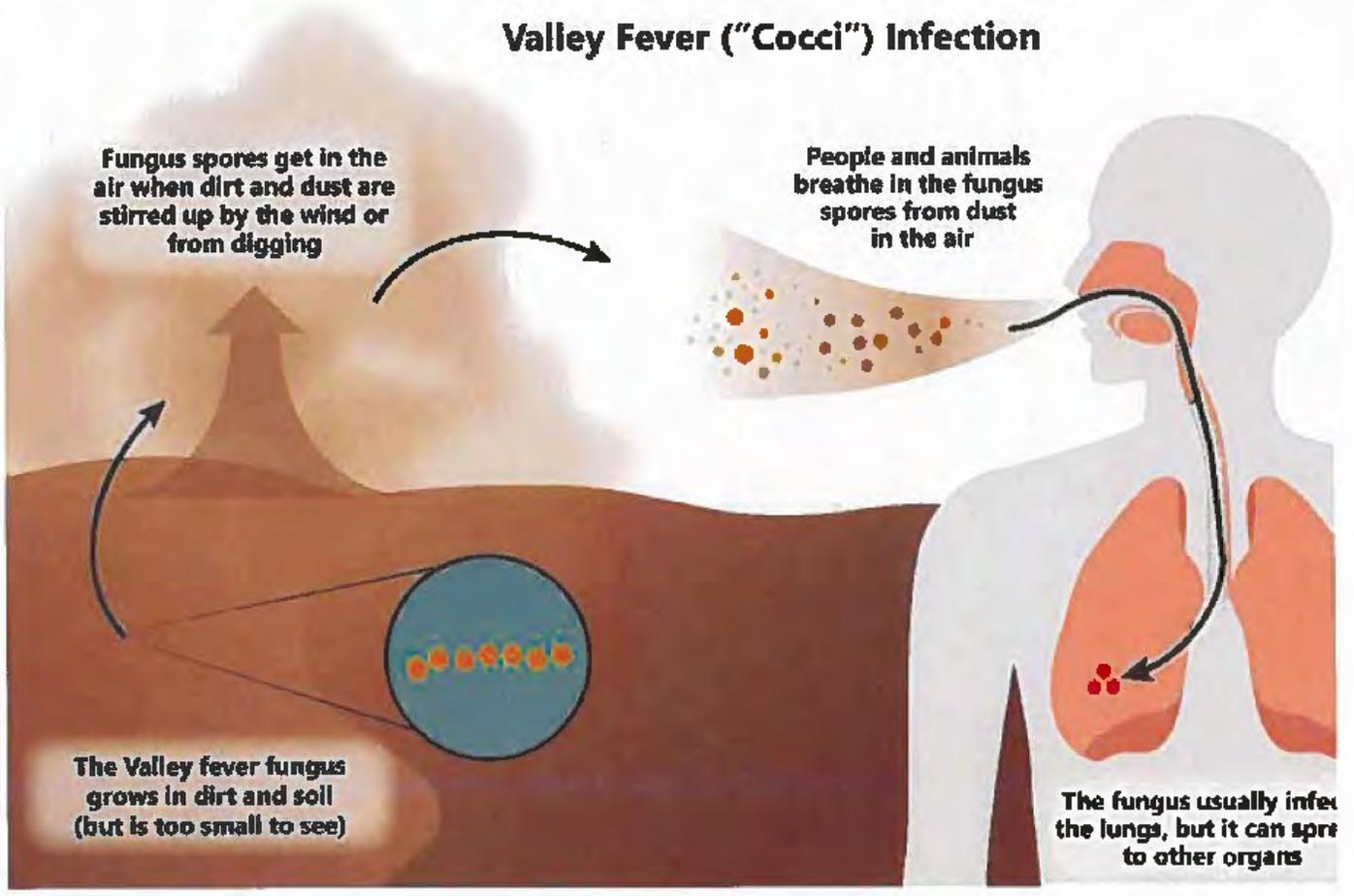
Protozoan is a single-cell animal of the family *Protista*, which includes the amoeba.

How Do You Get Infected?

From airborne spores

Coccidioides fungi live in the soil in what is called the mycelial phase (see SCIENCE SIDEBAR for detail) in environments that are dry (arid or semiarid). As the soil is disturbed—by human activities like excavation, animal activities, or weather events like earthquakes or fires—fungal arthrospores (we'll call them spores) are released into the air. These spores are not visible to the naked eye, and once in the air can travel 75 miles or more from where they became airborne. People can inhale these spores. Once inside the body, the fungus changes to a different form and grows into spherules, which eventually release new fungal cells and the process continues. This is the lifecycle of the fungus and the typical method of disease transmission.

Figure 2. Lifecycle of Cocci, showing the phases in the soil and in the mammalian host. Reproduced with permission Valley Fever Fact Sheet.



Through your skin

Less commonly, fungal spores can enter your skin through a cut, wound, or splinter and cause a skin infection. This is known as an implantation mycoses transmission is rare but has been documented in fieldworkers or people with traumatic injuries.

Frequently Asked Questions

Can Cocci be spread from person to person?

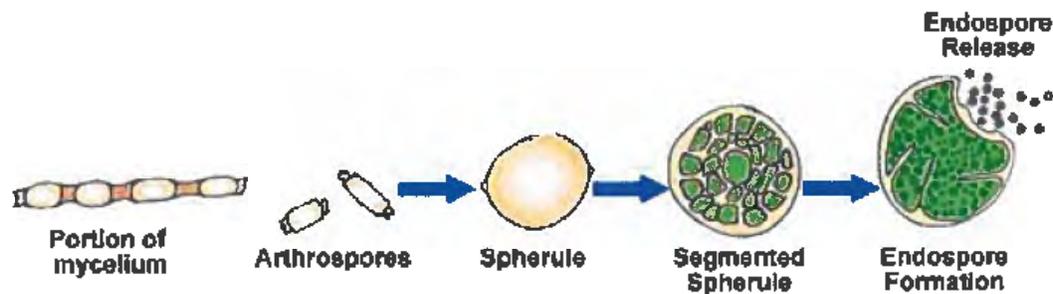
Key Terms:

Genus is a category of an organism that is "above" a species and "below" a family in the organism taxonomic (organizational) system.

Mycelium is a root like fungal structure with branching, thread-like filaments called hyphae.

Arthrospores are yeast-like individual fungal cells formed by the breaking down of hyphae.

Figure 3 Forms of Cocci during the different lifecycle stages. Modified from image provided by Saurabh Patil, via Wikimedia Commons.



Science Sidebar:

Coccidioides - the Shape Shifter

Coccidioides is a fungal **genus**. A genus is usually italicized and written with an initial capital letter. It is often written in connection with a specific species lowercase and is also italicized. Sometimes the genus is abbreviated to a 1 letter (eg, *C* for *Coccidioides*). Can you recognize this genus/species; *Homo sapiens*. The species of *Coccidioides* that cause disease are *Coccidioides immitis* and *Coccidioides posadasii*.

Coccidioides is described as a dimorphic fungus, which means it exists in two distinct forms as shown in Figure 3. It can exist as a **mycelium** (mold) commonly in the soil. When the soil dries out, hyphae develop into **arthrospores**. These arthrospores (spores) are small enough to become airborne and inhaled. Once a spore enters the lung, it undergoes a change to become a **spherule**, which is a big, sturdy sack-like structure. Inside the spherule, the spores become endospores, and fill up the sack. When the spherules rupture in a few weeks, the endospores are released and spread out (disseminate). They form new spherules, and the cycle continues.

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New Valley Fever Skin Test Shows Promise, But Obstacles Remain

KVPR | By **Kerry Klein**

Published November 21, 2016 at 12:51 PM PST



LISTEN • 5:55



Kerry Klein/KVPR

Eleven-year-old Faith Herrod, recovering from valley fever, plays with Moses, Ninja and her other four pets when she has the energy for it.

We continue our reporting this week on the fungal disease known as valley fever with a story about a potential route to prevention. One of the first lines of defense against the

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and a new skin test could be used to screen for that immunity—but that's only if the test overcomes some major hurdles.

Faith Herrod wants to be a veterinarian when she grows up. The 11-year-old lives in the small Central California town of Lemoore with her family, three dogs and three cats. Someday, she'll get a rabbit, too—as soon as her mother lets her.

In her free time, Faith should be out playing with her dogs. But for almost a year, she was not able to do so. She would come home from school at 4 p.m. and go right to bed. That's because last October the sixth-grader was diagnosed with valley fever, a fungal infection that kept her out of school for months and left her with regular headaches and chronic pain.

"Sometimes, when you get super tired, it'll feel like your ribs will go in," she said, wrapping her arms around her stomach. "It'll feel like your ribs go in and hurt really bad."

Faith contracted valley fever by breathing in fungal spores carried by the wind. That's how the disease is contracted, and it can happen at any time. Faith's mother, Caren Herrod, isn't entirely sure when it happened, but her best guess is while they were doing yard work one day—something they had done dozens of times before. Herrod never imagined that, after so much time, Faith would not have built up natural immunity and that she could still be at risk.

"If I had known that she was susceptible, it would've been different," Herrod said. "We would've done things differently."

As it turns out, Faith and her mother could have known. A new skin test called Spherusol can detect whether a person has developed natural immunity, meaning they've overcome valley fever before. Because most valley fever cases are asymptomatic, many people whose immune systems have battled the disease may never know it.

Advocates are excited about the test. So are doctors — like Dr. John Galgiani, director of the University of Arizona's Valley Fever Center for Excellence. He dreams of seeing Spherusol being used as a tool to screen for past infections.

"I think that Spherusol's best use will be in primary care doctors' offices to test their

Galgiani said. If patients knew they had never conquered valley fever, they could better prepare themselves against it; and doctors might be more likely to diagnose the disease if patients showed unusual symptoms.

Experts call for a change in FDA rules on promising test

But despite its promise, the test isn't in wide use.

"Frankly, I don't use it very often myself," Galgiani said. "Even specialists don't use it very often."

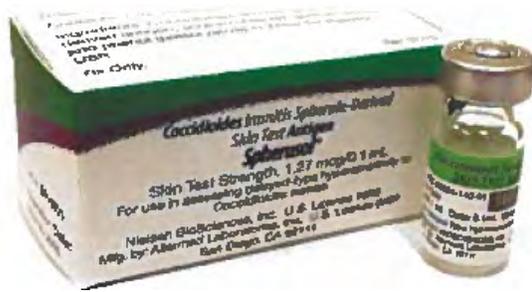
That's because the Food and Drug Administration hasn't approved Spherusol for testing immunity. Instead, the test is supposed to be used by clinicians only after a person has been diagnosed with the disease. Galgiani and others would like to see the FDA change the rules to allow its use whenever a clinician thinks a test is warranted.

"If the labeling is changed to allow the test to be used to test for prior infection, then it opens up a whole different value of the test to the clinical community," Galgiani said.

Valley fever lurks in dirt and dust in the desert throughout the Southwest. Most people who inhale the spores fight off the disease without ever knowing they had it. Some develop flu- or pneumonia-like symptoms. In rare cases, it can cause severe lung infection or disseminate throughout the body, requiring lifelong treatment or leading to fatal meningitis.

But there is some good news.

"Once you've had valley fever and gotten over it, you are for all practical purposes immune from a second infection," Galgiani said.



Credit Nielsen Biosciences

Spherusol comes in vials of 10 doses. A positive result indicates a previous bout with valley fever and an acquired immunity to the disease.

Revealing a disease exposure with a skin test

That's why Spherusol could have such an impact: It could reveal a person's history of exposure. Before, that was something most people could only wonder about.

Spherusol works similarly to a tuberculosis skin test. A clinician injects a small amount of spores under the skin, and the reaction indicates whether immunity has developed. Similar skin tests for valley fever were first developed in the 1930s, but the most recent iteration was discontinued in the 1990s after the company that produced it was unable to turn a profit.

Spherusol was released in 2014 and costs about \$62. No studies have directly compared its efficacy to previous tests.

Right now, Spherusol is only indicated for use after a patient has already been diagnosed with the disease. So, instead of being used as a way to determine valley fever exposure, it's considered a sort of immune system checkup for those recovering from the disease.

"It's indicated for understanding how their body is reacting to the disease," said Tom Carpenter, president and CEO of Nielsen Biosciences, the San Diego-based company that developed Spherusol. "Is their immune system engaged? Or is their immune

system overwhelmed? Or are they potentially immune-compromised and not even able to respond to the infection?"

Carpenter says that screening patients could be a great way to use the test, but getting the FDA to approve a change in the labeling could take years. It would involve new clinical trials and potentially millions of dollars of investment. He says his company is looking into it.

In the meantime, however, he points out that doctors are already allowed to use Spherusol for off-label uses.

"Health care providers right now have the ability to make a medical judgment on how best to use the skin test," Carpenter said. "So, it's certainly not preventing them from making that use, but we can't speak to that use."

But using Spherusol off-label has challenges —like its price tag. A single test may not break a budget, but regular valley fever screening would mean periodic trips to the doctor to pay \$62 for a prick under the skin. Most health insurers in California, including Medi-Cal, say they cover it — but only for its prescribed use. Even then, some insurers could reimburse as little as \$4. By contrast, a patient getting a flu shot would likely pay nothing, and the clinic would be reimbursed up to around \$35.

And then there's the fact that the test is packaged in bulk. Spherusol can only be bought in vials of 10 doses; once the vial is open, the countdown to expiration begins. Dr. Royce Johnson, chief of infectious disease at Kern Medical in Bakersfield, says the test is "extraordinarily stable." Even so, he said, many pharmacies have policies against storing products more than 30 days after they've been opened. "If you don't use it all, it costs a lot of money," Johnson said. "So there's some resistance to stocking it."

Another problem? Spherusol is only approved for 18- to 64-year-olds, even though children can be hit hard by valley fever and the CDC says people over 60 are most at risk.

Prisoners benefit from new test

Despite all of its obstacles, the test has been used to screen one very large patient group: California state prisoners, where it appears to be helping to prevent the disease

immunity to valley fever, are not sent to serve their terms in the two Central Valley prisons hit hardest by the disease.

Caren Herrod may wish that her daughter Faith had access to Spherusol a year ago, but she admits that still wouldn't have solved the root of the problem: that she didn't take valley fever seriously enough because so little information about it is available.

"It's so, so limited," Herrod said. "With a disease that is so prevalent, for there to be so little information, it's sad. It's very sad."

Meanwhile, Faith is back at school full-time, and hopes she can soon take her dogs Moses and Jasmine out for a walk.



This project results from a new venture – the Center for Health Journalism Collaborative – which currently involves the Bakersfield Californian, Radio Bilingüe in Fresno, Valley Public Radio in Fresno and Bakersfield, Vida en el Valle in Fresno, the Voice of OC in Santa Ana, the Arizona Daily Star in Tucson, La Estrella de Tucón and CenterforHealthJournalism.org. The collaborative is an initiative of the Center for Health Journalism at the University of Southern California's Annenberg School for Communication and Journalism.

Next in this series: Accurate valley fever counts elude health officials

Tags

- Health
- disease
- valley fever
- lemoore
- health
- centers for disease control and prevention
- valley fever center for excellence





Kerry Klein

Kerry Klein is an award-winning reporter whose coverage of public health, air pollution, drinking water access and wildfires in the San Joaquin Valley has been featured on NPR, KQED, Science Friday and Kaiser Health News. Her work has earned numerous regional Edward R. Murrow and Golden Mike Awards and has been recognized by the Association of Health Care Journalists and Society of Environmental Journalists. Her podcast Escape From Mammoth Pool was named a podcast "listeners couldn't get enough of in 2021" by the radio aggregator NPR One.

[See stories by Kerry Klein](#)

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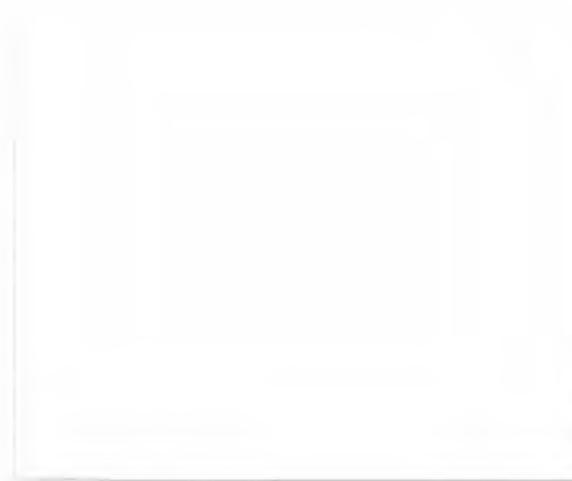
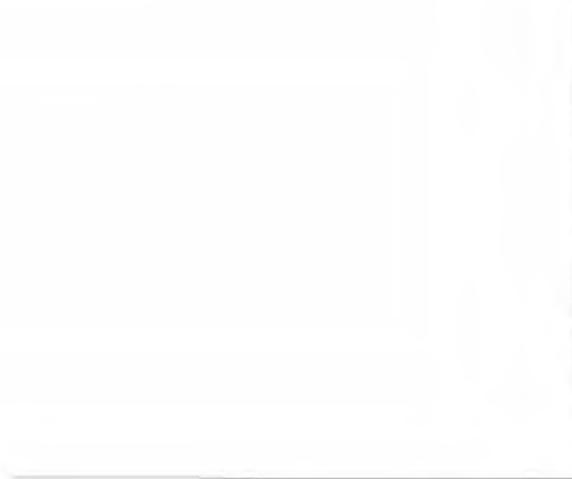
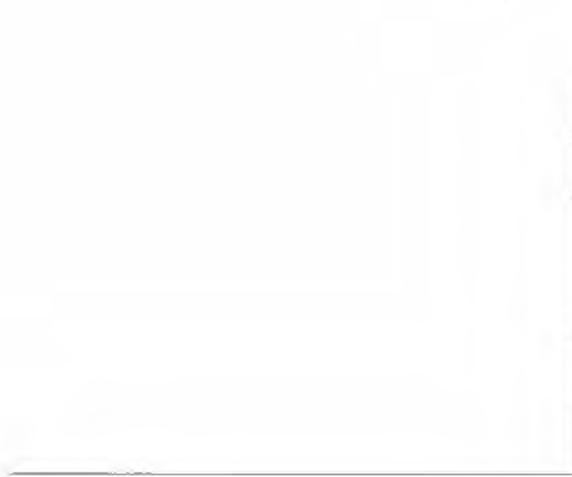
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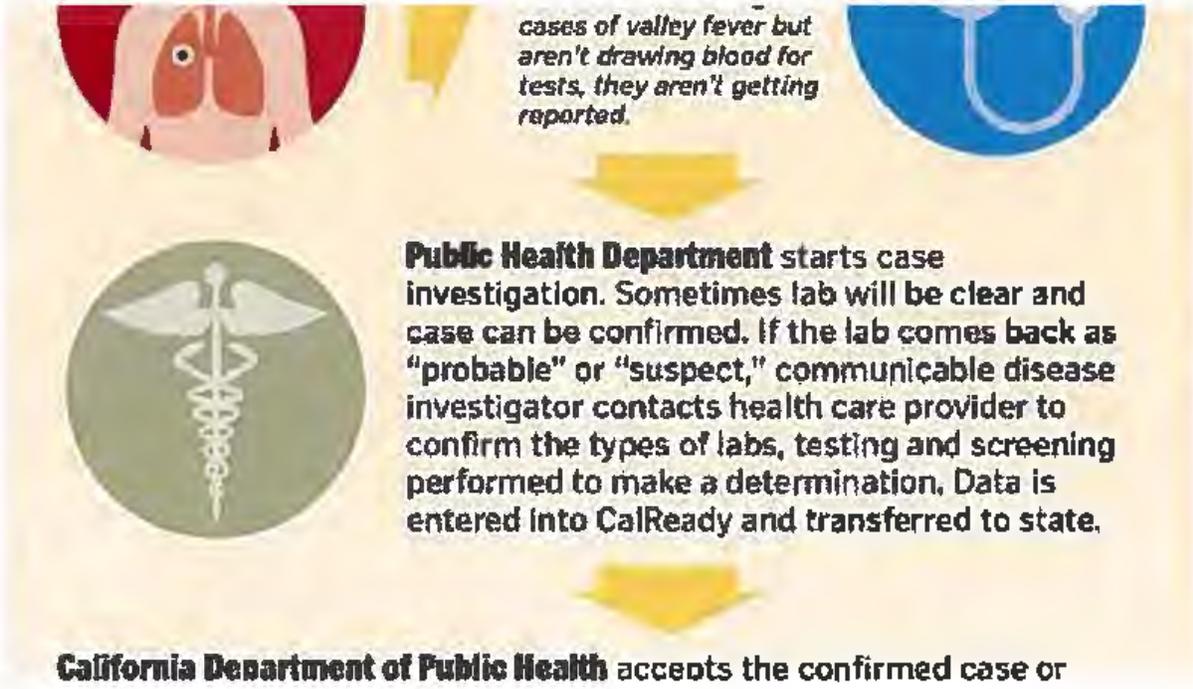
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May 7, 2021

Terrance Smalls
Kern County Planning and Natural Resources Department
2700 "M" Street Suite 100
Bakersfield CA, 93301

**Subject: Raceway 2.0 Solar, by sPower Development Corporation, LLC (Project)
Draft Environmental Impact Report (DEIR)
SCH No.: 2020079007**

Dear Mr. Smalls:

The California Department of Fish and Wildlife (CDFW) received a DEIR from the Kern County Planning and Natural Resources Department for the above-referenced Project pursuant to the California Environmental Quality Act (CEQA) and CEQA Guidelines.¹

2-A

Thank you for the opportunity to provide comments and recommendations regarding those activities involved in the Project that may affect California fish and wildlife. Likewise, CDFW appreciates the opportunity to provide comments regarding those aspects of the Project that CDFW, by law, may be required to carry out or approve through the exercise of its own regulatory authority under Fish and Game Code.

CDFW ROLE

2-B

CDFW is California's Trustee Agency for fish and wildlife resources and holds those resources in trust by statute for all the people of the State (Fish & G. Code, §§ 711.7, subd. (a) & 1802; Pub. Resources Code, § 21070; CEQA Guidelines § 15386, subd. (a)). CDFW, in its trustee capacity, has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species (*Id.*, § 1802). Similarly, for purposes of CEQA, CDFW is charged by law to provide, as available, biological expertise during public agency environmental review efforts, focusing specifically on projects and related activities that have the potential to adversely affect fish and wildlife resources.

¹ CEQA is codified in the California Public Resources Code in section 21000 et seq. The "CEQA Guidelines" are found in Title 14 of the California Code of Regulations, commencing with section 15000.

Terrence Smalls
Kern County Planning and Natural Resources Department
May 7, 2021
Page 2

CDFW is also submitting comments as a **Responsible Agency** under CEQA (Pub. Resources Code, § 21069; CEQA Guidelines, § 15381). CDFW expects that it may need to exercise regulatory authority as provided by the Fish and Game Code. As proposed, for example, the Project may be subject to CDFW's lake and streambed alteration regulatory authority (Fish & G. Code, § 1600 et seq.). v Likewise, to the extent implementation of the Project as proposed may result in "take" as defined by State law of any species protected under the California Endangered Species Act (CESA) (Fish & G. Code, § 2050 et seq.), related authorization as provided by the Fish and Game Code may be required.

2-C

Nesting Birds: CDFW has jurisdiction over actions with potential to result in the disturbance or destruction of active nest sites or the unauthorized take of birds. Fish and Game Code sections that protect birds, their eggs and nests include, sections 3503 (regarding unlawful take, possession or needless destruction of the nest or eggs of any bird), 3503.5 (regarding the take, possession or destruction of any birds-of-prey or their nests or eggs), and 3513 (regarding unlawful take of any migratory nongame bird).

PROJECT DESCRIPTION SUMMARY

Proponent: sPower Development Company, LLC

Project Description: The proposed project would involve construction and operation of two solar photovoltaic (PV) power-generating facilities, on six discontinuous sites, which would produce a combine total of approximately 291 megawatts (MW) of renewable electricity with up to 291 megawatt hours (MWh) energy storage on 1,330 acres of land in unincorporated Kern County.

2-D

Location: The proposed project is in the western extent of the Mojave Desert near Rosamond, California between Rosamond Boulevard and Avenue A, and between 70th Street West and 90th Street West in Sections: 20, 21, 28, 29 and 32, T9N/R13W in the eastern portion of unincorporated Kern County, California.

COMMENTS AND RECOMMENDATIONS

CDFW is concerned regarding potential impacts to special-status species including, but not limited to, the State and Federally threatened desert tortoise (*Gopherus agassizii*); the State threatened Swainson's Hawk (*Buteo swainsonii*); the State candidate for listing under CESA western Joshua tree (*Yucca brevifolia*); and the State species of special concern burrowing owl (*Athene cunicularia*). Mitigation Measures for these species, as proposed in the DEIR, may not reduce impacts to less than significant or result in unauthorized take. Our specific comments follow.

2-E

COMMENT 1: Western Joshua Tree (Joshua tree)

Table 4.4-3 states that no Joshua trees were observed on the Project site, but the species does occur within the gen-lia route. In addition, Table 4.4-1 lists 2.01 acres of Joshua tree

Terrence Smalls
Kern County Planning and Natural Resources Department
May 7, 2021
Page 3

woodland, a CDFW sensitive plant community, occurring within the gen-tie route. The DEIR cites measures from the Willow Springs Specific Plan that are applicable to Joshua tree. These measures include:

- Measure 15: Where possible, project development within the Specific Plan Update area shall be designed to avoid displacement or destruction of Joshua tree habitat, to the satisfaction of the Kern County Agricultural Commissioner's Office. Areas adjacent to the woodland shall have a 50-foot setback from the Joshua tree plants. Within that setback, a native plant cover should be restored to natural habitat values to serve as a buffer, if such plant cover is not present.
- Measure 16: A Joshua Tree Preservation and Transportation Plan shall be developed by the applicants for each parcel where Joshua trees are located on site. The plan shall be submitted to the Kern County Agricultural Commissioner's office for review and approval prior to grading permit issuance.
- Measure 23: A Joshua Tree Preservation and/or Transplantation Plan shall be developed by applicants of discretionary projects for each parcel where Joshua trees are located on site. The plan shall be submitted to the Kern County Agricultural Commissioner for review and approval prior to grading permit issuance.

2-E
(con.)

As noted above, Joshua tree is currently a candidate for listing pursuant to CESA. Candidate species are protected as if they were listed as a threatened or endangered species under CESA. Measures 16 and 23 would require take authorization from CDFW to relocate individual Joshua trees in order to comply with CESA. CESA applies to every life stage of a listed species, and for Joshua tree, this would include the seed bank. The 50-foot no-disturbance buffer from individual Joshua trees required in Measure 15 of the Willow Springs Specific Plan, as well as the 25-foot buffer listed in DEIR Mitigation Measure 4.4.-12 for special status plants, is likely insufficient to avoid impacts to the seedbank. Vander Wall et. al. 2006 documented 290 feet as maximum distance of seeds dispersed carried by rodents. A 290-foot buffer is warranted to not only avoid impacts to individual trees, but potential impacts to the seed bank as well. CDFW recommends the following edits to the DEIR.

Recommended Mitigation Measure 1: Western Joshua Tree Avoidance

CDFW recommends a no-disturbance buffer for individual western Joshua trees of 290 feet. If buffers cannot be maintained, then consultation with CDFW is warranted to determine appropriate minimization and mitigation measures for impacts to special-status plant species.

2-F

Recommended Mitigation Measure 2: Western Joshua Tree Take Authorization

If a 290-foot buffer for Joshua tree is not feasible, consultation with CDFW is warranted to determine if the Project can avoid take of that species. If take cannot be avoided, take

2-G

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Kern County Planning and Natural Resources Department
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Page 4

authorization would need to occur through acquisition of an Incidental Take Permit (ITP) from CDFW to comply with CESA and/or Fish and Game Code section 1900 and California Code of Regulations, title 14, section 786.9, subdivision (b). If Joshua trees will be translocated to comply with the Willow Springs Specific Plan, acquisition of an ITP is necessary to comply with CESA.

2-G
(con.)

COMMENT 2: Desert Tortoise

The DEIR (e.g., Table 4.4-3) states that the potential for desert tortoise to occur on-site is low because there is a lack of suitable habitat. The DEIR defines desert tortoise habitat as alluvial fans, washes, canyon bottoms, and hillsides. Desert tortoise have been observed in other habitat type and the lack of their presence does not preclude desert tortoise from occurring with the Project site. Based on the information provided, CDFW cannot conclude that desert tortoise is absent from the Project site. CDFW recommends the following edits to the DEIR.

2-H

Recommended Mitigation Measure 3: Desert Tortoise Protocol Surveys

CDFW recommends surveys for desert tortoise be conducted by a qualified wildlife biologist who understands and will follow the pre-project survey protocol as outlined in "Preparing for any action that may occur within the range of the Mojave Desert tortoise (*Gopherus agassizii*)" (USFWS, 2010) and has previous experience surveying for desert tortoise. Survey results are advised to be submitted to both CDFW and the USFWS.

2-I

Recommended Mitigation Measure 4: Desert Tortoise Take Authorization

If desert tortoise is found within the Project area during surveys advised in Recommended Mitigation 3 above, DEIR Mitigation Measure 4.4-4: Preconstruction Clearance Surveys, or construction activities, consultation with CDFW is advised to discuss how to implement the Project and avoid take; or if avoidance is not feasible, to acquire an ITP pursuant to Fish and Game Code section 2081 subdivision (b) prior to any vegetation- or ground-disturbing activities. Any take of desert tortoise without take authorization would be a violation of Fish and Game Code section 2080.

2-J

COMMENT 3: Swainson's Hawk (SWHA)

Table 4.4.-3 of the DEIR states that one active SWHA nest was observed on the Project site during 2020 burrowing owl surveys. The DEIR states that additional active nests occur within 5 miles of the Project site and that suitable foraging habitat occurs throughout the Project site. Several measures are provided as part of DEIR Mitigation Measure 4.4.-8: Swainson's Hawk Mitigation and Monitoring Plan. DEIR Mitigation Measure 4.4-8b requires "no new disturbances, habitat conversions, or other project-related activities that may cause nest abandonment or forced fledging occur within 0.5 miles of an active nest between March 1 and September 15. Buffer zones

2-K

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may be adjusted in consultation with CDFW and the County.” However, these Project activities are not defined and CDFW advises that the 0.5-mile buffer apply to all Project-related activities to avoid unauthorized take. We acknowledge that not all Project-related activities may require a 0.5-mile buffer, but the type of activity should be discussed as part of the consultation with CDFW and the County for a reduced buffer.

DEIR Mitigation Measure 4.4-8e requires habitat management (HM) lands to mitigate the loss of Swainson’s hawk foraging habitat by providing “HM lands within the Antelope Valley Swainson’s hawk breeding range at a minimum 1:1 ratio for such habitat impacted within a 5-mile radius of active Swainson’s hawk nest(s).” The Swainson’s Hawk Survey Protocols, Impact Avoidance, and Minimization Measures for Renewable Energy Projects in the Antelope Valley of Los Angeles and Kern Counties, California (CEC and CDFG 2010) recommends “mitigating loss of Swainson’s hawk foraging habitat by providing HM lands within the Antelope Valley Swainson’s hawk breeding range at a minimum 2:1 ratio for such habitat impacted within a five-mile radius of active Swainson’s hawk nest(s).” Based on the information provided in the DEIR, CDFW cannot conclude that a ratio lower than 2:1 will reduce impacts to Swainson’s hawk foraging habitat to less than significant. CDFW recommends the following edits to the DEIR.

Recommended Mitigation Measure 5: SWHA No Disturbance Buffer

CDFW recommends that the type of activities for the 0.5-mile buffer in DEIR Mitigation Measure 4.4-8b are changed from “project-related activities that may cause nest abandonment or forced fledgling” to all “all Project activities.” CDFW recommends the nest buffer remain in place until the breeding season has ended or until a qualified biologist has determined that the birds have fledged and are no longer reliant upon the nest or parental care for survival.

Recommended Mitigation Measure 6: SWHA Foraging Habitat

CDFW recommends that the amount of foraging habitat mitigation required by DEIR Mitigation Measure 4.4-8e is increased from a minimum 1:1 ratio to a minimum 2:1 ration to reduce impacts to SWHA foraging habitat to less than significant based on Swainson’s Hawk Survey Protocols, Impact Avoidance, and Minimization Measures for Renewable Energy Projects in the Antelope Valley of Los Angeles and Kern Counties, California (2010).

Recommended Mitigation Measure 7: SWHA Take Authorization

If an active SWHA nest is detected and a 0.5-mile no-disturbance buffer around the nest cannot feasibly be implemented, consultation with CDFW is warranted to discuss how to implement the project and avoid take. If take cannot be avoided, take authorization through the acquisition of an ITP, pursuant to Fish and Game Code section 2081 subdivision (b) is necessary to comply with CESA.



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COMMENT 4: Burrowing Owl (BUOW)

DEIR Mitigation Measure 4.4-6: Preconstruction Burrowing Owl Surveys requires a buffer of no fewer than 100 meters (330 feet) from an active BUOW burrow during the breeding season (i.e., February 1 to August 31) and buffer of no fewer than 50 meters (165 feet) from a BUOW burrow during the non-breeding season. CDFW typically recommends greater no-disturbance buffers based on the "Staff Report on Burrowing Owl Mitigation" (CDFG 2012). No explanation was provided as why these reduced buffers are sufficient to avoid take of BUOW or nest failure. Therefore, CDFW recommends extending the BUOW no-disturbance buffers. CDFW recommends the following edits to the DEIR.

2-O

Recommended Mitigation Measure 8: BUOW Avoidance

CDFW recommends the no-disturbance buffers listed in DEIR Mitigation Measure 4.4-6 be expanded to the buffers recommended in the "Staff Report on Burrowing Owl Mitigation" and listed in the table below. Specifically, CDFW's Staff Report recommends that impacts to occupied burrows be avoided in accordance with the following table unless a qualified biologist approved by CDFW verifies through non-invasive methods that either: 1) the birds have not begun egg laying and incubation; or 2) that juveniles from the occupied burrows are foraging independently and are capable of independent survival.

2-P

Location	Time of Year	Level of Disturbance		
		Low	Med	High
Nesting sites	April 1-Aug 15	200 m*	500 m	500 m
Nesting sites	Aug 16-Oct 15	200 m	200 m	500 m
Nesting sites	Oct 16-Mar 31	50 m	100 m	500 m

* meters (m)

Editorial Comments and/or Suggestions

Comment 5: Nesting birds

CDFW generally encourages Project implementation at individual Project sites occur during the bird non-nesting season if suitable nesting bird habitat is present. However, if ground-disturbing activities must occur during the breeding season (February through mid-September), the Project's applicant is responsible for ensuring that implementation of the Project does not result in violation of the Migratory Bird Treaty Act or relevant Fish and Game Codes as referenced above.

2-Q

To evaluate Project-related impacts on nesting birds if suitable habitat is present, CDFW recommends that a qualified wildlife biologist conduct pre-activity surveys for active nests no more than 10 days prior to the start of ground disturbance to maximize the probability that nests that could potentially be impacted are detected. CDFW also recommends that

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surveys cover a sufficient area around the work site to identify nests and determine their status. A sufficient area means any area potentially affected by the Project. In addition to direct impacts (i.e. nest destruction), noise, vibration, and movement of workers or equipment could also affect nests. Prior to initiation of construction activities, CDFW recommends a qualified biologist conduct a survey to establish a behavioral baseline of all identified nests. Once construction begins, CDFW recommends a qualified biologist continuously monitor nests to detect behavioral changes resulting from the Project. If behavioral changes occur, CDFW recommends the work causing that change cease and CDFW consulted for additional avoidance and minimization measures.



2-Q

If continuous monitoring of identified nests by a qualified wildlife biologist is not feasible, CDFW recommends a minimum no-disturbance buffer of 250 feet around active nests of non-listed bird species and a 500-foot no-disturbance buffer around active nests of non-listed raptors. These buffers are advised to remain in place until the breeding season has ended or until a qualified biologist has determined that the birds have fledged and are no longer reliant upon the nest or parental care for survival. Variance from these no disturbance buffers is possible when there is compelling biological or ecological reason to do so, such as when the construction area would be concealed from a nest site by topography. CDFW recommends that a qualified wildlife biologist advise and support any variance from these buffers and notify CDFW in advance of implementing a variance.

ENVIRONMENTAL DATA

CEQA requires that information developed in environmental impact reports and negative declarations be incorporated into a database which may be used to make subsequent or supplemental environmental determinations (Pub. Resources Code, § 21003, subd. (e)). Accordingly, please report any special-status species and natural communities detected during Project surveys to the California Natural Diversity Database (CNDDDB). The CNDDDB field survey form can be found at the following link: <https://www.wildlife.ca.gov/Data/CNDDDB/Submitting-Data>. The completed form can be mailed electronically to CNDDDB at the following email address: CNDDDB@wildlife.ca.gov. The types of information reported to CNDDDB can be found at the following link: <https://www.wildlife.ca.gov/Data/CNDDDB/Plants-and-Animals>.



2-R

FILING FEES

If it is determined that the Project has the potential to impact biological resources, an assessment of filing fees will be necessary. Fees are payable upon filing of the Notice of Determination by the Lead Agency and serve to help defray the cost of environmental review by CDFW. Payment of the fee is required for the underlying project approval to be operative, vested, and final (Cal. Code Regs, tit. 14, § 753.5; Fish & G. Code, § 711.4; Pub. Resources Code, § 21089).



2-S

Comment Letter 2: California Department of Fish and Wildlife

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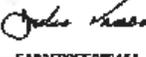
CDFW appreciates the opportunity to comment on the Project to assist the Kern County Planning and Natural Resources Department in identifying and mitigating the Project's impacts on biological resources.

↑
2-S
(con.)

More information on survey and monitoring protocols for sensitive species can be found at CDFW's website (<https://www.wildlife.ca.gov/Conservation/Survey-Protocols>). If you have any questions, please contact Jaime Marquez, Environmental Scientist, at the address provided on this letterhead, by telephone at (559) 243-4014, extension 291, or by electronic mail at Jaime.Marquez@wildlife.ca.gov.

↓
2-T

Sincerely,

DocuSigned by:

FAB3FD0E20945A
Julie A. Vance
Regional Manager

cc: Office of Planning and Research, State Clearinghouse, Sacramento

Final Environmental Impact Report

SCH# 2020079007

Volume 5

Chapter 7 Response to Comments

Raceway 2.0 Solar Project
By sPower Development Company

SPA 33, ZM 231; ZCC 154, ZM 231; CUP 116 ZM 231; SPA 34, ZM 231, SPA 35, ZM 231, ZCC 155, ZM 231,
CUP 117, ZM 231; SPA 36, ZM 231; SPA 37, ZM 231; ZCC 156, ZM 231; CUP 118, ZM 231; SPA 38, ZM 231;
CUP 119, ZM 231; CUP 4, ZM 231-20, SPA 39, ZM 231; SPA 3, ZM 231-20, SPA 5, ZM 231-21; SPA 5, ZM 231-26;
ZCC 3, ZM 231-21; ZCC 3, ZM 231-28; CUP 3, ZM 231-21; CUP 7, ZM 231-28; SPA 6, ZM 231-21; SPA 6,
ZM 231-28; SPA 7, ZM 231-21; ZCC 4, ZM 231-21; CUP 4, ZM 231-21,
Cancellation of a Williamson Act Contract 20-08;
Kern County Franchise Agreement



Kern County Planning and Natural Resources Department
2700 M Street, Suite 100
Bakersfield, CA 93301-2370
(661) 862-8600

Technical Assistance by
Environmental Science Associates
626 Wilshire Boulevard, Suite 2200
Los Angeles, CA 90017
(213) 599-4300

June 2021

Comment Letter 1: California Department of Fish and Wildlife (September 11, 2014)



State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Central Region
1234 East Shaw Avenue
Fresno, California 93710
(559) 243-4005
www.wildlife.ca.gov

EDMUND G. BROWN, JR., Governor
CHARLYN H. BONHAM, Director



September 11, 2014

Matthew Hall
Kern County Planning Department
2700 M Street, Suite 100
Bakersfield, California 93301-2323

Subject: Revised Draft Environmental Impact Report (RDEIR) for the Rosamond Solar Array Project by First Solar, Inc. (SCH No. 2010031030)

Dear Mr. Hall:

The California Department of Fish and Wildlife (CDFW) has reviewed the RDEIR for the Rosamond Solar Array Project by First Solar, Inc. (Project). The Project consists of constructing and operating a 150 megawatt (MW) photovoltaic solar power plant on approximately 1,175 acres in the Antelope Valley, at the western edge of the Mojave Desert. The power plant would consist of solar panels, an electrical collection system, a substation, an operations and maintenance building, security gates, fencing, temporary dust control ponds during construction, a temporary concrete batch plant during construction, and a three to five mile-long transmission line (gen-line) to connect to the existing Whirlwind substation, which is operated by Southern California Edison.

1-A

The revisions made in the RDEIR did not address most of the comments in CDFW's draft EIR comment letter, dated January 28, 2014. Therefore, many of the comments in this letter are the same as in the January letter.

The California Environmental Quality Act (CEQA) Mandatory Findings of Significance require that the lead agency find that the Project may have a significant effect on the environment if the Project has the potential to "... cause a fish or wildlife population to drop below self-sustaining levels..." The Swainson's hawk (*Buteo swainsoni*) population in the Antelope Valley is small and likely to drop below self-sustaining levels if renewable energy development continues without adequate habitat conservation within the Antelope Valley. As written, the RDEIR does not require the developer of this Project to conserve any habitat in the Antelope Valley or implement any other measures that would effectively conserve Swainson's hawk and burrowing owl (*Athene cunicularia*) populations in the Antelope Valley.

1-B

Mitigation measures 4.4-4 and 4.4-8 through 4.4-8 are not based on the baseline survey results, which were that the area supports abundant burrowing owls and Swainson's hawks, and instead defer the development of habitat compensation requirements to consultation with other agencies, based on less-comprehensive, future pre-construction survey results. CDFW recommends that the County instead require quantifiable habitat compensation in the Environmental Impact Report (EIR) based on the known baseline survey results and Project

1-C

Conserving California's Wildlife Since 1870

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Impacts, and require the pre-construction surveys primarily for avoiding direct "take" of wildlife during Project construction and to determine whether additional mitigation may be warranted.

1-C



In this letter, we recommend specific, quantifiable measures to minimize and offset the impacts to the Antelope Valley Swainson's hawk and burrowing owl populations based on the Project's baseline data in the RDEIR. Since there is potential that CDFW will be only a Trustee Agency on this Project, CDFW does not necessarily have a mechanism to require and enforce these measures; thus, we find that the RDEIR's method of deferring the development of habitat compensation measures to later discussions with CDFW is unlikely to mitigate the Project's biological impacts to less than significant levels as the RDEIR concludes.

1-D

Here is a summary of our comments and recommendations in this letter:

- Require 80 acres of desert tortoise (*Gopherus agassizii*) habitat compensation in perpetuity. 1-E
- Require 2:1 habitat compensation within the Antelope Valley for Swainson's hawk and burrowing owl for all permanent impacts, not just if Swainson's hawks are found within 0.6 mile during pre-construction surveys (the baseline surveys already found them nesting within 0.5 mile, and the foraging habitat that supports nesting extends greater than 0.5 mile from the nest sites). 1-F
- Require a 0.5-mile construction buffer from Swainson's hawk nests, and avoid converting suitable habitat within that buffer. 1-G
- Require transmission lines to be underground to minimize Swainson's hawk, burrowing owl, and other avian fatalities. 1-H
- Assume that all beavertail cacti within the Project limits are the State and federally endangered Bakersfield cactus (*Opuntia basilaris* var. *trichocarpa*) unless further genetic studies conclude otherwise. 1-I
- Prohibit the use of chain link fence or require that chain link fences are modified to prevent desert kit foxes (*Vulpes macrotis arizonus*) from placing their heads through the mesh openings and becoming ensnared. 1-J
- If dust palliatives are to be used, require the applicant to use only substances that are organic, non-petroleum, and non-salts, such as many of the plant-based products that are commercially available for fugitive dust control. 1-K

A discussion of CDFW's jurisdiction for this Project and specific comments on the RDEIR, follows.

CDFW Jurisdiction

CEQA and California Endangered Species Act (CESA) Authority: CDFW is a Trustee Agency for fish and wildlife resources with the responsibility under CEQA for commenting on projects that could impact fish and wildlife resources. In this role, CDFW is responsible for providing, as available, biological expertise to review and comment on environmental documents and impacts arising from project activities. Pursuant to Fish and Game Code §1802,

1-L

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CDFW has jurisdiction over the conservation, protection and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species.

CDFW is a Responsible Agency when a subsequent permit or other type of discretionary approval is required from CDFW, such as an Incidental Take Permit (ITP), pursuant to CESA, or a Lake or Streambed Alteration Agreement (LSAA) issued under Fish and Game Code §§1600 et seq. If direct take cannot be avoided, then the Project would warrant an ITP for take of Bakersfield cactus, which is listed as endangered pursuant to both the federal Endangered Species Act (ESA) and CESA, the federal endangered and State threatened species desert tortoise, and the State threatened species Swainson's hawk.

1-L

CDFW's issuance of an ITP and/or an LSAA is also considered a "project" subject to CEQA (CEQA Guidelines §15378). CDFW typically relies on the Lead Agency's CEQA compliance to make findings pursuant to CEQA Guidelines §15091. For the Lead Agency's CEQA document to suffice for CESA ITP issuance, it must fully describe the potential Project-related impacts to State-listed species, analyze potential impacts of the entire Project including private and public land components, and commit to measures to avoid or minimize, and fully mitigate impacts to these resources. CDFW may not be able to issue an ITP by relying on an EIR containing a Statement of Overriding Considerations when impacts to a State-listed species are not mitigated to less than significant.

If the EIR completed for this Project does not include mitigation measures to reduce impacts to State-listed species to less than significant, or if it does not describe and analyze all components of the Project (including those proposed on federal land), CDFW may as a result need to act as a CEQA Lead Agency and complete a subsequent EIR to support issuance of an ITP. This could significantly delay ITP issuance and consequently, Project implementation.

1-M

Specific Comments on the RDEIR

Mitigation Measure 4.4-4: This measure regarding pre-construction wildlife surveys begins with "Prior to construction, the Applicant may contact the United States Fish and Wildlife Service and California Department of Fish and Wildlife to determine if pre-construction surveys and exclusionary fencing are warranted given the low likelihood of occurrence of sensitive species." The pre-construction surveys are warranted. The baseline surveys for the Project documented burrowing owl sign (whitewash and pellets) at burrows within the proposed solar arrays and elsewhere surrounding the site. Thus, CDFW does not concur that there is a "low likelihood of occurrence of sensitive species" on this Project site. The already-documented presence is also sufficient evidence that burrowing owls are likely to be on and/or near the construction area and might be taken during construction. CDFW recommends the RDEIR require pre-construction surveys for burrowing owl to facilitate take avoidance measures.

1-N

Desert tortoises are known to occur in the native desert scrub communities that are contiguous with the 80 acres of desert scrub habitat in the northern solar array and along the gen-tie route. Because this Project would convert these 80 acres of creosote bush scrub to a solar array, and disturb ground in desert tortoise habitat along the gen-tie route, CDFW recommends pre-construction surveys for desert tortoise are included in the RDEIR as a mitigation measure to determine if desert tortoise occur in the Project area. In the event that desert tortoise is

1-O

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detected, consultation with CDFW would be warranted to discuss how to implement the Project and avoid take. If take can't be avoided, an ITP would be required to comply with CESA. Alternatively, the Project applicant can assume presence and apply for an ITP. 1-O

Swainson's hawks are also known to nest approximately 0.5 mile from the proposed solar arrays, as documented in the Project's baseline biological report. Given this proximity, the trees bordering the Project site have a relatively high potential to host nesting Swainson's hawks. CDFW recommends pre-construction surveys for Swainson's hawks to determine if the species is present within 0.5 mile during construction activities. Depending on the results of these surveys, consultation with CDFW may be warranted to determine if the Project can avoid take. If take can't be avoided, an ITP is necessary to comply with CESA. 1-P

Mitigation Measure 4.4-6: This measure regarding pre-construction surveys and exclusion fencing for desert tortoise also contains the word "may," and gives the Applicant an option to not perform pre-construction surveys or install exclusion fencing for desert tortoises. As discussed above, the proposed northern solar array areas contains 80 acres of native desert scrub that adjoins known, occupied desert tortoise habitat. We recommend that the County require the Applicant to complete pre-construction surveys to avoid take of tortoises within these 80 acres and to install tortoise exclusionary fence along the solar array construction area boundaries north of Rosemond Boulevard and along the gen-tie route. CDFW recommends exclusion fencing be installed only after pre-construction surveys are completed. If desert tortoise are observed within the exclusion fencing, CDFW may consider the individual's captured. The capture of any species listed under CESA would require an ITP, as capture (or attempt to do so) is defined as take under Fish and Game Code Section 86. 1-Q

Desert Tortoise: The 80 acres of the desert scrub that the Project would displace are part of a larger area of occupied desert tortoise habitat. CDFW recommends that the County require the applicant to conserve 80 acres of desert tortoise habitat in perpetuity to offset this habitat loss. 1-R

Burrowing Owl: The baseline surveys found nine burrows within 150 meters (m) of the gen-tie routes and a 150 m buffer of the eastern solar array area. They found that all of the Project site was suitable habitat. It is important to note that the owls using burrows in the non-tilled areas are foraging in the tilled areas, and that burrowing owls do breed in active agricultural fields in the Antelope Valley (Wikerson and Siegel, 2011). 1-S

This Project area is of relatively high value for conservation of burrowing owls. The baseline survey findings corroborate the finding of Wikerson and Siegel (2011) that burrowing owls in the Mojave Desert are clustered in the agricultural and urban interface areas of the Antelope, Apple, and Lucerne valleys.

Measure 4.4-7, regarding burrowing owl, requires that "Should burrowing owls be found on-site, compensatory mitigation for lost breeding and/or wintering habitat shall be implemented..." The context of that statement is following a pre-construction survey. This measure ignores the baseline data that confirmed that the Project site is indeed burrowing owl habitat. Since the site is already known to be burrowing owl habitat, we recommend clarifying that the determination of whether habitat compensation is required does not depend on the future pre-construction survey results. We recommend stating that the Applicant shall compensate for 1-T

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The already documented burrowing owl habitat loss and specifying a minimum acreage. That would also help to clarify that pre-construction surveys are for avoiding direct take of owls during construction and determining whether more owls may be present than were found in the partial surveys of 2010 or 2011. If pre-construction surveys find that the site supports more owls than have already been found, then additional habitat compensation should be required.

1-T

Measure 4.4-7 also does not prescribe any amount or location of habitat mitigation. The initial surveys were completed in 2010 and 2011; these baseline surveys provided enough information to form a mitigation plan in the RDEIR. We recommend including the burrowing owl habitat mitigation plan in the EIR and requiring that it be implemented prior to the habitat loss to minimize the temporal habitat impacts. For reference, burrowing owl kernel home ranges in desert agricultural settings have been estimated at 112 ± 45 acres (Rosenberg and Halsey, 2004). Rosenberg and Halsey also found that owls foraged mostly within 600 m of their burrows, which puts most of the eastern solar arrays well within core foraging range of the burrows that were documented in the 150 m buffer survey there. The number of owls found along the gentle ripples and in the eastern array buffer suggests that additional burrowing owl burrows occur within 600 m of the Project. Burrowing owl habitat compensation can be accomplished within the area to be used for Swainson's hawk mitigation in the Antelope Valley.

1-U

Mitigation measure 4.4-7 also allows the applicant to combine or "stack" burrowing owl habitat compensation with agricultural mitigation that may occur through in-lieu fee programs (none of which are identified in the RDEIR) and/or agricultural lands conservation in the Central Valley. Further, there is no requirement in the measure that the agricultural lands support burrowing owls. Neither of these options would mitigate impacts to the Antelope Valley population of burrowing owls, and may not provide any benefit to burrowing owls since the measure does not require actually conserving habitat that supports burrowing owls.

1-V

CDFW recommends requiring the burrowing owl habitat compensation to occur within the Antelope Valley, in areas that support burrowing owls and can be enhanced to support more burrowing owls.

Swainson's Hawk: Mitigation measure 4.4-8 requires Swainson's hawk habitat compensation only if Swainson's hawks are found within 0.5 mile of the Project during pre-construction surveys. CDFW does not concur that this approach would mitigate Swainson's hawk habitat impacts to a less than significant level. The baseline surveys for the Project already established that Swainson's hawks nest within 0.5 mile and that the project is within the core nesting and foraging area for the Antelope Valley Swainson's hawk population. Requiring habitat compensation only if they are found during the pre-construction survey ignores the baseline conditions. CDFW recommends pre-construction surveys to determine whether additional mitigation may be warranted based on changing circumstances and to detect new nest sites that need to be buffered from construction activities to avoid take, including nest failure. The measure as currently drafted is inconsistent with this approach and with CDFW's "Swainson's Hawk Survey Protocols, Impact Avoidance, and Minimization Measures for Renewable Energy Projects in the Antelope Valley of Los Angeles and Kern Counties, California" which requires habitat compensation for foraging habitat losses that occur within 5 miles of nest sites. Also inconsistent with the existing guidance is the RDEIR's requirement to mitigate only those habitat impacts within 0.5 mile of nest sites, and to allow habitat compensation to occur anywhere within 10 miles of a nest. Habitat 10 miles from a nest is much less valuable to

1-W

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nesting Swainson's hawk, and may be used very little by the species compared to habitat within 0.5 mile of a nest. The proposed measure would not provide habitat of equal or greater value.

1-W

Further, the measure allows in-flow fees and/or habitat compensation within the Central Valley which would not mitigate the impacts to the Antelope Valley population, and would likely contribute to the loss of this population. As discussed above for burrowing owl, this measure does not guarantee that any Swainson's hawk habitat would actually be conserved.

We could concur that Swainson's hawk habitat losses would be mitigated to less than significant levels if the County, as lead agency, required habitat mitigation based on the already-known habitat loss impacts.

1-X

Requiring that the mitigation occur within the Antelope Valley is important. The CEQA Mandatory Findings of Significance require that a lead agency find that the Project may have a significant effect on the environment if the Project has the potential to "... cause a fish or wildlife population to drop below self-sustaining levels." The Swainson's hawk population in the Antelope Valley is small and likely to drop below self-sustaining levels if renewable energy development continues without adequate habitat conservation within the Antelope Valley. As written, the RDEIR does not require the developer of this Project to conserve any habitat in the Antelope Valley or implement any other measures that would effectively conserve Swainson's hawk and burrowing owl populations in the Antelope Valley.



Lastly, the RDEIR does not specify a construction buffer distance from Swainson's hawk nests. CDFW recommends maintaining a 0.5-mile buffer from any active Swainson's hawk nest during construction. CDFW also recommends avoiding development on suitable habitat within 0.5 mile of known nests, and maintaining those areas as suitable foraging habitat.

1-Y

These recommendations are consistent with the California Energy Commission's and CDFW's June 2, 2010, recommendations titled "Swainson's Hawk Survey Protocols: Impact Avoidance, and Minimization measures for Renewable Energy Projects in the Antelope Valley of Los Angeles and Kern Counties, California." We encourage the County to adopt the habitat compensation measures already outlined in that document.

1-Z

Bakersfield Cactus: Recent genetic analysis on *Opuntia basilaris* varieties suggests that all of the *O. basilaris* found on the Project site have the potential to be *O. b. var. brevassei*, which is the State- and federally listed variety. The morphological characteristics used to attempt to differentiate the two varieties here are no longer believed to be reliable. Thus, absent genetic analysis of the cacti on the Project sites, CDFW recommends assuming that all *O. basilaris* found on site belong to the listed population. We recommend disclosing in the RDEIR a potential for the Project to take Bakersfield cactus so that, if take cannot be avoided, the final EIR may be used as a basis for CDFW issuance of an ITP.

1-A2

Desert Kit Fox: The Project is within the known range of desert kit fox. CDFW recommends that the County require the applicant to prevent kit foxes from becoming ensnared in chain-link fence. A kit fox was found dead, ensnared in a chain link fence, at a facility on the nearby Alta Oak Creek Mojave project. This is a known issue for San Joaquin kit foxes (*Vulpes macrotis nuttalli*) within their range as well. The foxes attempt to go through a chain-link fence headfirst.

1-B2

Matthew Hall
September 11, 2014
Page 7

find that the mesh openings are too small, and then cannot pull their heads back through the fence. Individuals may learn to go through chain link when they are pups only to become ensnared when they grow larger. We recommend either not constructing chain link fence or modifying the chain link (e.g., installing plastic privacy slats) to prevent foxes from putting their heads through the mesh openings. Leaving a 3.5-inch to 5-inch opening between two crossbars near ground level to allow free movement for foxes is one solution to minimize the risk of fatalities from chain link fence and also the direct habitat loss that would result from an impermeable fence. Another solution used on other constructed solar projects is to install inverted deer fence (larger openings at the bottom) instead of chain link. Both of these designs have met safety and security requirements on utility-scale solar projects even larger in size than the proposed Project.

1-B2

Dust Palliatives: It has come to CDFW's attention that salts, surfactants, and other toxic compounds are being used to control dust on projects in the Project vicinity. Many are toxic to both plants and animals, can migrate from the site with runoff, and can degrade into other toxins. This Project is within endangered species habitat and habitat for other wildlife, and application of such materials may have unintended, adverse impacts to these species. CDFW recommends that if dust palliatives are to be used, the County require the applicant to use only substances that are organic, non-petroleum, and non-salts, such as many of the plant-based products that are commercially available for dust control.

1-C2

Overhead Transmission Lines: Collisions with overhead power lines are one of the most common causes of California condor mortality and injury. Power lines also kill high numbers of other bird species, particularly raptors, even when diverters are installed. CDFW recommends that all power lines to be constructed for this Project be placed underground to avoid take of burrowing owls, Swainson's hawks, and other birds.

1-D2

Thank you for the opportunity to provide input on the RDEIR for this renewable energy project. If you have any questions regarding these comments, please contact Dave Hacker, Senior Environmental Scientist (Specialist), at 3198 Higuera Street, Suite A, San Luis Obispo, California 93401, by telephone at (805) 584-6152, or by e-mail at David.Hacker@wildlife.ca.gov.

Sincerely,

Dean Mauston for

Jeffrey R. Single, Ph.D.
Regional Manager

cc: Jessica Rempel
United States Fish and Wildlife Service
2493 Portola Road, Suite B
Ventura, California 93003

ec: California Department of Fish and Wildlife
Julie Vance, Central Region
Dave Hacker, Central Region

Matthew Hall
September 9, 2014
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Volume III

Chapter 7

Response to Comments

SCH# 2010031030

Rosamond Solar Array Project
by First Solar, Inc.

Conditional Use Permit 25, Map 232
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**Kern County Planning and
Community Development Department
Bakersfield, California**

September 2014



NEWS

Lawsuits Threatened Over Shoreline Noise

By **Carolyn Zinko**, Style Reporter

Nov 28, 1996



Frustrated by Mountain View's refusal to respond to its concerns about noise from Shoreline Amphitheater, a group of Palo Alto residents is threatening to sue to muffle the roar.

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The Mountain View City Council rebuffed a request by Palo Alto to turn down the volume at the amphitheater, the source of noise that has led to more than 10,000 complaints from homeowners during the decade the theater has operated.

Council members on Tuesday said they did not want to lower the volume because they weren't convinced it would work, arguing that the inversion layer phenomenon along the bay front is what causes sound to bounce into the atmosphere and carry miles from its source.

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They also said they didn't want to hurt the amphitheater's viability. It pays the city about \$1.6 million annually in rent.

"It's terrible," Councilwoman Dena Bonnell said of the noise problem, made clear to her this summer when a Palo Alto resident phoned and made her listen to the applause and music audible in the caller's back yard. "But I don't want to try something that won't work and give residents false hope."

In response, a Palo Alto coalition called Abate Shoreline Amphitheater Noise is drawing up battle plans, vowing to take its complaints en masse to small claims court. Both the city of Mountain View and Bill Graham Presents, which operates Shoreline, could be named in the suits.

Palo Alto might assist with the small claims action, said City Attorney Ariel Calonne.

"I talked to some residents who were just coming unglued over the issue, and my sense is they're not about to take last night's decision without a fight," said the coalition's founder, Jim Lewis.

The coalition also plans to ask Santa Clara County District Attorney George Kennedy to file charges against Shoreline for disturbing the peace, and it hopes to persuade Palo Alto to make its noise ordinance more stringent so it will have more ammunition to fight Mountain View.

Citizens have used small claims actions to eradicate nuisances like crack houses in their neighborhoods and airport noise, among other problems. A judge could impose an injunction preventing Shoreline from operating or award damages to residents if the amphitheater were found to be a nuisance, Calonne said.

He expressed surprise at the Mountain View council's reaction to Palo Alto's proposal.

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"Saying they shouldn't do anything for noise reduction unless it will completely solve the problem is like saying you're not going to research a cure for cancer because there's always going to be cancer," Calonne said.

Complaints about Shoreline are not unique: Such problems affect other outdoor amphitheaters across the state and the nation.

Sacramento recently filed suit to block construction of a new 23,000-seat arena next to the Cal Expo amphitheater, charging that its potential impact on air quality, traffic and noise has not been adequately reviewed. Noise from concerts at Cal Expo has plagued nearby residents for years.

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Near Chicago, the New World Music Theatre in Tinley Park was fined \$13,000 in 1993 for violating state noise pollution laws more than two dozen times.

And in Columbus, Ohio, the Polaris Amphitheater has been forced to hire a noise consultant to monitor sound during rock concerts to appease the complaints of citizens from neighboring Westerville, where the sound drifts. Weeknight concerts there have been limited to 10 p.m.

Nov 28, 1996



Carolyn Zinko
STYLE REPORTER



Carolyn Zinko, a native of Wisconsin, joined The San Francisco Chronicle in 1993 as a news reporter covering Peninsula crime, city government and political races. She worked as the paper's society columnist from 2000 to 2004, when she wrote about the lifestyles of the rich but not necessarily famous. Since then, she has worked for the Sunday Style and Datebook sections, covering gala night openings and writing trend pieces. Her profiles of personalities have included fashion designer Diane von Furstenberg, Twitter co-founder Biz Stone and Emanuel Ungaro fashion house owner Asim Abdullah, to name a few. In a six-month project with The Chronicle's investigative team, she recently revealed the misleading practices of a San Francisco fashion charity that took donations from wealthy philanthropists but donated little to the stated cause of helping the developmentally disabled. On the lifestyle front, her duties also including writing about cannabis culture for The Chronicle and its cannabis website, www.GreenState.com website.

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A synthesis of two decades of research documenting the effects of noise on wildlife

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ABSTRACT

Global increases in environmental noise levels – arising from expansion of human populations, transportation networks, and resource extraction – have catalysed a recent surge of research into the effects of noise on wildlife. Synthesising a coherent understanding of the biological consequences of noise from this literature is challenging. Taxonomic groups vary in auditory capabilities. A wide range of noise sources and exposure levels occur, and many kinds of biological responses have been observed, ranging from individual behaviours to changes in ecological communities. Also, noise is one of several environmental effects generated by human activities, so researchers must contend with potentially confounding explanations for biological responses. Nonetheless, it is clear that noise presents diverse threats to species and ecosystems and salient patterns are emerging to help inform future natural resource-management decisions. We conducted a systematic and standardised review of the scientific literature published from 1990 to 2013 on the effects of anthropogenic noise on wildlife, including both terrestrial and aquatic studies. Research to date has concentrated predominantly on European and North American species that rely on vocal communication, with approximately two-thirds of the data set focussing on songbirds and marine mammals. The majority of studies documented effects from noise, including altered vocal behaviour to mitigate masking, reduced abundance in noisy habitats, changes in vigilance and foraging behaviour, and impacts on individual fitness and the structure of ecological communities. This literature survey shows that terrestrial wildlife responses begin at noise levels of approximately 40 dBA, and 20% of papers documented impacts below 50 dBA. Our analysis highlights the utility of existing scientific information concerning the effects of anthropogenic noise on wildlife for predicting potential outcomes of noise exposure and implementing meaningful mitigation measures. Future research directions that would support more comprehensive predictions regarding the magnitude and severity of noise impacts include: broadening taxonomic and geographical scope, exploring interacting stressors, conducting larger-scale studies, testing mitigation approaches, standardising reporting of acoustic metrics, and assessing the biological response to noise-source removal or mitigation. The broad volume of existing information concerning the effects of anthropogenic noise on wildlife offers a valuable resource to assist scientists, industry, and natural-resource managers in predicting potential outcomes of noise exposure.

Key words: acoustics, noise pollution, human disturbance, vocal communication, acoustic metrics, masking, physiology, behaviour, mitigation, fitness, conservation.

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[†] Authors contributed equally to the study.

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I. INTRODUCTION

Noise generated by human activities has increased dramatically over recent decades as a result of population growth, urbanisation, globalisation of transportation networks, and expansion of resource extraction. Road traffic in the USA, for example, has outstripped population growth over the past 40 years by a factor of ten, and the number of domestic passenger flights has more than tripled since the early 1980s (Barber, Crooks & Fristrup, 2010). In marine environments, the distribution and effects of human activity (e.g. offshore oil extraction, commercial ship traffic) are extensive (Halpern *et al.*, 2008), and shipping alone is estimated to have increased low-frequency background sound levels by 12 dB over the past few decades (Hildebrand, 2009). With the rapid escalation of noise pollution, there is growing concern regarding its impacts on human health and the functioning of natural systems (Chepesiuk, 2005; McGregor *et al.*, 2013).

Anthropogenic changes to the acoustic environment include increases in the number of high-intensity noise events and chronically elevated and homogenised background sound levels. The impact of these changes has been most thoroughly assessed in humans, with profound physiological and psychological consequences, including increased risk of cardiovascular disease (Babisch *et al.*, 2005; Hansell *et al.*, 2013), sleep deprivation (Fyhri & Aasvang, 2010), and cognitive impairment (Szalma & Hancock, 2011). These impacts are estimated to cost at least one million healthy life years per annum in Western Europe (Fritschl *et al.*, 2011). Protective legislation for human communities was implemented four decades ago in the USA (Noise Control Act of 1972, Quiet Communities Act of 1978) and more recently

in the European Union (Environmental Noise Directive 2002/49/EC).

Quantifying the effects of anthropogenic noise on wildlife is challenging. Sensitivity to noise varies widely across taxa (Kaselon & Tyson, 2004; Brumm & Slabbekoorn, 2005; Morley, Jones & Radford, 2013; Slabbekoorn, 2013), and may also vary depending upon context, sex, and life history (Ellison *et al.*, 2012; Francis & Barber, 2013). Noise can induce compound biological responses (e.g. shifts in vocalisation and movement; McLaughlin & Kunc, 2013), and is rarely isolated from other forms of environmental disturbance, such as habitat alteration and visual disturbance, confounding interpretation of biological responses to noisy environments (Summers, Cunningham & Fahrig, 2011). Furthermore, determining the scale and extent of disturbance involves carefully measuring characteristics of the sound source, such as duration (chronic, intermittent), frequency content, and intensity (Nowacek *et al.*, 2007; Southall *et al.*, 2007; Francis & Barber, 2013; Gill *et al.*, 2015).

Despite these challenges, a coherent research focus on noise impacts has recently emerged. Review papers have either focussed broadly on wildlife (Brumm & Slabbekoorn, 2005; Barber *et al.*, 2010; Kight & Swaddle, 2011), or targeted specific taxonomic groups such as birds (Patricelli & Bickley, 2006; Slabbekoorn & Ripmeester, 2008; Ortega, 2012; Slabbekoorn, 2013), fish (Slabbekoorn *et al.*, 2010; Radford, Kerridge & Simpson, 2014), and invertebrates (Morley *et al.*, 2013). The Marine Mammal Protection Act stimulated noise regulation for marine mammals, and there have been several reviews of the effects of noise on these species (Richardson *et al.*, 1995; Boyd *et al.*, 2008; Tyack, 2008; Southall *et al.*, 2009; Ellison *et al.*, 2012). Some reviews have focused on specific behaviours (Luttrell & Gentry, 2013) or responses to noise (Wright *et al.*, 2007; Hotchkiss & Parks,

2013), while conceptual frameworks for evaluating noise impacts to wildlife have also recently been published (Moore *et al.*, 2012; Francis & Barber, 2013).

This review provides a systematic and standardised synthesis of the peer-reviewed literature published from 1990 to 2013 reporting responses of wildlife to anthropogenic noise in terrestrial and aquatic habitats. It documents prominent trends in research topics and methods, the kinds of noise sources that have been studied and the measurements used to characterise them, and gaps in research coverage that merit attention in future research. Ultimately, we highlight the utility of existing scientific information concerning the effects of anthropogenic noise on wildlife for predicting potential outcomes of noise exposure and implementing meaningful mitigation measures.

II. LITERATURE REVIEW METHODOLOGY

We conducted a detailed literature search using Thompson's *ISI Web of Science* within the following subject areas 'Acoustics', 'Zoology', 'Ecology', 'Environmental Sciences', 'Ornithology', 'Biodiversity Conservation', 'Evolutionary Biology', and 'Marine Freshwater Biology' from 1990 to 2013. The specific search terms were [WILDLIFE or ANIMAL or MAMMAL or REPTILE or AMPHIBIAN or BIRD or FISH or INVERTEBRATE] and [NOISE or SONAR]), which returned a total of 2205 scientific peer-reviewed articles. These papers were filtered so only empirical studies focussed on documenting the effects of anthropogenic noise on wildlife were included in the final data set ($N=242$). Reviews, syntheses, method papers ($N=32$), and studies dealing solely with natural acoustic sources ($N=22$) were excluded.

We reviewed the remaining publications to systematically characterise each study using 21 attributes, including details on the publication (journal, discipline, and year published), study design (playback or natural experiment, field or laboratory-based), and biological information (geographic region, general taxonomic grouping, and whether the study occurred in aquatic or terrestrial habitats). Journal titles were used to classify each of the papers using the following disciplinary categories: acoustics, behaviour, captive animals and welfare, conservation and management, ecology, environment, general biology, taxon-specific, physiology, and other. In addition, studies were classified based on the type of anthropogenic noise source, the acoustic metrics reported to describe the noise source and the biological responses measured in the study (see online Supporting Information, Appendix S1 for full details of extracted information).

Prior to commencing the full literature review process, we characterised ten randomly selected publications as a group to ensure accuracy and consistency of reporting across individual reviewers. Each of the authors then characterised a subset of the publications (five studies) across all 21 attributes to ensure that definitions of categories were

clear and assignments were unambiguous. To improve the consistency of the data-collection process further, each paper was reviewed independently by at least two authors with G.S. and M.F.M. resolving any inconsistencies.

(1) Noise-source categories

We considered all anthropogenic sound sources as noise, regardless of whether the noise was intentionally produced, such as seismic exploration, sonars, acoustic deterrents, or an unintended by-product of human activity such as maritime shipping, traffic corridors, and construction. Furthermore, we categorised noise sources based on anthropogenic activity, not necessarily the characteristics of the noise stimulus, although we also recorded and present this information (see online Appendix S1). Six noise-source categories were used: environmental, transportation, industrial, military, recreation, and other.

Studies were assigned to the environmental noise category when the noise investigated was not attributed to a specific source, but rather included all the acoustic energy generated by human activity at a given location and time, also known as urban noise or background noise. In many cases, these acoustic environments include sources from the other defined noise categories that were not identified in the experimental design. Noise sources in the transportation category comprised both commercial and private vehicles, including road traffic (motorcycles, automobiles, buses), waterway traffic (boats, ferries, commercial ships, and non-military aerial traffic (commercial jets, helicopters)). Studies that investigated specific recreational activities, such as whale-watching boats and air tour helicopters, were separated from the transportation studies. The industrial noise source category included studies that examined the effects of energy exploration (e.g. seismic surveys), construction (e.g. pile driving), and the operations associated with different energy sectors. Military sources included gunfire, explosions, aircraft, naval sonar, and in some cases, entire military training operations. We categorised the remainder of the studies as 'other', with most studies in this category using a simulated noise source, such as white noise, and not representing a specific human activity.

(2) Acoustic measurements

We evaluated if complete and accurate characterisation of acoustic environments, signals or stimuli, was provided. Information was collected on the acoustic metrics reported, where the reported level was measured (i.e. on site, on animal, not reported, estimated), and if background sound levels were measured. In addition, we recorded whether details on spectral characterisation (e.g. bandwidth and frequency weighting and analysis (e.g. duration of measurement, sampling frequency, reference pressure) were reported. If details on the analysis of the acoustic data were not presented, we noted whether the study referenced an established standard or included details on the settings of a commercially available instrument.

(3) Biological responses

A categorical framework was developed to summarise the biological responses measured in each study. The biological responses were classified into nine distinct categories to help assess the distribution of studies across types of responses. These included: (i) physiology (stress, hearing loss/damage, immune function, gene expression); (ii) direct fitness metrics (survival, fecundity, clutch size); (iii) mating behaviour (attraction, mating success, territorial behaviour, pair bonding); (iv) foraging behaviour (foraging rate, predation rate, hunting/foraging success); (v) movement (spatial distribution, fleeing rate, avoidance, dive pattern); (vi) vigilance; (vii) vocal behaviour (call rate, intensity/amplitude, frequency shift, song length, call type, signal timing); (viii) population metrics (abundance, occupancy, settlement, density); and (ix) community-level metrics (species composition, predator-prey interactions). If studies measured multiple biological responses, a second category was noted.

III. STATE OF THE KNOWLEDGE

Research on the impacts of anthropogenic noise on wildlife has steadily risen over the past two decades (1990–2013), with a rapid increase in the volume of published, peer-reviewed articles since 2010 (Fig. 1). The 242 studies that we reviewed have been published in 97 scientific journals, covering a broad range of scientific disciplines from general biology to conservation to physiology (Table 1). Documented responses to a variety of anthropogenic noise sources (Table 2) have included shifts in physiology (e.g. impaired hearing, elevated stress hormone levels), alteration of key behaviours (e.g. foraging, vigilance, movement), and interference with ability to detect important natural sounds (e.g. vocalisations of conspecifics) (Table 3). In the following sections, we explore topics that emerged from our analysis of the existing literature and provide supporting examples.

(1) The taxonomic and geographical diversity of noise research

Many animals have specialised auditory organs and utilise sound for a variety of ecological functions from navigation and detection of resources to alerting conspecifics to the presence of predators. It is not surprising that noise impacts have been investigated in many taxonomic groups of animals, including vertebrates and invertebrates, and across a diverse range of terrestrial and aquatic habitats (Table 1). This broad taxonomic and geographic sampling is crucial to understanding how animals respond to noise across a range of auditory capabilities, behavioural contexts, levels of prior exposure, and noise sources. Further, investigating the effects of noise on a diversity of taxa within a study system enables detailed exploration of the complex and

potentially differential responses to the same noise source. For example, in the woodlands of north-western New Mexico, USA, species richness of nesting birds was reduced as a function of anthropogenic noise, but birds that were able to tolerate noisier habitats had higher reproductive success due to reduced predation (Francis, Ortega & Cruz, 2009).

Although the published literature includes broad taxonomic sampling, birds and marine mammals are by far the most studied groups (Table 1; Fig. 1). Terrestrial research has focused mainly on effects on vocal communication, while aquatic research has also explored noise effects on movement, foraging, and physiology (Table 3). Underrepresented taxa in the published literature include reptiles, amphibians, and invertebrates (Table 1). Invertebrate studies, for instance, contributed only 4% of the total data set, yet this group contains 97% of the world's documented animal species, fulfilling varied and important ecological roles, such as prey species, pollinators, and serving as sensitive indicators of environmental change (de Soto *et al.*, 2013). Invertebrate species also provide excellent model species for studying the complex effects of noise given their size, rapid generation time, and the ease of maintaining laboratory populations (reviewed by Morley *et al.*, 2013).

Similar to its taxonomic focus, research on the effects of anthropogenic noise on terrestrial systems has been geographically biased, with 81% of the research conducted in either North America or Europe (this includes all laboratory and theoretical studies), while South America, Asia, and Africa remain underrepresented (Table 1). Yet developing nations are likely to experience the greatest level of population and economic growth over coming decades (Bloom, 2011). This situation provides important opportunities and motivation to study the effects of noise in less-disturbed habitats and to introduce known mitigation strategies to avoid negative consequences, particularly given that South America, Asia, and Africa are also home to some of the most biodiverse regions on the planet (Jenkins, Pimm & Joppa, 2013). Individual-, population-, and community-level reactions to a novel noise stimulus will likely differ between areas previously exposed to anthropogenic noise over extended periods of time and areas where anthropogenic noise exposure is lower and the source was recently introduced.

(2) Isolating the effects of noise

Anthropogenic noise is commonly associated with human activities that produce multiple types of disturbances (e.g. visual, habitat fragmentation). A number of experimental approaches have been developed to isolate noise from these other confounding variables, these include natural experiments contrasting noisy and quiet areas while holding other variables constant (e.g. natural gas compressor studies; Habib, Bayne & Boutin, 2006; Bayne, Habib & Boutin, 2008; Francis *et al.*, 2009), and controlled playback experiments where noise is introduced in isolation to the other forms of disturbance (e.g. for free ranging populations of marine

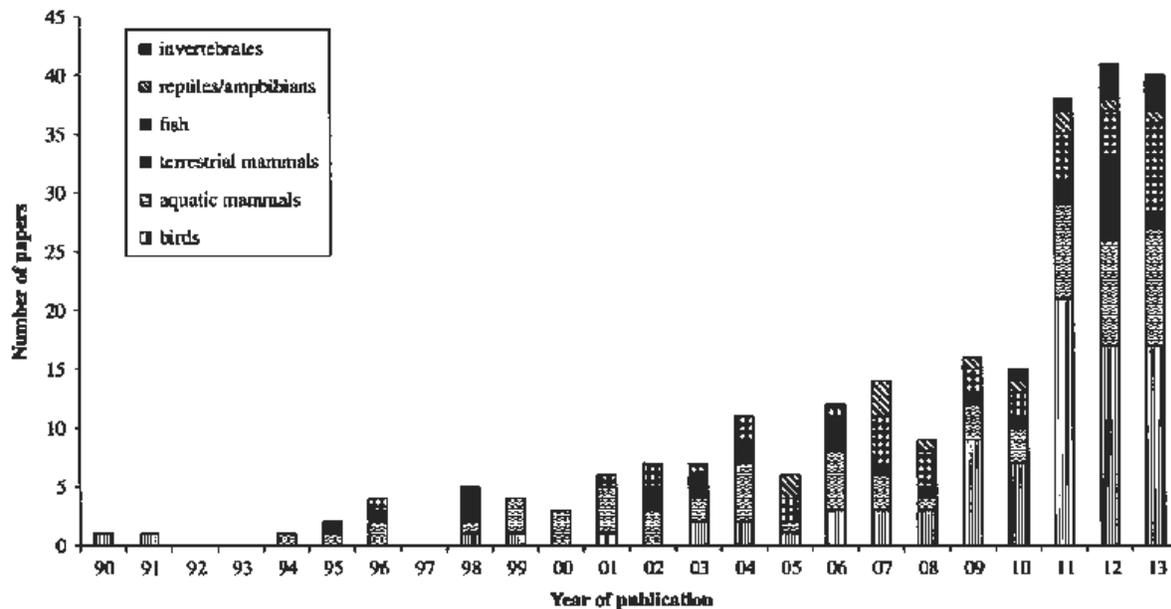


Fig. 1. Number of peer-reviewed publications reporting the effects of anthropogenic noise on wildlife from 1990 to 2013. Publications are divided into broad taxonomic categories: birds, aquatic mammals, terrestrial mammals, fish, reptiles/amphibians and invertebrates.

mammals and birds: Blickley, Blackwood & Patricelli, 2012a; Blickley *et al.*, 2012b; Goldbogen *et al.*, 2013; McClure *et al.*, 2013).

Studies that have isolated noise from potentially confounding variables have provided crucial evidence that noise alone can directly alter behaviour (Karp & Root, 2009; DeRuiter *et al.*, 2013b), reduce habitat quality (Blickley *et al.*, 2012b), and cause physiological impacts (Mooney, Nachtigall & Vlachos, 2009) across a range of species. For example, a recent playback study created a 0.5 km 'phantom acoustical road' to compare migratory bird habitat utilisation during 'on' and 'off' conditions (McClure *et al.*, 2013). The results from this sequence of trials, combined with concurrent observations of nearby control habitat (similar vegetation, no noise playback), provide decisive evidence that noise alone causes rapid changes in habitat use.

A combination of research approaches has proved important in identifying the consequences of noise disturbance. Natural experiments utilising existing acoustical gradients over time or space (48% of reviewed studies) have the potential to confound the effects of noise with other disturbances (see Summers *et al.*, 2011), but can be complementary to controlled playback experiments conducted on free-ranging populations (15% of reviewed studies). Furthermore, biologically relevant responses at the individual, population, and community level can be identified in the field, whereas noise and the specific mechanisms driving changes in behaviour and physiology can be isolated with greater ease under laboratory conditions (Kight & Swaddle, 2011).

(3) Relationship between the perception of noise and response

Biological responses to noise are varied (Table 3), in part because responses depend upon the perception of noise (reviewed by Francis & Barber, 2013). Noise can be perceived as a threat, as observed when animals respond similarly to playbacks of anthropogenic noise and predator calls (e.g. Tyack *et al.*, 2011). In other cases, noise causes sensory degradation or the inability to detect acoustic cues from conspecifics, predators, prey or the environment, which can alter predator-prey interactions (Siemers & Schaub, 2011), reduce reproductive success (Halfwerk *et al.*, 2011b), and change settlement dynamics (Holles *et al.*, 2013). Additionally, noise can distract animals from attending to more crucial stimuli in the environment (Chan *et al.*, 2010), it can be a direct stressor causing pain or elevated stress hormone levels (Blickley *et al.*, 2012b; Rolland *et al.*, 2012), or in some instances, noise may provide a shelter from disturbance-sensitive predators (Francis *et al.*, 2009; Brown *et al.*, 2012).

The mechanisms by which animals respond to noise are not necessarily mutually exclusive. For example, animals that remain in a 'noisy' habitat because it provides a shelter from predators will likely have to contend with sensory degradation, either through changes in vocalisations (Mockford & Marshall, 2009; Mockford, Marshall & Dabelsteen, 2011) or vigilance patterns (Quinn *et al.*, 2005; Rabin, Coss & Owings, 2006). Noise can also induce the same response via compound mechanisms; for instance, reductions in foraging activity may be driven by a combination of increased perceived predatory threat,

Table 1. Summary of peer-reviewed literature reporting the effects of anthropogenic noise on wildlife published from 1990 to 2013 ($N = 242$)

Journal type	Taxon-specific	Environment	Conservation and management	Behaviour	Acoustics	Ecology	Physiology	Captive animals & welfare	Other
General biology									
22%	13%	13%	12%	12%	11%	8%	3%	2%	2%
Taxonomic diversity									
Birds	Aquatic mammals	Fish	Terrestrial mammals	Reptiles/amphibians	Invertebrates	Multiple species			
37%	28%	15%	11%	4%	4%	1%			
Terrestrial geographic distribution ($N = 128$, two studies that occurred in both aquatic and terrestrial habitats were excluded)									
North America	Lab/theoretical	Europe	South America	Australia	Asia	Global	Africa	Antarctica	
36%	24%	21%	7%	7%	4%	1%	0%	0%	
Aquatic geographic distribution ($N = 110$, two studies that occurred in both aquatic and terrestrial habitats were excluded)									
Lab/theoretical	Atlantic Ocean	Pacific Ocean	Mediterranean Sea	North/Norwegian Sea	Arctic	Australia	Africa estuary	Antarctica	Indian Ocean
44%	25%	12%	7%	5%	3%	2%	1%	1%	1%
Noise sources									
	Transportation	Environmental	Industrial	Military	Other	Recreation			
Aquatic	28%	5%	30%	22%	12%	3%			
Terrestrial	30%	35%	13%	8%	12%	2%			
Biological responses									
	Vocalisation	Movement	Physiological	Population	Vigilance	Foraging	Mating	Direct fitness	Community
Aquatic	21%	37%	32%	4%	0%	4%	1%	2%	0%
Terrestrial	44%	15%	10%	16%	6%	2%	4%	2%	2%

Table 2. Proportion of studies in different noise-source categories

Noise-source category	Examples	Per cent of terrestrial studies	Per cent of aquatic studies
Environmental	General background noise (urban and developed areas, no specific source identified)	5	35
Transportation	Commercial (maritime shipping, commercial aircraft, train, bus) and private (general traffic, automobile, motorcycle, small boat) transport noise	30	13
Industrial	General construction, machinery, energy (wind, oil and gas) development and operation, pile driving, seismic survey (air-guns), echo sounder, and underwater communication network noise	23	8
Military	Gun fire, explosion, naval sonar, and aircraft noise	12	12
Recreation	Hunting, whale-watching, air tour, snowmobile, and race-track noise	3	2
Other	Simulated (white, pink, tones), human voice, alarm, aquarium, and chainsaw noise	27	31

distraction, stress-induced loss of appetite, and masking of prey cues (Bracciali *et al.*, 2012; Wale, Simpson & Radford, 2013).

Evidence suggests that the characteristics of the acoustic signal (e.g. frequency, duration, onset, intensity) and the biology of the species in question (e.g. hearing range, behavioural state, habitat, vocal behaviours) are important for predicting how noise is likely to affect a particular organism (reviewed by Francis & Barber, 2013; Parris & McCarthy, 2013). Chronic noise sources are likely to degrade auditory cues important for predator/prey detection (Siemers & Schaub, 2011), communication (Hatch *et al.*, 2012) and orientation (Ellison *et al.*, 2012), especially if the noise source is high intensity and overlaps in frequency with an organism's hearing capabilities or the sound of interest (e.g. footfalls, leaves rustling; see Goerlitz, Greif & Siemers, 2008). Shifts in vocal rate, call intensity, call type, call frequency (as reviewed by Slabbekoorn, 2013), and timing of singing (Fuller, Warren & Gaston, 2007), and duration of calling (Diaz, Parra & Gallardo, 2011) have been studied extensively among birds (and marine mammals) to explore how vocal communication is affected by anthropogenic noise (see Tables 1 and 3), and to examine possible behavioural adaptations that are employed to overcome masking. The link between vocal flexibility and persistence in noisy environments has been demonstrated in a number of species (Francis *et al.*, 2011*d*; Proppe, Sturdy & St Clair, 2013*b*) and vocal behaviour and ability to learn can influence a vocal response to noise (Hu & Cardoso, 2010; Rios-Chelén *et al.*, 2012). Recent theoretical work predicted the reduction in active space of vocal signals for birds moving from rural to urban habitat and identified the communication benefits of raising vocal frequency in noisy environments, particularly for species with calls in the lower frequency range (reviewed by Parris & McCarthy, 2013). Nevertheless, a change in vocalisation may come with significant consequences, including altered energy budgets and loss of vital information (Read, Jones & Radford, 2014).

Although explored to a lesser extent, responses to reduced cue detection, such as movement away from the noise (e.g. Miksis-Olds & Wagner, 2011; McLaughlin & Kunc, 2013) and a reduction in foraging efficiency (Schaub, Ostwald & Siemers, 2008; Siemers & Schaub, 2011), have also been demonstrated in the presence of chronic noise.

Noise sources that are novel, unpredictable, or are acoustically similar to biologically relevant sounds are predicted to elicit responses similar to those associated with predation risk (flee, hide, startle responses; reviewed by Francis & Barber, 2013). Although the sound must be detected, the noise does not need to overlap with peak hearing capabilities or be received at a high intensity to elicit antipredator behaviour. For example, beaked whales (*Ziphius cavirostris*) responded similarly to playbacks of military sonar and calls of killer whales (their main predator) (Tyack *et al.*, 2011). In this case sonar overlapped with the peak hearing range of the study species, but sonar also elicited antipredator responses in blue whales (*Balaenoptera musculus*) with hearing sensitivities in much lower frequencies (Goldbogen *et al.*, 2013), and failed to elicit responses in Atlantic herring (*Clupea harengus*), despite overlap with their most sensitive hearing range (Doksæter *et al.*, 2009). Thus, the frequency and intensity of noise are just a few of the factors driving responses, with temporal and spatial context of the disturbance, prior experience and similarity to relevant biological sounds also playing key roles (reviewed by Ellison *et al.*, 2012).

Current research is furthering our understanding of the specific mechanisms driving the observed biological responses to noise and the contextual factors that shape them. For example, the presence of young (Maier *et al.*, 1998), social status (Bruitjes & Radford, 2013), and spatial orientation relative to a noise source (Delaney *et al.*, 1999; Ellison *et al.*, 2012) can all drive differential responses. The duration and timing of noise stimuli are also important, as extended exposure to a chronic noise source may ultimately lead to tolerance or habituation, particularly if it provides an indirect benefit (e.g. a predator shelter; Francis *et al.*, 2009;

Table 3. Distribution of studies by biological response and noise source

	Biological response	Noise source				
		Environmental	Transportation	Industrial	Military	Other
All Studies (N=212)	vocal behaviour	20.3%	9.9%	1.4%	1.9%	2.8%
	movement	1.9%	4.2%	5.7%	6.1%	4.2%
	physiology	–	4.2%	5.2%	2.4%	7.5%
	population metrics	1.4%	4.2%	4.7%	0.5%	–
	vigilance	–	0.9%	0.5%	0.9%	0.5%
	mating behaviour	–	1.4%	0.9%	–	0.5%
	foraging behaviour	–	2.4%	–	0.5%	–
	direct fitness metrics	0.5%	0.5%	0.9%	–	–
	community-level metrics	0.5%	–	0.5%	–	–
	Terrestrial Studies (N=120)	vocal behaviour	–	11.7%	–	–
movement		2.5%	2.5%	–	3.3%	3.3%
physiology		–	0.8%	2.5%	0.8%	5.8%
population metrics		2.5%	5.8%	7.5%	0.8%	–
vigilance		–	1.7%	0.8%	1.7%	0.8%
mating behaviour		–	1.7%	1.7%	–	0.8%
foraging behaviour		–	1.7%	–	–	–
direct fitness metrics		0.8%	–	0.8%	–	–
community-level metrics		0.8%	–	0.8%	–	–
Aquatic Studies (N=92)		vocal behaviour	5.4%	7.7%	3.3%	4.3%
	movement	1.1%	6.5%	–	3.3%	5.4%
	physiology	–	2.2%	6.7%	4.3%	3.3%
	population metrics	–	2.2%	1.1%	–	–
	vigilance	–	–	–	–	–
	mating behaviour	–	1.1%	–	–	–
	foraging behaviour	–	3.3%	–	1.1%	–
	direct fitness metrics	–	1.1%	1.1%	–	–
	community-level metrics	–	–	–	–	–

Only studies that reported a statistically measured response were included. Colour shading indicates the relative number of studies in each category.

Brown *et al.*, 2012). Studies combining different metrics of response, such as spatial distribution and vocal activity, may offer further insight into the varied consequences and trade-offs for species and communities exposed to noise (McLaughlin & Kunc, 2013). Ultimately, predicting how noise characteristics, behavioural contexts, and animal biology interact will be central in identifying habitats that are of conservation concern and implementing effective mitigation strategies.

(4) Ecological consequences of noise

A diverse range of biological responses to noise, from altered hearing thresholds of captive fish to changes in movement and foraging behaviour of large marine mammals in the open ocean, have been measured. Of the 242 studies included in this review, 88% reported

a statistically measured biological response to noise exposure (see Table 3 & online Appendix 1 for further details). A small number of these studies have begun examining the impacts of noise using metrics associated with population persistence (survival, reproductive fitness), community interactions (predator–prey interactions), and ecosystem services (pollination) to understand the biological costs of anthropogenic noise. For example, studies on the impacts of noise to population persistence measured declines in productivity of breeding (Kight, Saha & Swaddle, 2012), reduction in fitness (Schroeder *et al.*, 2012), and change in timing of settlement (Pine, Jeffs & Radford, 2012).

Investigating the effects of noise on multiple taxa within a study system enables detailed exploration of the complex and interactive nature of noise impacts. Noise was found to impact key ecological services, enhancing pollination

via reduced predation in noisy areas for hummingbirds, while decreasing seed dispersal for dominant plants because key dispersers avoided noisy areas (Francis *et al.*, 2012). Investigating the effects of noise on lower trophic levels can also reveal community-level impacts of noise. For instance, exposure to continuous turbine noise interfered with natural settlement cues for two species of abundant estuarine crabs, likely disrupting food-web interactions (Pine *et al.*, 2012). Noise altered species interactions, including predator-prey interactions in terrestrial (Schaub *et al.*, 2008; Siemers & Schaub, 2011) and marine (Kuningas *et al.*, 2013; Wale *et al.*, 2013) communities, while social interactions of cichlid fish shifted in the presence of boat noise (Bruinjes & Radford, 2013). Although these studies did not directly test the consequences for community structure and function, changes in species interaction may ultimately translate into community-level effects.

The majority of noise research has used comparatively short-term natural or controlled experiments that commonly focus on behavioural change in single species and are spatially discrete. While this approach has proved pivotal in revealing the widespread impacts associated with noise, evidence for long-term effects on populations and communities is generally only suggestive. Long-term experiments conducted over broad spatial scales may offer a more complete understanding of the population-level and interacting effects of noise on wildlife.

(5) Application of research to develop and implement noise mitigation

The global increase in anthropogenic noise levels across both human-dominated and natural habitats presents a significant conservation challenge, especially when considered in conjunction with other threats to wildlife and ecosystem integrity. There is a real need for research on the impacts of noise on wildlife to translate into management actions or recommendations (Tabarelli & Gascon, 2005). While a variety of noise-mitigation methods exist, only 9% of the studies reviewed provided specific recommendations. Recommendations included the use of physical barriers to noise, geographical and temporal restrictions to human activity, and quiet technology (Table 4), yet few studies directly tested the effectiveness of these methods. The majority of studies with mitigation statements were published in conservation, ecology, and environmental journals and focussed primarily on terrestrial ecosystems.

Physical barriers are a commonly suggested mitigation tool that have been used along roadways to reduce noise levels for human populations (Murphy & King, 2011) and wildlife (Slabbekoorn & Ripmeester, 2008). However, the benefits of these barriers extend a relatively short distance. Barriers also can compound fragmentation effects by restricting animal movement, and their costs may well exceed other mitigation approaches (Summers *et al.*, 2011). Collectively, these considerations suggest that noise barriers are most suitable for roadside habitat of especially high

conservation value, or to enhance the effectiveness of road-crossing structures or tunnels. Alternative options to reduce road noise include restrictions to traffic flows during sensitive life-history periods, speed reductions, improved road surface substrates, and new tyre technology. Controlled studies documenting changes in wildlife behaviour and habitat utilisation in response to reducing roadway noise would extend the findings of recent noise broadcast studies, and document the conservation value of quiet-road investment.

The noise barrier approach can be effective for industrial activities such as resource extraction and construction, where machinery generates a point noise source that is spatially compact (Table 4). Specific methods have included the use of bubble curtains to reduce pile-driving noise in marine environments (Würsig, Greene & Jefferson, 2000), and the erection of sound barriers to minimise noise from terrestrial gas compressor stations (Francis *et al.*, 2011*a*). Implementing barrier mitigation measures may prove expensive (e.g. \$175–200 million to reduce oil and gas extraction noise by 4 dB; Bayne *et al.*, 2008), making it unlikely that industry will adopt these measures without specific regulations in place (Ortega, 2012).

(6) Characterising complex acoustic stimuli

Anthropogenic noise is a complex and challenging source of pollution to quantify, varying in duration, amplitude, and frequency content, while being modified by the medium through which it travels. The detailed reporting of acoustic measurements is necessary to repeat experiments, provide insight on the kinds of noise stimuli that induce a response, and synthesise results across studies. We were surprised that acoustic metrics and measurement methods were not always documented in these papers. Although the majority of studies used common acoustic metrics such as root-mean square sound pressure level (SPL), sound exposure level (SEL), or equivalent noise level (Leq) (see online Appendices S1 and S2 for descriptions of these metrics), 30% provided no details on the received sound levels of the noise stimulus and 10% simply reported a dB level without information on how the value was measured or calculated (Fig. 2). A notable proportion of studies (38%) lacked a record of the spectral analysis, such as duration of the measurement, frequency range, and weighting function (Fig. 2). Measurements of the background acoustic environment prior to exposure to a noise source (excluding the environmental noise category) were reported in only 53% of the literature (Fig. 2). Given the cross-disciplinary nature of terrestrial and aquatic bioacoustic research and the difference in reference pressure between air and water, it is surprising that the majority of studies (51%) did not report the reference pressure used when reporting a dB value (see Rossing, 2007 for further details). Ninety per cent of these studies were conducted in terrestrial environments, implying the use of the standard reference pressure in air, but this is a potential source of confusion (reviewed by Chapman & Ellis, 1998).

Table 4. Examples of reported mitigation methods for reducing the negative effects of noise on wildlife

	Environmental	Transportation	Industrial	Military
Birds	<p>Urban planning e.g. maintaining green spaces and reducing noise levels to maintain biological communities [3]</p> <p>Reduction of aircraft noise exposure to <80 dBA of river habitats used by harlequin ducks [5]</p> <p>Placement of new acoustically dominant features roads, machinery further from nesting areas, limits to production during sensitive periods of breeding; abatement of current noise by altering structures (e.g. sound walls, dense vegetation, removing highly reflective surfaces, rerouting traffic [6]</p>	<p>Engineering solutions e.g. road surfaces, tyres and vehicle engines that reduce noise [13]</p> <p>Closing key roads during breeding season; reducing traffic speed and volume [10]</p> <p>Use of 105 m hemispherical protection to eliminate owl flush response to overflights, minimising flights 3 h following sunset and preceding dawn; separating overflights by at least 7 days [2]</p> <p>Restricting traffic flow and heavy truck use [14]</p> <p>Wise planning along transportation corridors and mitigation of noise along their paths to enhance habitat for the highest number of bird species [16]</p>	<p>Use of sound barriers around compressors to reduce affected area by 70% and maintain occupancy and nest success rates [4]</p>	
Terrestrial mammals		<p>Setting criteria for height and density of road bordering vegetation, filling in gaps in tree lines and encouraging canopy growth [15]</p>	<p>Noise barriers; construction scheduling to avoid noise sensitive experiments [12]</p>	<p>Limiting military training exercises during calving and post-calving season [8]</p>
Aquatic fish/mammals		<p>Ship design and construction that includes methods to reduce underwater noise and limited navigation permitted within fish spawning grounds during the spawning season [17]</p> <p>Definition of noise-free areas or seasonal restriction of noise activities during sensitive biological periods [11]</p>	<p>Air bubble curtains and 'Hydro Sound Dampers' [18]</p> <p>Avoiding pile-driving during calving and when animals are in 500 m exclusion zone; soft start or alarm sound before operations; restricting operations to low tide; decoupling equipment from hull of piling vessel; use of bubble curtain within 25 m radius of the pile [1]</p>	<p>Use of dose function methods in predicting the harassment of marine mammals [20]</p> <p>Consider the likely contexts of exposure and the foraging ecology of baleen whales in planning military sonar operations [19]</p>

Table 4. Continued

	Environmental	Transportation	Industrial	Military
Reptiles & amphibians	Use of noise barriers on road network; construction of new roads at distances away from protected areas; technological advances; laws with standard noise emission for vehicles, speed and driver behaviour [7]	Dense vegetation along roadsides (as a less costly alternative to solid barriers) to attenuate traffic noise [9]		
Invertebrates			Applying the precautionary principle when planning high-intensity activities such as explosions, construction or seismic exploration, in spawning areas of marine invertebrates with high natural and economic value [21]	

[1] David (2006); [2] Delaney *et al.* (1999); [3] Fontana, Burger, & Magnusson (2011); [4] Francis *et al.* (2011*d*); [5] Goudie & Jones (2004); [6] Kight *et al.* (2012); [7] Lengagne (2008); [8] Maier *et al.* (1998); [9] Parris & Schneider (2009); [10] Parris *et al.* (2009); [11] Picculini *et al.* (2010); [12] Rasmussen *et al.* (2009); [13] Summers *et al.* (2011); [14] Zhang *et al.* (2012); [15] Zurcher, Sparks, & Bennett (2010); [16] Proppe *et al.* (2013*b*); [17] Liu *et al.* (2013); [18] Dähne *et al.* (2013); [19] Goldbogen *et al.* (2013); [20] Houser, Martin & Finnetun (2013*b*); [21] de Soto *et al.* (2013).

IV. IDENTIFYING NOISE LEVELS THAT ELICIT A BIOLOGICAL RESPONSE

Our compilation and synthesis of research on the effects of anthropogenic noise on wildlife offers an opportunity to identify the noise levels that elicit biological responses. To integrate information on wildlife responses to noise into a common framework, we identified a subset of studies (69 terrestrial and 62 aquatic) that documented a significant response to a noise stimulus and also reported an acoustic value and metric at which a response occurred. Our classification of a 'significant response' was based upon the study reporting a statistical change in the particular biological metric as a function of noise exposure. A variety of metrics with different frequency weighting and bandwidths were reported in this subset of studies (see online Appendix S2). It was not possible to adjust all values to a common acoustic metric to compare across studies. Instead, we reported the metrics used in each study and the specific sound level (see Fig. 3); this provided graphical indications of the different metrics to reveal potential artefacts or differences in interpretation (Madsen, 2005).

Extracted noise levels were sorted to produce a cumulative weight-of-evidence curve as a function of the noise level at which a biological response was documented, thereby summarising the number of studies reporting a response at or below a given noise level. We compiled the results for terrestrial and aquatic studies separately because they used

different reference pressures to derive noise levels. These cumulative curves span a wide range of species and biological responses, in addition to different acoustic metrics. This framework was modelled after a dose-response relationship, but each increment in the weight-of-evidence function does not represent an increasing number of responsive species. Rather, these curves depict an increasing number of studies documenting a response at a given noise level. Therefore, the curves suggest accumulation of evidence, not accumulation of response.

The cumulative weight-of-evidence curves provide support for natural resource managers seeking to establish management objectives for anthropogenic impacts or developing policy on noise (Fig. 3). For example, a limit on allowable noise levels can be supported by citing the percentage or number of studies that have documented biological impacts at or below that level. Lower noise thresholds are more protective, but they are supported by a smaller number of studies. Note that responses have been documented in terrestrial environments at noise exposure levels as low as 40 dB SPL, and 14 studies documented responses below 50 dB (Fig. 3A). Predictions of natural sound levels for the coterminous USA range from 24 to 40 dB (LA_{eq}, 1 s, median summer daytime level; Mennitt, Fristrup & Nelson, 2013). The terrestrial weight-of-evidence curve includes all noise-source categories and species groups, although representation is unbalanced (Table 5). Multiple bird studies documented changes in song characteristics,

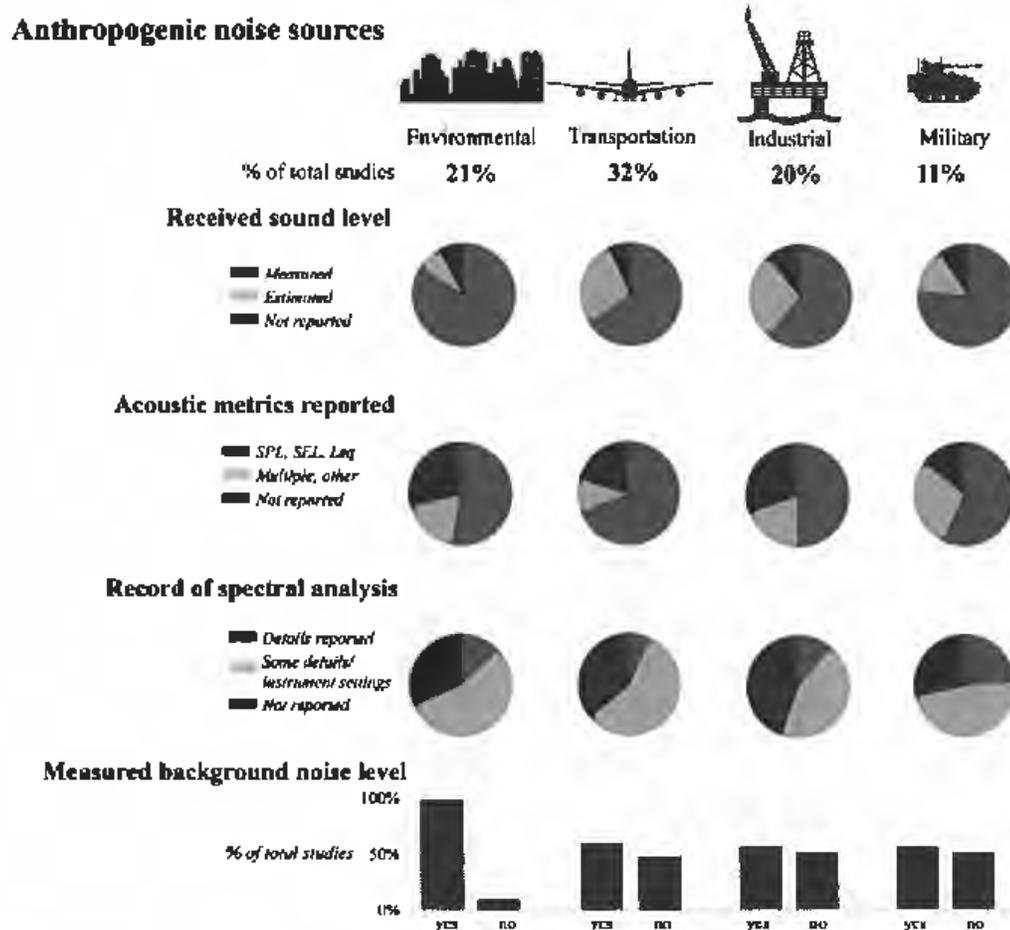


Fig. 2. Reporting of acoustic noise-source measurements. The chart divides all of the studies into noise source categories and highlights different components of acoustic analysis, including whether the received sound level was measured, the types of acoustic metric reported (see online Appendices S1 and S2 for acoustic metric definitions), whether details of the spectral analysis were provided and whether background noise was measured (note that background noise provided the noise source for most studies in the environmental category). Black-filled graphics indicate the proportion of studies in which details were not reported.

reproduction, abundance, stress hormone levels, and species richness at levels ≥ 45 dBA SPL (re 20 μ Pa). Terrestrial mammals exhibited increased stress levels and decreased reproductive efficiency at noise levels between 52 and 68 dBA SPL (re 20 μ Pa). Traffic noise exceeding 60 dBA SPL (re 20 μ Pa) impacted the vocal behaviour of male anurans and traffic noise exceeding 80 dBA SPL (re 20 μ Pa) reduced the foraging efficiency of gleaning bats.

The diversity of responses and metrics creates opportunities for misinterpretation. For example, it might seem reasonable to utilise the median of this cumulative distribution as a noise-impact criterion that is robustly supported by this body of literature. This would yield a value of 60 dB. This level would be cause for concern in a community setting; it causes conversational speech interference. The EPA (1974) recommended a 55 dB criterion to protect the health and welfare of the American public. The inflated character of this median can be

explained by examining the metrics associated with the points in Fig. 3A. Many of the studies that fall above the median utilised metrics that typically exceed LAeq (SPL max, SEL), or the studies did not specify the metric and measurement procedure. Accordingly, the most useful portion of this curve lies to the left of the median.

To provide insight into the relative effects of noise on humans and wildlife, the cumulative curve for the terrestrial wildlife studies was compared against human responses to noise derived from a meta-analysis of human survey data on annoyance at different noise levels (ANSI, 2005). The human response curve represents the predicted percentage of residents in quiet rural communities predicted to be highly annoyed by a new or unfamiliar noise source. Despite the heterogeneity in the wildlife noise metrics and responses, the range of noise levels documented to induce annoyance in humans and responses in terrestrial wildlife are similar (40–100 dB SPL re 20 μ Pa). Evidence

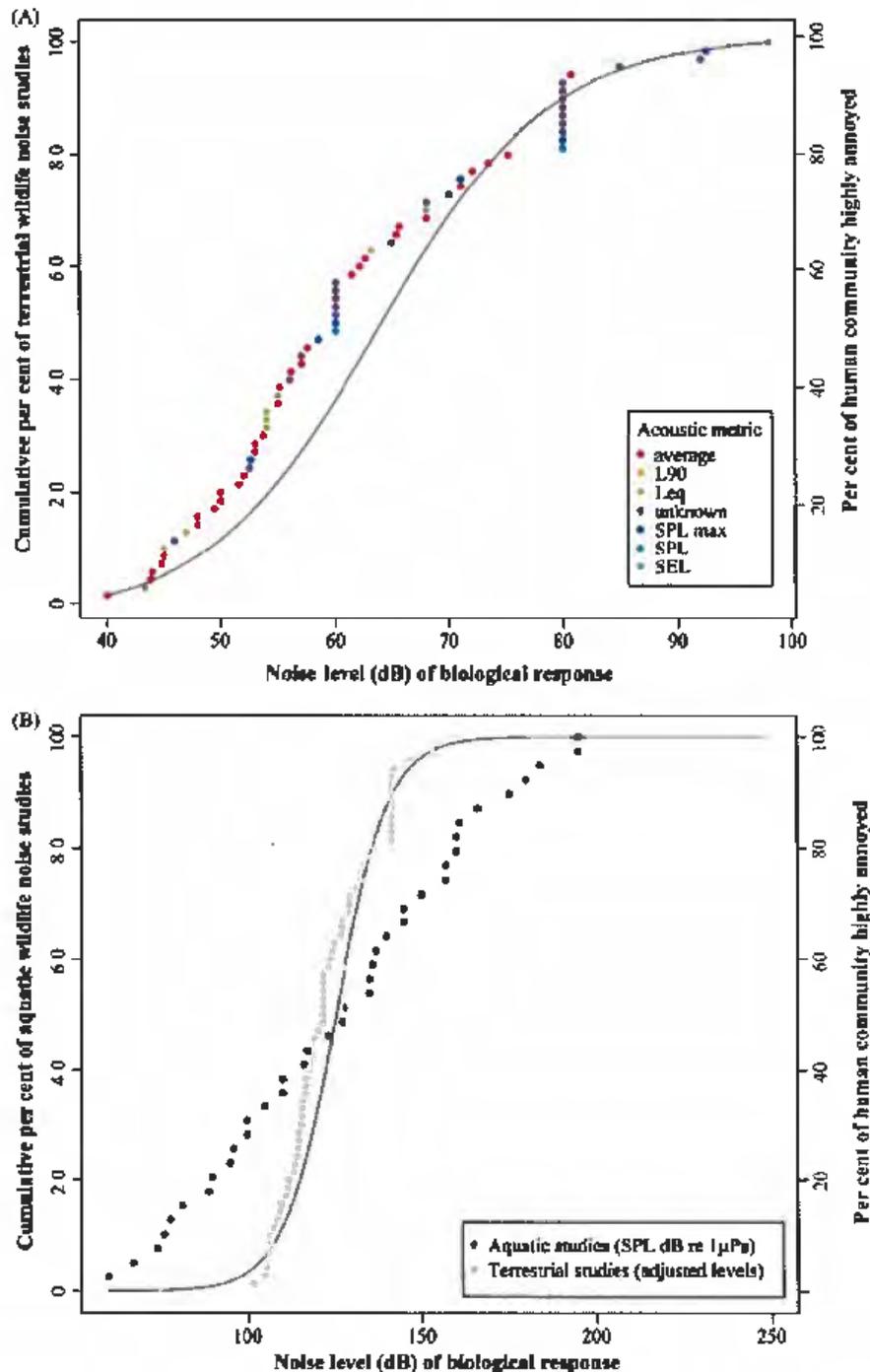


Fig. 3. Cumulative per cent of studies reporting biological responses by wildlife for a given noise level. Only studies that reported acoustic measurements are included ($N = 131$). See Appendices S1 and S2 for additional details on the noise levels, acoustic metric definitions, frequency weighting and bandwidths for each study used to generate these curves. (A) Results from terrestrial studies. Coloured symbols are used to reveal the potential influence of different metrics on the shape of the terrestrial curve. The human response curve (solid line) represents the predicted percentage of residents in quiet rural communities predicted to be highly annoyed by a new or unfamiliar noise source. (B) Results from the aquatic studies. Only SPL dB values were used to generate the cumulative curve. For comparison, received levels from the terrestrial wildlife studies and the human response curves (right y axis) are also plotted. The noise levels in the terrestrial wildlife and human studies were adjusted to the same scale as the aquatic studies. This was done by adding 61.5 dB to the sound level values to account for the difference in reference pressure and impedance.

for wildlife responses to noise accumulates at lower exposure levels than the rural human annoyance curve, although the slopes are similar. Another connection between human and wildlife noise studies is the onset of health effects. Epidemiological studies suggest that humans may experience elevated risk of hypertension when LAeq is greater than 55 dB (Stansfeld & Matheson, 2003). Physiological and fitness effects were documented by five papers included in this review at noise exposure levels of 52, 52, 58, 60, and 68 dBA SPL.

The aquatic studies generally provided better descriptions of their measurements, although in this literature variation in the bandwidth of the noise stimulus varies and presents a challenge for interpretation of the cumulative evidence curves. Fifty per cent of the aquatic studies measured a biological response at or below 125 dB (re 1 μ Pa) (Fig. 3B). The different reference pressure and acoustic impedances between air and water account for 61.5 dB of the differences in levels between terrestrial and aquatic studies (Leighton, 2012). The terrestrial data and human annoyance curves are included in Fig. 3B after accounting for this correction factor.

The studies contributing to the aquatic weight-of-evidence curve include all noise source categories and species groups (Table 6). Manatees shifted their foraging and movement behaviour when one-third octave band levels (4 kHz) exceeded 60 dB SPL, a notably low level. Otherwise, fishes, mammals, and invertebrates responded to noise across a wide range of noise levels (67–195 dB SPL re 1 μ Pa) (see online Appendix S2). Industrial noise, particularly high-intensity sound sources such as seismic air guns, impacted the physiology, vocal communication, and activity budgets of aquatic species, with reduced abundance and catch rates of fishes during relatively high levels of industrial noise (248 dB SPL re 1 μ Pa). Marine mammals responded to industrial noise by altering spatial movement patterns (107 dB Leq re 1 μ Pa), hearing thresholds (226 dB peak–peak re 1 μ Pa), and calling behaviour (82 dB SPL re 1 μ Pa) (Table 6). Naval sonar was the main source of concern in the military category (92% of aquatic studies with military sources). Sonar caused active avoidance, disrupted foraging, and temporary hearing loss among marine mammals in close proximity to the source (67 dB SPL re 1 μ Pa), yet showed limited effects on fish with all documented responses occurring at higher noise levels (195 dB SPL re 1 μ Pa) (Table 6).

V. RESEARCH RECOMMENDATIONS

Our review has highlighted the substantial body of information concerning the effects of anthropogenic noise on wildlife. Such research can assist scientists, natural resource managers, industry, and policy makers in both predicting potential outcomes of noise exposure as well as implementing meaningful thresholds and mitigation measures. Refinement and focus on several key research areas will further strengthen the conclusions and inferences that can be drawn regarding the impacts of noise on wildlife.

(1) Expand geographic and taxonomic sampling

Research on the effects of anthropogenic noise on terrestrial systems has been taxonomically and geographically biased, with 65% of studies conducted on birds and marine mammals and 81% of research carried out in either North America or Europe (includes all theoretical and laboratory-based studies). Investigating the effects of noise across a broader array of species and habitats is crucial for developing theories that explain variations in response to noise in terms of unique auditory capabilities, social structure, life history, ecological role, and evolutionary adaptation. Greater knowledge of taxon-level responses to noise will also be useful in predicting the likely responses of species that are too rare or elusive to study directly and may reveal responses in species previously thought unaffected because they occupy noisy areas (Shannon *et al.*, 2014) or have peak hearing sensitivities outside of a particular noise source (Goldbogen *et al.*, 2013).

(2) Explore interacting effects

In most cases, it remains unclear whether responses to noise will be further compounded by the introduction of potentially heterotypic stressors such as artificial light and habitat fragmentation. Designing studies that explore and quantify how the addition of other stressors influences observed biological responses to noise will facilitate evaluation of the benefit of reducing noise in environments facing multiple threats.

(3) Remove or reduce noise

Documenting biological responses in environments that have experienced a reduction in noise, such as closure of a road, closure of an energy facility, or a change in ship traffic routes, may reveal how systems recover from chronic noise exposure. Successful design requires knowledge and coordination with proposed changes in order to capture conditions prior to the reduction in noise levels.

(4) Invest in large-scale studies

To date there are very few studies that have attempted to explore the effects of noise at the landscape scale and/or over long temporal periods (e.g. seasonal, yearly), likely due to the logistical and experimental challenges that it presents, particularly in isolating the effects of noise from other sources of disturbance (e.g. habitat fragmentation, human presence). Nonetheless, in contrast to single-exposure, single-species research, larger-scale approaches can provide direct insight into the cumulative effects of noise exposure related to population persistence, ecological integrity, and evolutionary processes. Developing a systematic approach to sampling of multiple species within a community and multiple metrics of biological responses will therefore require coordination across scientific disciplines and organisations.

Table 5. Biological responses to different noise-source categories by terrestrial taxa. Studies in this table are included in Fig. 3A

	Environmental		Transportation		Industrial		Military		
Birds	Changes in frequency components of vocalisations [1–22]	44–73 dBA# 54 dBA** 60 dBA* 59 dBA+ 53–80 dBA?	Changes in frequency components of vocalisations [33–35]	60–65 dBA? 50 dBA#	Changes in song frequency and length [53]	45 dBA**	Increase in vigilance and alert behaviour [64, 65]	63 dBA** 80 dBA†	
	Changes in call rate and duration [14–18]	60 dBA* 48–66 dBA# 57 dBA?	Increase in amplitude of vocalisations [36]	57 dBA#	Increase in physiological stress levels [54]	52 dBA#			
	Increase in amplitude of vocalisations [19–23]	54 dBA\$,** 53–62 dBA# 80 dBA?	Shifts in timing of vocalisations [37]	80 dBA?	Reduced breeding success [55]	68 dBA#			
	Shifts in timing of vocalisations [24]	63 dBA#	Preference for roosting in quieter areas [38]	47 dBA**	Decline in occupancy and abundance [56–58]	48 dBA#			
	Decreases in acoustic complexity of songbird community [25]	53 dBA+	Reduction in reproductive success in presence of road noise [39]	68 dBA?	Changes in community and species interactions [59, 60]	55 dBA# 45 dBA# 60 dBC?			
	Decline in species diversity [26, 27]	40 dBA\$# 45 dBA*	Effects on physiology and development [40]	60 dBA†		50 dBC#			
	Avoidance of noisy environments [28]	70 dBA?	Changes in abundance, species richness, distribution and occupancy [41–43]	46 dBA? 45 dBA# 55 dBA**					
	Decline in reproductive success [29, 30]	58 dBA* 43 dBA***							
	Mammals	Shifts in call frequency and amplitude for echolocating bats [31]	80 dBA\$	Disruption of foraging in gleaning bats [44, 45]	80 dBA*	Increase in physiological stress from construction noise [61, 62]	52 dBA# 92 dBA?	Short-term increase in heart rates and shifts in resting and movement behaviours of ungulates [66–68]	85 dBA\$* 98 dBA† 92 dBA\$†
						Reduced reproductive efficiency of laboratory mammals exposed to construction noise [63]	68 dBA**		

Table 5. Continued

	Environmental		Transportation		Industrial		Military	
Reptiles and amphibians	Shifts in energy distribution of cicadas songs towards higher frequency [32]	62 dBC#	Reduction in chorus tenure and duration by male anurans exposed to traffic noise [46–48]	72 dBA#	60–80 dBC?			
			Difficulty locating mates [49]					75 dBC#
			Increased minimum frequency of vocalisations [50]					60 dBA?
			Change in calling time [51]					71 dBC†
Invertebrates			Higher frequency components in courtship signal of grasshoppers [52]	81 dBA?				

Symbols: * sound pressure level (SPL); ** equivalent continuous sound level (Leq or LAeq); † SPL max; ‡ sound exposure level (SEL); # average; ? unknown.

See Appendices S1 and S2 for acoustic metric definitions. **A-weighting**, like the human ear, cuts off the lower and higher frequencies that the average person cannot hear. At higher sound levels (100 dB and above), the ear's response is flatter, as shown in the **C-weighting**. **L** (linear) or **unweighted** (also known as **Z-weighting**) is a flat frequency response of 10–20 kHz \pm 1.5 dB.

‡ indicates studies where it was unclear if a frequency weighting function was applied.

[1] Pohl *et al.* (2012); [2] Seger-Fullam, Rodewald & Soha (2011); [3] Bermúdez-Cuamatzin *et al.* (2011); [4] Dowling, Luther & Marra (2012); [5] Bermúdez-Cuamatzin *et al.* (2009); [6] Mendes, Colino-Rabanal & Peris (2011); [7] Nemeth & Brumm (2010); [8] Hu & Cardoso (2010); [9] Proppe *et al.* (2012); [10] Slabbekoorn & Peet (2003); [11] Goodwin & Podos (2013); [12] Montagué, Danck-Gontard & Kunc (2013); [13] Nemeth & Brumm (2009); [14] Mockford & Marshall (2009); [15] Halfwerk & Slabbekoorn (2009); [16] Rios-Chelén *et al.* (2013); [17] Potvin, Parris & Mulder (2011); [18] Gross, Pasinelli & Kunc (2010); [19] Redondo, Barrantes & Sandoval (2013); [20] Pohl *et al.* (2009); [21] Nemeth *et al.* (2013); [22] Wood & Yezzerinac (2006); [23] Lowry, Lill & Wong (2012); [24] Fuller *et al.* (2007); [25] Pierotti & Farina (2013); [26] Patón *et al.* (2012); [27] Proppe *et al.* (2013b); [28] McLaughlin & Kunc (2013); [29] Kight *et al.* (2012); [30] González-Oreja *et al.* (2012); [31] Hage *et al.* (2013); [32] Shieh *et al.* (2012); [33] Halfwerk *et al.* (2011b); [34] Potvin & Mulder (2013); [35] Verzijden *et al.* (2010); [36] Brumm (2004); [37] Arroyo-Solis *et al.* (2013); [38] Zhang *et al.* (2012); [39] Halfwerk *et al.* (2011a); [40] Crino *et al.* (2013); [41] Arévalo & Newhard (2011); [42] Goodwin & Shriver (2011); [43] McClure *et al.* (2013); [44] Schaub *et al.* (2008); [45] Siemers & Schaub (2011); [46] Lengagne (2008); [47] Sun & Narins (2005); [48] Kaiser *et al.* (2011); [49] Bee & Swanson (2007); [50] Cunningham & Fahrig (2010); [51] Lampe *et al.* (2012); [52] Vargas-Salinas & Amézquita (2013); [53] Francis, Ortega, & Cruz (2011a); [54] Blickley *et al.* (2012b); [55] Schroeder *et al.* (2012); [56] Bayne *et al.* (2008); [57] Blickley *et al.* (2012a); [58] Francis, Ortega, & Cruz (2011c); [59] Francis *et al.* (2009); [60] Francis *et al.* (2012); [61] Powell *et al.* (2006); [62] Westlund *et al.* (2012); [63] Rasmussen *et al.* (2009); [64] Conomy *et al.* (1998); [65] Goudie & Jones (2004); [66] Krausman *et al.* (1998); [67] Maier *et al.* (1998); [68] Weisenberger *et al.* (1996).

Table 6. Biological responses to different noise-source categories by aquatic taxa. Studies in this table are included in Fig. 3B

Environmental		Transportation		Industrial		Military		
Fishes			Decrease in detection of communication signals and increase in stress hormones [5–7]	135 dBL** 111 dBL** 153 dBL**	Change in the movement behaviour of fishes [23, 24]	195 dB* 147 dB‡	Change in movement behaviour in the presence of sonar signals [39]	137 dB*
			Changes in spatial movement and orientation [8–10]	142 dB** 135 dB* 90 dB*	Reduction in local abundance and catch rate [25]	248 dB†	Auditory threshold shift in fish exposed to low frequency active (LFA) sonar [40, 41]	193 dB† 195 dB*
			Changes in territorial and social behaviour [11, 12]	161 dBL** 127 dB*	Damage to fish ears [26, 27]	180 dB* 174 dB‡		
			Temporary loss in hearing [13]	142 dBL**				
Mammals	Adjustments to vocalisation and singing behaviour [1–3]	110 dB# 105 dB* 117 dB#	Loss of communication space [14]	166 dB*	Changes in movement behaviour [28–32]	184 dB* 170 dB† 116 dB** 107 dB** 139 dB‡	Change in auditory response [42–45]	196 dB+ 67 dB* 75 dB* 210 dB‡
	Changes in the proportion of time spent feeding and milling [4]	60 dB*	Adjustment to vocalisation and singing behaviour [15, 16]	110 dB* 135 dB* 95 dB*	Shifts in hearing thresholds after exposure to seismic airguns [33]	226 dB+	Disruption in trained behaviour [46, 47]	150 dB* 175 dB*
			Increase in stress hormones [17]		Changes in vocalisations [34, 35]	82 dB# 116 dB#		
			Change in spatial movement patterns [18–20]	78 dB* 161 dB* 74 dB*			Change in spatial distribution and behaviour [48–51]	128 dB# 140 dB* 89 dB* 116 dB+
Invertebrates			Increase in larval settlement [21]	100 dB*	Damage to sensory systems in cephalopod [36]	157 dB*		
			Disruption of foraging and anti-predator behaviour [22]	145 dB*	Development delays and body malformations [37, 38]	136 dB* 145 dB*		

Symbols: * sound pressure level (SPL); ** equivalent continuous sound level (Leq); † SPL max (Lmax, peak SPL); ‡ sound exposure level (SEL); + SPL peak – peak.

See Appendices S1 and S2 for acoustic metric definitions

[1] Holt, Noren, & Eamons (2011); [2] Parks *et al.* (2011); [3] Scheifele *et al.* (2005); [4] Miksis-Olds & Wagner (2011); [5] Codarin *et al.* (2009); [6] Vasconcelos, Amorim, & Ladich (2007); [7] Wysocki, Dittami, & Ladich (2006); [8] Picciulin *et al.* (2010); [9] Sarà *et al.* (2007); [10] Holles *et al.* (2013); [11] Sebastianutto *et al.* (2011); [12] Bruinjes & Radford (2013); [13] Liu *et al.* (2013); [14] Hatch *et al.* (2012); [15] Holt *et al.* (2009); [16] Meleón *et al.* (2012); [17] Rolland *et al.* (2012); [18] Lermon *et al.* (2006); [19] de Soto *et al.* (2006); [20] Tripovich *et al.* (2012); [21] Wilkens, Stanley, & Jeffs (2012); [22] Wale *et al.* (2013); [23] Wardle *et al.* (2001); [24] Fewtrell & McCauley (2012); [25] Engås *et al.* (1996); [26] McCauley, Fewtrell, & Popper (2003); [27] Casper *et al.* (2013); [28] Brandt *et al.* (2011); [29] Gosd (1996); [30] Kastelein *et al.* (2005); [31] Kastelein *et al.* (2006); [32] Dähne *et al.* (2013); [33] Finneran *et al.* (2002); [34] Risch *et al.* (2012); [35] Blackwell *et al.* (2013); [36] Solé *et al.* (2013); [37] de Soto *et al.* (2013); [38] Pine *et al.* (2012); [39] Dokxater *et al.* (2012); [40] Popper *et al.* (2007); [41] Halvorsen *et al.* (2013); [42] Finneran *et al.* (2000); [43] Kastelein, Hoek, & de Jong (2011a); [44] Kastelein, Hoek, & de Jong (2011b); [45] Mooney *et al.* (2009); [46] Houser, Martin, & Finneran (2013a); [47] Houser *et al.* (2013b); [48] McCarthy *et al.* (2011); [49] Tyack *et al.* (2011); [50] Deruiter *et al.* (2013a); [51] Deruiter *et al.* (2013b)

(5) Measure responses over a gradient of noise levels

Additional studies are needed that investigate a gradient of noise exposure rather than quiet *versus* loud treatments. A gradient design provides insight on the levels of noise at which a response is initiated and how the response changes with increasing noise levels. This design can also reveal how animals recover from exposure to noise, while exploring the relationship between levels and duration of noise exposure and habituation or sensitisation by different species.

(6) Evaluate mitigation measures

There is a need to evaluate the ecological benefit of mitigation measures in both terrestrial and aquatic environments. Technological innovations (such as quieter ship propellers, ear and aeroplane engines, tyres, and asphalt), modifications to standard operations (e.g. slower ship and vehicle speeds, traffic flow control, road closures), and sound barriers can significantly reduce noise levels in a particular habitat; however the benefits to wildlife are not fully understood. For example, how long does a road need to be closed for the biological community to recover from traffic noise? Do the unintended consequences of sound barriers (e.g. fragmentation or acoustically reflective surfaces) outweigh the benefits (Parris & Schneider, 2009)? Further, design and implementation of mitigation methods should match the timing and locations of biological activity, particularly during biologically sensitive periods, such as breeding (e.g. lekking behaviour in sage grouse *Centrocercus urophasianus*; Blickley *et al.*, 2012a,b) or seasonal movement (e.g. spring migration in cetaceans; Patenaude *et al.*, 2002).

(7) Improve reporting of acoustic metrics

Identifying the conditions that elicit biological responses is impossible without exposure information. Relevant details should include specification of acoustic metrics, temporal characteristics of the measurement ('duration of recordings'), frequency range measured, weighting filters applied, and the reference pressure used. Additionally, recording equipment and measurement procedures ('distances and duration') should be documented for the source and received levels. Spectral descriptions or graphics provide important detail on the dominant frequencies of the noise source and can be compared to the hearing sensitivities of different species. The current state of the literature limits proper meta-analytical approaches that would allow compilation, comparison, and projection.

VI. CONCLUSIONS

(1) The substantial body of scientific research reviewed here provides considerable evidence that anthropogenic noise is detrimental to wildlife and natural ecosystems.

(2) Expertise from a diverse range of disciplines is required to improve understanding of the impacts associated with noise, especially considering that the effects may be expressed from the cellular to the ecosystem level.

(3) It is essential that research on the effects of anthropogenic noise evolves to report acoustic metrics accurately, test gradients of noise exposure, measure long-term consequences of responses to noise, assess cumulative effects of disturbance, investigate effectiveness of mitigation measures and recovery from chronic noise exposure, and fill in gaps with more diverse taxonomic groups and noise sources.

(4) We provide a cumulate weight-of-evidence summary of the recent literature, an initial step in providing guidance for natural resource managers when evaluating anthropogenic impacts or developing conservation policy.

(5) The interface between marine mammal research, regulation, and mitigation regarding noise provides an exemplar for controlling impacts for other taxa and ecosystems (Southall *et al.*, 2007; Stokstad, 2014). While the strides taken in the past decades have been impressive and provide a solid basis for shaping this critically important field of research, future activities should attempt to manage these impacts on temporal and spatial scales relevant to wildlife.

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IX. SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article.

Appendix S1. Summary of information gathered from all studies used in this review.

Appendix S2. Summary of information gathered from studies used to generate Fig. 3.

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**Swainson's Hawk
Survey Protocols, Impact Avoidance, and Minimization Measures
for Renewable Energy Projects in the Antelope Valley of Los Angeles and Kern
Counties, California**

State of California
California Energy Commission and Department of Fish and Game
June 2, 2010

Swainson's Hawk Background Information

The Swainson's hawk (*Buteo swainsoni*) is listed as a California state threatened species under the California Endangered Species Act (CESA). The species is not listed as threatened or endangered under the federal Endangered Species Act. To comply with state wildlife protection requirements and receive project approvals, renewable energy project developers proposing projects in the Desert Renewable Energy Conservation Plan (DRECP) area may be required to conduct surveys and avoid or minimize impacts to Swainson's hawks and related nesting and foraging habitat. The survey protocols and mitigation and monitoring plan recommendations provided below suggest approaches and measures for complying with protection requirements.

Antelope Valley Swainson's hawks are known to have historically nested in Joshua tree woodlands and foraged in grasslands and native desert scrub communities. Currently, they nest in Joshua tree woodlands, ornamental roadside trees, and windrow or perimeter trees in active and historical agricultural areas. Foraging habitat includes dry land and irrigated pasture, alfalfa, fallow fields, low-growing row or field crops, new orchards, and cereal grain crops. Swainson's hawks may also forage in grasslands, Joshua tree woodlands, and other desert scrub habitats that support a suitable prey base. Gophers dominate the prey base of agriculturally based pairs while Swainson's hawks nesting in natural desert habitats consume a wider variety of prey species. While California's Central Valley Swainson's hawk population winters in Mexico, Central America South America, and a small percentage in the Central Valley, the migration habits of the Antelope Valley population are unknown. Recent observations suggest that they may arrive in nesting territories generally later than the Central Valley Population (Pete Bloom, raptor biologist, personal communication).

Environmental Review Considerations

The California Environmental Quality Act (CEQA), Warren-Alquist Act and implementing regulations, and CESA require consideration of direct, indirect, temporary, permanent, individual project, and cumulative impacts. CEQA allows approval of projects with significant effects when measures have been included to avoid or mitigate those effects, or specific considerations make such measures infeasible and specific benefits outweigh the significant effects. (CEQA Guidelines §21081). CESA regulates the

taking of state-listed species. "Take" is defined as to "hunt, pursue, catch, capture, or kill, or to attempt to hunt, pursue, catch, capture, or kill." (Fish and Game Code §86). Incidental take authorization requires that all impacts to the species are minimized and fully mitigated and that mitigation is roughly proportional to the extent of the impacts of the taking. (14CCR § 783.4). This "full mitigation" standard is intended to ensure that the status of the species is the same or better after project and mitigation implementation as it was prior to project implementation.

Renewable energy project development could cause direct, indirect, individual, and cumulative adverse impacts to Swainson's hawks when facility construction and operation areas (such as wind turbines, power plants, solar panels and tower sites, access roads, staging areas, and pulling/splicing locations) occur in areas where hawks are present. Potential impacts include loss of foraging habitat and disruption of breeding activities due to increased dust, noise, and human presence. Direct mortality from vehicle strikes and collisions with wind turbines is also known to occur. Construction disturbance during the breeding season and habitat loss could cause incidental loss of fertile eggs or nestlings, or otherwise lead to nest abandonment.

The current land uses in the Antelope Valley area support approximately 10 breeding pairs. This area comprises the southernmost edge of the known breeding range for this species in California. The small number of breeding Swainson's hawks in the Antelope Valley and the potential isolation from other Swainson's hawk populations makes the Antelope Valley population particularly susceptible to extirpation. Swainson's hawks have high nest site fidelity, meaning they return to the same site year after year (Estep 1989, Woodbridge et al. 1995). This may limit exchange of individual birds between distant breeding groups (Hull et al. 2007). Hull et al. (2007) found evidence suggesting that the Central Valley population has had little recent genetic exchange with other populations east of the Sierra Nevada. Due to the geographical isolation of the Antelope Valley Swainson's hawk population from other breeding populations, together with the species' high site fidelity, it is reasonable to infer that rapid re-colonization of the Antelope Valley would be unlikely if nesting pairs were lost. Given these facts, the California Department of Fish and Game (Department) would consider impacts to breeding pairs to be potentially significant because they may cause the population to become less than self-sustaining.

A substantial reduction in numbers or habitat of a rare, threatened, or endangered species would be considered a significant impact under CEQA. Potentially significant impacts may result from activities that cause nest abandonment, loss of nest trees, loss of foraging habitat that would reduce nesting success (loss or reduced health or vigor of eggs or young), or direct mortality. Due to the Swainson's hawk's known preference for areas of low vegetation that support abundant prey, such as grasslands or alfalfa fields (Becherd 1982, Babcock 1995), the Department considers conversion of foraging areas to renewable energy power plant facility sites to be habitat loss. For example, solar panel arrays are expected to eliminate most or all foraging potential. Significant habitat loss may result from individual projects and cumulatively, from multiple projects. Each

project which contributes to a significant cumulative effect must offset its contribution to that effect in order to determine that the cumulative impacts have been avoided.

The Department considers a nest site to be active if it was used at least once during the past 5 years. Impacts to suitable habitat or individual birds within a five-mile radius of an active nest will be considered significant and to have the potential to "take" Swainson's hawks as that term is defined in §86 of the Fish and Game Code. Please consult with the Department when determining whether "take" authorization is warranted for a specific project.

Special Considerations for Wind Energy Development

Wind turbines present an additional, continuous, long-term risk of Swainson's hawk take throughout the life of a project. This continuous risk is not always considered in the environmental analyses for other types of projects that may have limited short-term impacts (e.g. construction related impacts). It has been documented elsewhere in California that Swainson's hawks are killed by wind turbines. Turbine strikes could occur during migration or during the nesting season. Swainson's hawk surveys for wind energy development should follow the same methods as for solar energy projects, described below, but the impacts analysis and corresponding mitigation should consider the additional continuous long-term risk of turbine-related fatalities. Habitat impact analysis should consider both the ground surface area and the air space that is used by Swainson's hawks. The mitigation methods described below are specific to ground surface impacts. Wind energy development project proponents should consult with the Department to develop avoidance measures and mitigation specific for the loss of air space and the potential for on-going take of Swainson's hawk during project operations." For additional avian considerations that are applicable to Swainson's hawk, please refer to the "California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development" (California Energy Commission and California Department of Fish and Game 2007). The guidelines can be found at <http://www.energy.ca.gov/windguidelines/index.html>.

Survey Protocol

The following survey protocols and monitoring/mitigation recommendations suggest surveys and acquisition of mitigation lands prior to construction of the project if nests are found within five miles of a project site. Before conducting surveys for a particular project, project developers are encouraged to contact the Department and the appropriate lead agencies for up-to-date, site-specific issues and possible refinement of the following survey protocols and monitoring/mitigation recommendations. Survey methods may be flexible depending on surveyor experience and/or already-known nesting status for a given site. Please contact the Department (Region 4 for Kern County and Region 5 for Los Angeles County) to use an alternate survey plan from that suggested within this document.

A qualified raptor biologist with Swainson's hawk survey experience, approved by the Department and the appropriate lead agency, should conduct surveys in a manner that maximizes the potential to observe the adult Swainson's hawks and the nest/chicks via visual and audible cues within a five-mile radius of the project. All potential nest trees within the five-mile radius shall be surveyed for presence of nests. Surveys should be conducted prior to environmental analysis. Surveys should be repeated within the 5-mile radius if a survey season ensues or elapses before the onset of project related activities. If construction begins mid-survey season the year after the initial surveys, then the surveys should continue for that part of the season before construction.

Examples of suitable habitats are Joshua tree woodlands, grasslands, desert scrub communities, and agricultural lands (such as alfalfa, fallow fields, beet, tomato, onions, and other low-growing row or field crops, dry-land and irrigated pasture, cereal grain crops [including corn after harvest], and new orchards). Consult with the Department when determining whether the project site is within five miles of already-known nest sites. If hawks or known nest sites are found within the five-mile radius, consult with the Department and the appropriate lead agency for follow-up to the surveys.

Minimum Equipment

Minimum survey equipment includes a high-quality pair of binoculars and a high quality spotting scope. Surveying even the smallest project area will take hours, and poor optics often result in eye-strain and difficulty distinguishing details in vegetation and subject birds. Other equipment includes good maps, GPS units, flagging, and notebooks.

Walking vs Driving

Driving or "windshield surveys" are usually preferred to walking if an adequate roadway is available through or around the project site. While driving, the observer can typically make a closer approach to a hawk without causing the bird to fly. Although it might appear that a flying bird is more visible, they often fly away from the observer using trees as screens; and it is difficult to determine from where a flying bird originated. Walking surveys are useful in locating a nest after a nest territory is identified, or when driving is not an option.

Angle and Distance to the Tree

Surveying subject trees from multiple angles will greatly increase the observer's chance of detecting a nest or hawk, especially after trees are fully leafed and when surveying multiple trees in close proximity. When surveying from an access road, survey in both directions. Maintaining a distance of 50 meters to 200 meters from subject trees is optimal for observing perched and flying hawks without greatly reducing the chance of detecting a nest/young. Once a nesting territory is identified, a closer inspection may be required to locate the nest.

Speed

Travel at a speed that allows for a thorough inspection of a potential nest site. Survey speeds should not exceed 5 miles per hour to the greatest extent possible. Stop frequently to scan subject trees with binoculars and a spotting scope.

Visual and Audible Cues

Focus surveys on both observations and vocalizations. Observations of nests, perched adults, displaying adults, and chicks during the nesting season are all indicators of nesting Swainson's hawks. In addition, vocalizations are extremely helpful in locating nesting territories. Vocal communication between hawks is frequent (1) during territorial displays, (2) during courtship and mating, (3) through the nesting period as mates notify each other that food is available or that a threat exists, (4) and as older chicks and fledglings beg for food.

Distractions

Minimize distractions while surveying. Although two pairs of eyes may be better than one pair at times, conversation may limit focus. Radios should be off, not only are they distracting, they may cover a hawk's call.

Notes and Species Observed

Take thorough field notes. Detailed notes and maps of the location of observed Swainson's hawk nests are essential for filling gaps in the California Natural Diversity Data Base; please note all observed nest sites, including date and time of observation, location name, UTM coordinates, number of young, and any behavioral observations. Also document the occurrence of nesting great horned owls, red-tailed hawks, red-shouldered hawks and other potentially competitive species. These species will infrequently nest within 100 yards of each other, so the presence of one species will not necessarily exclude another.

Timing

To meet *the minimum level* of protection for the species, surveys should be completed for *at least* the two survey periods immediately prior to a project's initiation. For example, if a project is scheduled to begin on June 1, you should complete three surveys in Period II and three surveys in Period III. However, it is always recommended that surveys be completed in Periods II, III, and IV prior to environmental review.

Survey Period I

Survey dates: January-March 31 (optional but recommended; pre-arrival)

Survey Time: All day

Number of Surveys: 1

Justification and search image: Prior to Swainson's hawks arrival from wintering grounds, it is very helpful to survey the project area to determine potential nest locations. Most nests are easily observed from relatively long distances, giving the surveyor the opportunity to identify potential nest sites, as well as becoming familiar with the project area. It also gives the surveyor the opportunity to locate and map competing species nest sites such as great horned owls from February on, and red-tailed hawks

from March on. After March 1, surveyors may observe Swainson's hawks staging in traditional nest territories.

Survey Period II

Survey dates: April 1 – April 30 (arrival; nest building)

Survey Time: All day

Number of Surveys: 3

Justification and search image: Most Antelope Valley Swainson's hawks return by April 1, and immediately begin occupying their traditional nest territories. For those few that do not return by April 1, there are often hawks ("floaters") that act as place-holders in traditional nest sites; they are birds that do not have mates, but temporarily attach themselves to traditional territories and/or one of the site's "owners." Floaters are usually displaced by the territories' owner(s) if the owner returns. Most trees are leafless and are relatively transparent; it is easy to observe old nests, staging birds, and competing species. The hawks are usually in their territories during the survey hours, but typically soaring and foraging in the mid-day hours. Swainson's hawks may often be observed involved in territorial and courtship displays, and circling the nest territory. Potential nest sites identified by the observation of staging Swainson's hawks will usually be active territories during that season, although the pair may not successfully nest/reproduce that year. Both males and females are actively nest building, visiting their selected site frequently. Later in this survey period, territorial and courtship displays are increased, as is copulation. The birds tend to vocalize often, and nest locations are most easily identified. This period may require a great deal of "sit and watch" surveying.

Survey Period III

Survey dates: May 1 – May 30 (egg laying; incubation)

Survey Time: daylight hours, as needed to monitor known nest sites only

Number of Surveys: 3

Justification and search image: Nests are extremely difficult to locate this time of year, and even the most experienced surveyor may miss them, especially if the previous surveys have not been done. During this phase of nesting, the female Swainson's hawk is in brood position, very low in the nest, laying eggs, incubating, or protecting the newly hatched and vulnerable chicks; her head may or may not be visible. Nests are often well-hidden, built into heavily vegetated sections of trees or in clumps of mistletoe, making them all but invisible. Trees are usually not viewable from all angles, which may make nest observation impossible. Following the male to the nest may be the only method to locate it, and the male will spend hours away from the nest foraging, soaring, and will generally avoid drawing attention to the nest site. Even if the observer is fortunate enough to see a male returning with food for the female, if the female determines it is not safe she will not call the male in, and he will not approach the nest; this may happen if the observer, or others, are too close to the nest or if other threats, such as rival hawks, are apparent to the female or male.

Survey Period IV

Survey dates: June 1 – July 15 (fledging)

Survey Time: Sunrise to 1200, 1600 to sunset

Number of Surveys: 3

Justification and search image: Young are active and visible, and relatively safe without parental protection. Both adults make numerous trips to the nest and are often soaring above, or perched near or on the nest tree. The location and construction of the nest may still limit visibility of the nest, young, and adults.

Reporting

Provide the Department and the appropriate lead agency with pre-construction survey results in a written report, within 30 days prior to commencement of construction activities. Report should include date of the report, authors and affiliations, contact information, introduction, methods, study location (include map), results, discussion, and literature cited. For surveys intended to support environmental impact analyses prior to project approval, provide the Department and the lead agency with written survey reports within 30 days of survey completion. Submit California Natural Diversity Database (CNDDDB) forms for any listed, fully protected, or species of special concern/countered and positively identified. CNDDDB forms may be found at the following link: http://www.dfg.ca.gov/bioqecode/cnddb/pdfs/CNDDDB_FieldSurveyForm.pdf.

Monitoring and Mitigation Plan Recommendations

1. If surveys locate a nest site, prepare a Swainson's hawk Monitoring and Mitigation Plan in consultation with the Department and the appropriate lead agency. Plans should be prepared by a qualified biologist approved by the Department and the appropriate lead agency. Include in the plans detailed measures to avoid and minimize impacts to Swainson's hawks in and near the construction areas. For example:
 - a. If a nest site is found, design the project to allow sufficient foraging and fledging area to maintain the nest site.
 - b. During the nesting season, ensure no new disturbances, habitat conversions, or other project-related activities that may cause nest abandonment or forced fledging occur within 1/2 mile of an active nest between March 1 and September 15. Buffer zones may be adjusted in consultation with the Department and the lead agency.
 - c. Do not remove Swainson's hawk nest trees unless avoidance measures are determined to be infeasible. Removal of such trees should occur only during the timeframe of October 1 and the last day in February.

2. Monitoring plans should include measures for injured Swainson's hawks:
 - a. For hawks found injured during project-related activities on the project site, plans should call for immediate relocation to a raptor recovery center approved by a Department regional representative.
 - b. A system should be set-up so that costs associated with the care or treatment of such injured Swainson's hawks will be borne by the project developer.
 - c. Include appropriate contact information for immediate notification of the Department and the appropriate lead agency of a hawk injury incident. Have approved procedures in place to notify the Department and the lead agency outside normal business hours. Notify the appropriate personnel via telephone or email, followed by a written incident report. Include the date, time, location, and circumstances of the incident in the reports.
3. Mitigation plans should focus on providing habitat management (HM) lands. Lands which are currently in urban use or lands that have no existing or potential value for foraging Swainson's hawks will not require mitigation nor would they be suitable for mitigation. The plans should call for mitigating loss of Swainson's hawk foraging habitat by providing HM lands within the Antelope Valley Swainson's hawk breeding range at a minimum 2:1 ratio for such habitat impacted within a five-mile radius of active Swainson's hawk nest(s). The Department considers a nest active if it was used one or more times within the last 5 years.

Project developers may consider delegating responsibilities for acquisition and management of the HM lands to the Department or a third party, such as a non-governmental organization dedicated to Mojave Desert habitat conservation. Seek approval of such delegations from the Department and the appropriate lead agency.

Approaches for acquisition and management of HM lands:

- a. HM Land Selection Criteria. Identify the region within which lands would be acquired, and the type/quality of habitat to be acquired. Foraging habitat should be moderate to good with a capacity to improve in quality and value to Swainson's hawks, and must be within the Antelope Valley Swainson's hawk breeding range. Foraging habitat with suitable nest trees is preferred.
- b. Review and Approval of HM Lands Prior to Acquisition. Provide an acquisition proposal to the Department and the appropriate lead agency for their approval at least 3 months before acquiring the property. The proposal should discuss the suitability of the property by comparing it to the selection criteria.
- c. Land Acquisition Schedule and Financial Assurances. Complete acquisition of proposed HM lands before initiating ground-disturbing project activities. If an irrevocable letter of credit or other form of security is provided, complete land acquisition within 12 months prior to beginning ground-disturbing project

activities. Provide financial assurances for dedicating adequate funding for impact avoidance, minimization and compensation measures required for project approval (see 3. d. below).

- d. **HM Lands Acquisition.** Be prepared to provide a preliminary title report, initial hazardous materials survey report, biological analysis, at a minimum to the Department and the appropriate lead agency. The information will likely also be reviewed by the California Department of General Services, Fish and Game Commission and/or Wildlife Conservation Board.

Fee title or conservation easement will likely be transferred to a Department of Fish and Game-approved non-profit third party and the Department, or solely to the Department. Be prepared to support enhancement and endowment funds for protection and enhancement of acquired lands. The Department will approve establishment and management of the funds, ensuring that qualified non-profit organizations or the Department will manage the funds in an appropriate manner. Contributed funds and any related interest generated from the initial capital endowment would support long-term operation, management, and protection of the approved HM lands, including reasonable administrative overhead, biological monitoring, improvements to carrying capacity, law enforcement measures, and any other action designed to protect or improve the habitat values of the HM lands. Be prepared to reimburse the Department or other entities for all land acquisition costs.

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CALIFORNIA AMPHIBIAN
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FOREWORD

California boasts one of the most biologically diverse faunas in the United States, as well as one of the most threatened. One of the key elements of the state's efforts to protect its vertebrate fauna is through its Species of Special Concern program. The current volume, *California Amphibian and Reptile Species of Special Concern*, is an essential foundation upon which both biologists and state and federal agencies can manage the biological resources of the state. California has exceedingly sensitive species and ecosystems, many of which are at risk of extirpation or extinction as the state's environment changes at rates greater than at any time in history.

This book builds upon the shoulders of its predecessor from two decades ago (Jennings and Hayes 1994a), but it is not just a simple update. Jennings and Hayes surveyed an enormous number of experts to create a comprehensive publication on California's special concern amphibians and reptiles, and their volume was a key management tool for a generation of biologists. However, this new book goes several steps further, making it a necessary reference for wildlife and land managers, biologists, and nature lovers interested in amphibians and reptiles.

First, the maps generated for this book are stunning. They are literally beautiful enough to

be framed, and detailed enough to guide resource managers. Second, there are color images of every taxon, generally taken in the field and highlighting the key features of each species. Third, the authors rely on the published literature to the maximum extent possible, pulling in the gray literature only when it is needed (which is often because many of these species are poorly known). But perhaps most importantly, the authors used multifactorial risk metrics that bring several measures of potential and actual threat into a single numeric score that captures the sensitivity of the species. The result is a tool that provides an important first pass at the difficult task of identifying those taxa that should be candidate Special Concern species.

Of course, there will always be important biological considerations that may argue against a strict interpretation of the metric scores, as the authors fully realize. For example, there are species on the Special Concern list that are so narrowly precinctive that the narrowness of their geographic range alone signals reason to be extra cautious about the species. The sandstone night lizard is one such taxon; its geographic range is much smaller than listed species such as black toad (*Bufo exsul*), and we know much less about the night lizard

than we do about black toads. Regardless of the risk model score, this is a scary situation, and the narrowness of geographic range alone signals reason to be extremely cautious. Herpetologists are well aware of extinctions of entire species that were so narrowly precinctive that very subtle (sometimes unknown) environmental changes have caused those extinctions (e.g., the golden toad of Costa Rica, which had a geographic range the same size as that of the sandstone night lizard).

There are other species covered in this volume that will be challenging to manage for their protection in California. For example, the Gila monster (*Heloderma suspectum*) can be found in the extreme eastern part of the Mojave Desert in California (east of 116° longitude), where it has been recorded fewer than 30 times in the last 150 years. Within the distribution of Gila monsters in California, the pattern of rainfall includes winter rains and summer (monsoonal) rains; this biphasic pattern is typical in Utah, Nevada, and Arizona where Gila monsters are relatively more common. Throughout their geographic range, Gila monsters depend upon climate conditions conducive for reproduction by small mammals because neonatal small mammals are the principal prey for this species. However, climate is demonstrably changing in California to be warmer (especially in summers) and with increased frequencies of drought. These changes may not be mitigable at a local level, and this creates conservation challenges. Nevertheless, knowledge of both changes of climate and the biology of Gila monsters is meager, and this signals both that the Gila monster is clearly a reasonable candidate for SSC status and a need for additional research.

In keeping with this example, this volume calls for significantly increasing research and monitoring of these species. This is a recommendation that must be taken very seriously. Change to California wildlife is accelerating at a more rapid rate than ever before in history, and the best chance to protect California's Species of Special Concern from extirpation or extinction is increasing our knowledge of these poorly studied animals. Long-term monitoring of the status of populations is key, and contemporary methods such as population genomics can provide insights into population status and viability that were not possible just a few years ago.

As complete as it is, this volume should be considered a beginning, rather than a final set of definitive answers, for understanding ecologically sensitive amphibians and reptiles in California. It constitutes an enormously valuable benchmark, and also provides solid information about the biology and ecology of amphibian and reptile species in California. Now we need to pursue its recommendations so that we can facilitate the needed science that will help us protect California's biological resources. California needs to expand science and management of the state's precious biological resources so that our children and grandchildren, hopefully, will be able to experience no fewer species than are present in California today. This book is an important step in that direction.

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PREFACE

California's amphibians and reptiles are unique in the United States for the tremendous amount of evolutionary and ecological diversity that they represent. California is second only to Texas in terms of the number of native amphibians and reptiles found within a state and contains endemic species of all major groups except turtles and tortoises. The state is home to what might be the best-known example of ring speciation (in *Ensatina* salamanders), which provides a unique view into the process of species diversification. California is home to the tailed frog (*Ascaphus truei*), a species that is among the last surviving members of an ancient lineage that is the sister group to all other frogs on earth. It houses reptile and amphibian species with genetic- and temperature-dependent sex determination; species that lay eggs in the water, on land, or that are live-bearing; and species with a two-staged life cycle that undergo a profound metamorphosis, switching between distinctly different habitats in the process.

The California Department of Fish and Wildlife (formerly, California Department of Fish and Game) is the trustee agency for California's fish and wildlife resources. The challenges associated with effective management and conservation of these resources are formidable in California, where a large human population, diverse stakeholder interests, and extremely high biotic diversity must be jointly managed. Despite the

challenge of implementing effective conservation in the state, doing so is an important and worthy goal given the vast diversity that the state supports. We have attempted to evaluate conservation status for the state's amphibians and reptiles openly and transparently, relying on both the best available science and the breadth of expert opinions relating to amphibian and reptile conservation in California. We have sought (and received) broad feedback from a wide range of interested parties including agency representatives, academic scientists, and avocational herpetologists and used this combined input to make informed recommendations about conservation risk and management needs for California's amphibians and reptiles. We have also highlighted where data are lacking and discussed how the community might fill these gaps in our knowledge. Our goal is for this volume to serve as both a summary of where we stand and a launching point for what we can achieve in the management and restoration of healthy amphibian and reptile populations in California.

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OVERVIEW

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ABSTRACT

We provide a synthesis of the conservation risk faced by amphibians and reptiles in California that qualify as Species of Special Concern. After assembling a full list of the native amphibian and reptile taxa that are known to occur in the state, we developed a potential set of 73 nominee taxa that might qualify as Species of Special Concern. We developed eight metrics that capture key elements of declining and at-risk species, scored them for all 73 nominee taxa based on an extensive literature review, examined them on a case-by-case basis, and developed a final set of 45 Species of Special Concern. We then developed species accounts for each Species of Special Concern, documenting available information on their basic biology, known or hypothesized reasons for decline, and proposed management and future research needs. Overall, we sought to produce a clear, transparent document that explicitly states why decisions were made and supported with a summary of the best available science. We relied on peer-reviewed literature whenever possible to support those decisions.

Our evaluation resulted in 16 Species of Special Concern categorized as Priority 1 (those of greatest concern), 14 as Priority 2, 12 as Priority 3, and 3 which we could not prioritize based on available data. Our comparative analyses demonstrated that there were certain sets of organisms, geographic areas, and groups of ecological specialists in which species of greatest concern tended to be concentrated. Taxonomically, frogs, salamanders, and turtles all had higher average metric scores than lizards or snakes, mirroring the fraction of those taxa listed at the state and federal levels, and suggesting that these lineages are often of greatest conservation concern. There was also a strong trend for aquatic taxa to experience a greater conservation risk than terrestrial species. Geographically, southern California harbored more Species of Special Concern than central or northern California. This pattern was driven primarily by reptiles, which have a preponderance of at-risk species in the Southern California Coast, Southern California Mountains and Valleys, and the Mojave Desert ecoregions. Amphibian Species of Special Concern tended

to be more evenly distributed across northern and southern California ecoregions.

In a troublingly large number of cases, we found a striking lack of critical data for many aspects of the basic biology of amphibian and reptile species, and this lack of field ecology, natural history, and genetic data hindered our ability to make strong management recommendations. The solution to this lack of data is clear: California needs to launch a program that funds strong, peer-review quality analyses of basic ecology, combined with long-term monitoring studies to evaluate demographic trends at a set of sites for each species. Such studies need not be expensive and would make an enormous difference in our ability to manage many Species of Special Concern, hopefully precluding the need for future state and/or federal listing. Meaningful collaboration between the California Department of Fish and Wildlife and other research groups (be they other agencies, universities, nongovernmental organizations, or avocational groups) has helped to fill some of these gaps, particularly for federally listed species, and such collaborations for Species of Special Concern are the key to developing management plans into the future. We also found that in many cases population genetic approaches can help to fill critical gaps in our knowledge regarding species and subspecies boundaries, effective population sizes, corridors of likely habitat use, migration frequencies and pathways, and levels of hybridization with native and introduced species. These genetic measures should complement, rather than replace field studies, and they offer the opportunity to conduct relatively fast analyses that can and should provide critical early guidance for management decisions.

As critical basic biodiversity work in California continues, we are increasingly recognizing that the complex geology and changing environmental conditions in the state have led to the evolution of an amazing array of endemic taxa, many of which are extreme habitat specialists. To our knowledge, none of these sensitive species have been lost to extinction yet,

although several are dangerously close. However, at least four taxa whose range limits historically entered the margins of the state may already be gone from California's boundaries, and some of the endemic species may be next. The identification of Species of Special Concern and the compilation of information, research needs, and management recommendations represents an important step to help California land managers prevent further declines, stabilize key populations, and potentially initiate recovery programs before formal listing is necessary.

INTRODUCTION

From a biodiversity perspective, California resides at one of the most important crossroads in the United States. The California Floristic Province is the only globally recognized biodiversity hot spot in North America north of Mexico, and one of three recognized in the north-temperate region (Myers et al. 2000). With a 2010 population of more than 37 million people, California accounts for roughly one-eighth of the human population of the United States (US Census Bureau 2013), has the largest agricultural production of any state in the country (USDA 2007), and has one of the highest average land values in the nation (Davis and Heathcote 2007). Conserving biodiversity in California is therefore both enormously important and extremely difficult from an economic and political standpoint and requires strong scientific guidance and the collective will of multiple stakeholder groups.

Formal species protection in California is accomplished via the California Endangered Species Act and/or the Federal Endangered Species Act. The California Department of Fish and Wildlife (CDFW) is responsible for implementing the latter. As of January 2014, over 150 animals in our state were listed as threatened or endangered under either one or both acts. To help preclude the need to list additional species, the CDFW administratively designates Species of Special Concern. The

intent of designating Species of Special Concern is to (1) focus attention on animals at conservation risk by the CDFW, other state, local, and federal governmental entities, regulators, land managers, planners, consulting biologists, and others; (2) stimulate needed research on poorly known species; and (3) achieve conservation and recovery of these animals before they meet California Endangered Species Act criteria for listing as threatened or endangered. Species of Special Concern carry no formal legal status but are widely viewed as one of the important front lines in species conservation planning and management. Regardless of the stakeholder group involved, whether members of the conservation, agricultural, or urban development communities, it is in everyone's best interest to maintain stable populations of Species of Special Concern to avoid the need for formal listing.

The Species of Special Concern designation is used to promote conservation in various ways by the CDFW, land managers, and others to promote conservation. For example, Species of Special Concern are considered "Species of Greatest Conservation Need" in California's Wildlife Action Plan (Bunn et al. 2007, <http://www.wildlife.ca.gov/SWAP>). State Wildlife Action Plans outline the steps needed to conserve these taxa before they become rarer and more costly to protect and provide access to funds for this purpose. Species of Special Concern are also considered when evaluating environmental impacts under the California Environmental Quality Act (California Public Resources Code Sections 21000-21177). The California Environmental Quality Act requires state agencies, local governments, and special districts to evaluate and disclose impacts to wildlife and habitat from proposed projects. Specifically, Species of Special Concern may meet the definitions of endangered, rare, and/or threatened in Section 15380 of the California Environmental Quality Act guidelines. Also, Section 15065 relates to the standards under which the lead agency determines if impacts to biological resources should be considered

significant. Impacts to Species of Special Concern are generally considered significant if they are based on factors such as population-level effects, proportion of the taxon's range affected by the project, and effects on habitat. Environmental impact reports that analyze and evaluate the potential impacts on Species of Special Concern caused by the proposed project must be prepared before planned projects can move forward. Large-scale planning efforts, such as Habitat Conservation Plans and Natural Community Conservation Plans, also may include conservation measures for non-listed, at-risk species including Species of Special Concern. In addition, Species of Special Concern are tracked by the California Natural Diversity Database (<http://www.dfg.ca.gov/biogeodata/cnddb>), an important source of information on species distribution. Federal land management agencies like the Bureau of Land Management and US Forest Service often add Species of Special Concern to their sensitive species lists to focus attention on these taxa. In all, the Species of Special Concern designation results in a greater depth of knowledge about species as well as proactive conservation aimed at maintaining or restoring populations to avoid the need for future, formal listing.

In this volume, we update and evaluate the original Species of Special Concern document for amphibians and reptiles (Jennings and Hayes 1994a). The first Species of Special Concern document compiled was for birds (Remsen 1978). Over the following three decades, documents have been published or updated for birds (Shuford and Gardali 2008), mammals (Williams 1986; Bolster 1998), and fishes (Moyle et al. 1989, Moyle et al. 1995). As these documents have matured and been revised, so too have the methods by which Species of Special Concern have been identified from the potential pool of candidate taxa. With the exception of the 2008 bird publication, previous iterations of these assessments were largely based on expert opinion. A list of native California taxa was assembled, screened for risk potential, and evaluated by a small team of

experts (usually in consultation with many additional experts throughout the state). The most at-risk taxa not already listed under the California Endangered Species Act were then selected as Species of Special Concern.

The Species of Special Concern assessment process changed profoundly with the 2008 bird publication (Shuford and Gardali 2008). A key change, and one that we also follow here, was to formalize the criteria by which species receive this designation. Following Shuford and Gardali (2008) and current CDFW standards (<http://www.dfg.ca.gov/wildlife/nongame/ssc/index.html>), we created a set of eight metrics that capture the extent to which an amphibian or reptile species is at risk of extinction in California. We used this system to increase transparency, facilitate clear feedback from a broad group of individuals on our scoring, and enhance the ability of the CDFW and other agencies to replicate this process in the future. We then ranked all species by their summed metric scores, presented that ranking to a wide-ranging group of experts, and determined inclusion or exclusion from the special concern list. This approach provided a clear connection between data and ranking, and an explicit description of the most important factors contributing to ongoing declines. It also provided a strong connection between the evaluation process for different taxonomic groups and therefore greater uniformity in the methodology used among all CDFW Species of Special Concern publications.

The current volume is divided into two sections. In Part I (this section), we provide a detailed description of our methods, including the metrics and their scoring, outreach strategies for public input, locality mapping, and the roles of different contributors in producing the set of Species of Special Concern taxa. Following this is an overview of the results of our review and several quantitative descriptions of geographical, ecological, and taxonomic patterns of Species of Special Concern. We end with a discussion of the results and present recommendations for the conservation of amphib-

ian and reptile Species of Special Concern in California. Throughout, we emphasize immediate research needs, both for particular species and for broader assemblages and landscapes within the state. Part II consists of a series of species accounts that provide a synopsis of information for each Species of Special Concern. Each account also includes a map documenting localities where the species has been collected or observed along with a depiction of its current range.

Throughout this document, we have used the peer-reviewed literature as our primary source of information and have included unpublished reports, web sites, and data from the field notes of professional and avocational herpetologists to fill in gaps in the primary literature. We rely primarily on the peer-reviewed literature because it has been evaluated by independent experts and deemed admissible into the scientific literature. However, we also recognize that the published literature for many species is sparse, and in those cases we also evaluated and included a large amount of unpublished information. Finally, we particularly emphasized the more recent, post-1990 literature, given the extensive review by Jennings and Hayes (1994a) of the earlier literature.

METHODS

Overview of Project Design and Process

The process of developing this document involved cooperation among several groups. The initial study design was developed collaboratively between the CDFW and the authors (Thomson, Wright, and Shaffer). We then assembled a Technical Advisory Committee comprising members with broad geographical and taxonomic expertise in California's amphibian and reptile fauna. This group developed the set of metrics used in evaluating potential Species of Special Concern, as well as a standardized format for species accounts. We then reached out to all segments of the herpetology community, including academics, land

and resource managers, avocational herpetologists, and the interested public for further information, feedback, and review at various points in the process. Our goal throughout was to keep our actions and decisions transparent and accessible to anyone with an interest in herpetological conservation in California.

We began by developing a current list of all native amphibian and reptile species and subspecies known to occur in the state (Appendix 1). Based on the broad knowledge of field herpetology represented by the authors and the Technical Advisory Committee, we used this list to develop a set of Special Concern nominees. Our goal was to include in this nominee list all taxa that anyone felt were declining or in need of protection in the state. The authors conducted preliminary reviews of each of these taxa, searching the literature and interviewing experts, and used these data to produce a set of preliminary scores for each of the nominees using the risk metrics. These scores were reviewed and refined by the Technical Advisory Committee and then further reviewed and refined based on input from the herpetological community at large. The authors and Technical Advisory Committee used the metric scores, as explained later in this document, to construct a set of taxa for inclusion as Species of Special Concern. After the list was finalized, we produced species accounts for each of the Species of Special Concern.

During this evaluative process, we compiled locality information for each taxon, which we then combined with data from the California Natural Diversity Database and Biogeographic Observation and Information System to produce distribution maps for each nominee species. The Technical Advisory Committee, the CDFW, and other experts reviewed these range maps, resulting in the maps in this document.

Species List, Taxonomy, and Units of Conservation

We developed our species list by compiling information from existing taxonomic lists and

recent taxonomic literature. We included all recognized or proposed species, subspecies, and distinct population lineages that have been identified. We generally used the most recent revisionary studies, although we sometimes made decisions based on the degree to which the scientific community had accepted proposed changes and the quality and strength of data informing proposed revisions. Little consensus exists on taxonomy for certain groups (e.g., California mountain kingsnake, *Lampropeltis zonata*), and we tried to strike a balance between incorporating the most current, reliable information while also maintaining taxonomic stability in the face of current uncertainty. For example, Frost et al. (2006a) proposed a large number of taxonomic changes for California amphibians, often shifting species into new generic name combinations (e.g., the western toad, *Bufo boreas*, changes to *Anaxyrus boreas* under this scheme). These changes have been vigorously debated (Crother et al. 2009, Frost et al. 2009a, Pauly et al. 2009), and we have taken the conservative approach of retaining the traditional nomenclature.

We focused our evaluation primarily at the species level, although we also considered subspecies and (rarely) parts of an otherwise stable species range that appeared to be in decline. This follows most similar efforts to date in recognizing species as the fundamental units of conservation, while still acknowledging that significant diversity exists and should be maintained within species. This also allowed us to limit the extent to which taxonomic controversy might negatively impact important conservation efforts. For example, if we were to consider only species (or formally described subspecies), we would fail to consider currently unnamed populations in need of conservation action. The southern populations of the common garter snake (*Thamnophis sirtalis*) are an example of such a population, as are the southern populations of the Coast Range newt (*Taricha torosa*). Throughout this document we use the term "taxa" to refer to species, subspecies, or distinct populations.

Development of the Nominee List

The first stage in the process was to develop a list of nominee Species of Special Concern from the comprehensive list of taxa that occur in the state. We included all taxa from the previous amphibian and reptile Species of Special Concern document (Jennings and Hayes 1994a), those that were recently extirpated or possibly extirpated from the state, and all taxa currently listed under the Federal Endangered Species Act. We excluded any taxa that were already legally designated by the state (i.e., Endangered or Threatened under the California Endangered Species Act), because Species of Special Concern status would provide no further state-level protections. Although federally listed taxa also experience a higher level of protection than Species of Special Concern, we still considered them in the evaluation process because federal status could potentially be the result of conservation needs from parts of the species' range outside of California. Because of this, an assessment of each species focusing on its California range provides information about its status within the state.

We included additional nominee taxa that members of the Technical Advisory Committee identified as potentially at risk based on their experience with that taxon in the field. If at least one member of the committee suspected that a taxon might qualify as a Species of Special Concern, we included it for evaluation. Additional taxa were added through consultation with experts on specific species or larger taxonomic groups and by suggestion during the public comment phase of the project (see below). We then evaluated these taxa with the risk metrics and used the resulting scores as our primary basis for Species of Special Concern determination (see below).

Definition of Species of Special Concern

We define a Species of Special Concern as any native species, subspecies, or distinct population of amphibian or reptile occurring in the

state that currently meets one or more of the following criteria (see also Comrack et al. 2008):

- Is extirpated from the state within the recent past;
- Is listed as federally, but not state, Threatened or Endangered and/or meets the state definition of Threatened or Endangered but has not formally been listed;
- Is experiencing, or formerly experienced, serious, noncyclical, population declines or range retractions that, if continued or resumed, could qualify it for state Threatened or Endangered status;
- Has naturally small populations and/or range size and exhibits high susceptibility to risk from any factor(s) that, if realized, could lead to declines that would qualify it for state Threatened or Endangered status.

We developed a set of risk metrics to address the latter two criteria. Taxa scoring high on these risk metrics were then judged to be prime candidates for inclusion on the list. Taxa meeting the first two criteria were included automatically. All taxa were scored for the risk metrics and included in our quantitative analyses.

Risk Metrics

Working with the Technical Advisory Committee and using CDFW criteria (<http://www.dfg.ca.gov/wildlife/nongame/ssc/index.html>), we developed a set of conservation risk metrics to quantify the level of threat to California's at-risk amphibians and reptiles. Although quantification of conservation risk is necessarily approximate, the metric approach allows for improved repeatability between Species of Special Concern updates and a framework for discussion and revision. Earlier Species of Special Concern documents were based largely on expert opinion and the use of risk metrics does not completely eliminate this important element of the assessment process. Rather, the

risk metrics place expert opinion, as well as data, within a standardized framework that makes decisions more transparent. For example, our ecological tolerance metric provides a clear definition of how we quantified the ecological specialization of each taxon and how it relates to conservation risk. If, at a later time, additional data become available or other workers disagree with our interpretation of the existing data, there now exists a clear way in which this new information can be incorporated into the overall score for any species.

The possible score for each metric ranged from 0 (little or no risk) up to a maximum of 25 (high risk), reflecting the relative importance of the risk quantified by that metric. We weighted metrics that measure *documented* conservation concerns, such as declines in abundance, more highly than other metrics that focused on *potential* conservation concerns, such as life history factors that contribute to sensitivity. We did this for two reasons. First, our weighting reflects the emphasis on these factors in the definition of Species of Special Concern. Second, documented conservation concerns usually require more immediate management action and are likely more serious threats to survival than potential conservation concerns. The result of this decision is that some metrics, such as those measuring declines in distribution or abundance, affected the overall risk metric score more than, for example, a naturally small range size. The eight risk metrics are as follows.

i. Range Size

The range size metric estimates the percentage of California that each taxon occupies. Though this measure could be treated as continuous, we have approximated it with discrete categories for two reasons. First, we have little biological reason to believe that a taxon that occupies, for example, 35% of California is under any greater conservation risk than a taxon that occupies 42%. Both of these hypothetical taxa occupy moderate portions of the state and probably experience similar risk arising from the size of their range. Second, there is inherent uncer-

tainty in many amphibian and reptile range predictions as portrayed in range maps, and we felt that it was more appropriate to broadly categorize ranges rather than attempt to precisely estimate them. We therefore categorize range size as *small*, which includes those taxa that are at immediate risk from relatively small scale disturbances; *medium*, which includes taxa that occupy a portion of the state that is big enough so that a single large catastrophic event would be unlikely to affect the entire range; and *large*, which includes those taxa that occupy such a large portion of the state that range size itself is unlikely to have any significant impact on threat. Patchiness and ecological specialization of species that limit range on a local scale are quantified in other metrics. Our aim for this metric is only to estimate the actual size of the species range. In the few cases where the known range is strictly limited by habitat specialization or limitation (e.g., desert populations of the regal ring-necked snake, *Diadophis punctatus regalis*, or the Gila monster, *Heloderma suspectum*) and the taxon almost certainly does not occur between isolated habitat patches, we treated the known populations as individual polygons in scoring this metric.

(I) RANGE SIZE (% OF CALIFORNIA OCCUPIED)	SCORE
Small (<10%)	10
Medium (10–50%)	5
Large (>50%)	0

ii. Distribution Trend

The distribution trend metric aims to quantify documented decreases in the overall range of each taxon based on extirpation of previously known localities. The total score for this metric comes from two sources. First, we attempted to quantify the extent of known range reductions, scoring them using the categories below. We classified the extent of range reduction into discrete categories for similar reasons as range size. We then added an additional 5 points if the documented reduction in range appears to have been

ongoing since the last Species of Special Concern document was published (Jennings and Hayes 1994a) and has not yet stabilized or reversed. We did this to increase the weight of declines that are continuing at present, and which therefore are likely to continue in the immediate future. As a result, a species might attain a particular score through either a documented reduction or a less severe reduction that is ongoing. In scoring this metric, we used peer-reviewed published data whenever possible. The best data for this metric came from repeated field surveys of habitat through time, and we used them whenever they were available. However, datasets of this type are, at present, uncommonly available for amphibian and reptiles of California.

(II) DISTRIBUTION TREND	SCORE
Severely (>80%) reduced	20
Greatly (>40–80%) reduced	15
Moderately (>20–40%) reduced	10
Slightly (<20%) reduced or suspected of having been reduced but trend unknown	5
Stable (~0% reduced) or increasing	0
Add 5 additional points if negative trend is ongoing for a total of 25 points possible for this metric.	

iii. Population Concentration/Migration

This metric focuses on whether features of the life history of individual taxa, such as migration events or aggregations, make them naturally vulnerable to decline or extirpation. For instance, taxa that migrate to breed in ponds are exposed to additional risk during the migration itself (e.g., road crossings) as well as increased risk while concentrated in the breeding habitat. This latter risk could come about if a catastrophic event occurs during the breeding concentration (e.g., if a toxic spill or group of predators killed the breeding animals) or because the actual breeding site is destroyed (e.g., draining of the aquatic breeding habitat). We score this trait either *present* or *absent* based on the available life history data for each taxon.

(III) POPULATION CONCENTRATION/MIGRATION	SCORE
Vulnerable life stages present	10
No vulnerable life stages	0

iv. Endemism

The endemism metric captures the percentage of a species' entire range that occurs in California. Endemism determines the extent to which conservation actions in California are likely to impact the taxon's persistence range-wide. From another perspective, this is a way of measuring California's responsibility to conserve individual species. Taxa whose range is completely, or nearly completely, contained within California's borders are in need of greater conservation consideration from our state than taxa whose range only extends peripherally into California. We recognize that this presumes appropriate conservation measures are also being implemented in other areas of North America (including Mexico and Canada). We again made this measure discrete in recognition of the inherent uncertainty in our knowledge of range limits.

(IV) ENDEMISM (% OF ENTIRE RANGE IN CALIFORNIA)	SCORE
100% (endemic)	10
>66–99%	7
33–66%	3
<33%	0

v. Ecological Tolerance

This metric measures ecological specialization. Species that are narrow specialists on specific ecological resources (such as habitat, prey, temperature regimes) are inherently more sensitive to ecological disturbance than species that can tolerate a wider range of ecological conditions. In addition to the degree of specialization, we also considered the extent to which the resource that each taxon specializes on is common or rare. For instance, several saxicolous (rock loving) lizard species (e.g., the leaf-toed gecko, *Phyllodactylus nocticolus*) use rocky habitats that

occur throughout extensive areas of the species' total range. We scored cases like this as specialists on a common resource. Conversely, vernal pool breeding amphibians (e.g., Couch's spadefoot, *Scaphiopus couchii*) require temporary aquatic pools that are rare throughout their range for successful breeding. We scored these taxa as specialists on a rare resource. We adjusted the rareness of the resource with respect to its availability within the species' range, rather than its availability within the state.

(V) ECOLOGICAL TOLERANCE	SCORE
Narrow ecological specialist on a rare resource	10
Narrow ecological specialist on a common resource	7
Moderate ecological specialist	3
Broad ecological tolerance	0

vi. Population Trend

The population trend metric captures changes in abundance at localized, population-level sites. This is distinct from the distribution trend, which measures extirpation of localities; population trend captures declining abundances at localities that are not extirpated. In many cases, distributional declines as measured by distribution trend will be associated with earlier declines as measured by population trend. This raises the potential of scoring taxa twice for the same decline. To avoid this, we scored population declines that have led to extirpation under the distribution trend metric. We gave those same taxa high scores for the population trend metric only if additional population declines have been documented at currently extant sites. We scored population trend in the same way as distribution trend, first scoring the extent of the decline and then adding an additional 5 points if evidence suggests that the trend is ongoing. As a result, a species might attain a particular score through either a documented reduction or a less severe reduction that is ongoing.

(VI) POPULATION TREND	SCORE
Severe declines (>80% reduced)	20
Great declines (>40–80% reduced)	15
Moderate declines (20–40%)	10
Slight (<20%) or suspected declines	5
Stable (–0% reduced) or increasing	0
Add 5 additional points if declines are ongoing.	

vi. Vulnerability to Climate Change

The climate change metric measures a taxon's sensitivity to the projected effects of climate change. We scored this metric using the projected impacts on California landscapes based on the California Climate Action Team assessments (Cayan et al. 2008a), followed by our interpretations of how these impacts are likely to affect each taxon based on life history and habitat requirements. For example, climate projections suggest that snowpack in the Sierra Nevada is likely to decrease by 30–90% (depending on carbon emissions and the climate model used) over the next 100 years, leading to a narrower window of time over which the spring snowmelt will occur (Maurer and Duffy 2005, Cayan et al. 2006, Maurer 2007). This is likely to have an impact on the snowmelt-dependent aquatic habitats that many Sierran amphibians use for one or more life stages, and may also reduce the time period over which moist microhabitats will occur in forest ecosystems. Other impacts that we considered for this metric included changing hydrology (amount and variation of precipitation), temperature, wildfire frequency and intensity, and changes in the extent of habitat and vegetation types. Given our imprecise knowledge of both future climate change effects and their impacts on species, we discretized this impact into four broad categories.

(VII) VULNERABILITY TO CLIMATE CHANGE	SCORE
Highly sensitive	10
Moderately sensitive	7
Slightly sensitive	3
Unlikely to be sensitive	0

viii. Projected Impacts

The projected impacts metric estimates the effect that future threats may have on each species over the near term (20 years). It does not incorporate threats arising from changing climate, because these are captured in a separate metric. This includes impacts stemming from known threats, such as planned or projected habitat loss and, to a lesser extent, impacts from irregularly occurring threats, such as disease outbreaks. Given the potential for these risks to be reduced by management, plus the inherent uncertainty associated with complex projections, we considered potential threats to be of relatively less importance than documented threats such as population declines.

{VIII} PROJECTED IMPACTS {OF THREATS OVER THE NEXT 20 YEARS}	SCORE
Serious	10
Moderate	7
Slight	3
No substantial impact	0

Scoring Nominee Taxa

We scored all of the nominee taxa for each of the eight metrics based on the best available evidence. To begin with, the primary authors produced a brief summary of the state of conservation knowledge for each nominee taxon and used these summaries to perform a preliminary scoring assessment. In making these assessments, we included the peer-reviewed literature, unpublished reports, survey data, field notes, and the opinions of knowledgeable biologists. In several cases, few data were available to make assessments for a given metric. In these cases, if the data appeared to be strong enough to clearly indicate that a threat was present, we scored that taxon using the most precise estimate that we were able to make. In cases where no data were available or the limited data were ambiguous, we scored taxa as "data deficient" for that metric. Following these preliminary assessments, we circulated all of

the scores and taxon summaries to the Technical Advisory Committee for review and further input. In the rare cases of substantial disagreement, we discussed the issue and evaluated the data as a group, and reached a consensus on the most reasonable score for a given taxon.

After this preliminary scoring process was complete, we created an overall score for each taxon by summing its metric scores and dividing by the total score possible for that taxon (Total Score/Total Possible). Using the ratio of total score to total possible score allowed us to normalize the scores across varying levels of data deficiencies. For example, in cases where a taxon was scored as data deficient for one or more metrics, the total possible score was lower than would be the case if all metrics had been scored. This would result in a lower risk assessment due to uncertainty as opposed to data, and we used standardization by the Total Possible score in order to focus on documented risks.

Public Comment

After the scoring assessments were complete, we opened a 60-day public comment period by posting all of our initial findings on the project's website and sought input widely on herpetological and conservation-oriented email lists and websites (Appendix 2). We requested comments and feedback on the initial set of scores, additional data that could inform the scoring (particularly for the metrics that had been scored as data deficient), and feedback on the process to date. When individuals suggested changes to the metric scores, we asked for a short explanation of what should be changed and why, along with any data and/or field notes that were available to support the proposed change. At the close of the public comment period, we compiled and evaluated all of the information that we received (see Results, Public comment). We evaluated each proposed change on a case-by-case basis, usually making the change if it was reasonable, supported by information (in the form of unpublished reports, data, or field notes), and not in strong

conflict with other existing data. In cases where a suggested change was in strong conflict with other data, we asked that the contributor supply additional data justifying their viewpoint and made a decision on the final resolution of any conflicting information.

We also asked that contributors send additional data that could be incorporated into the locality maps (see below). To facilitate this process, we supplied a standardized data sheet similar to that used for data submission to the California Natural Diversity Database. These localities were added to the California Natural Diversity Database and to our set of existing localities, and they were used in developing range maps.

Ranking and Determination of Species of Special Concern Status

After incorporating the information received during the public comment period, we worked with the Technical Advisory Committee to develop the set of Species of Special Concern taxa. Taxa with the highest scores were included on the list, while those with intermediate scores were evaluated on a case-by-case basis; this combined approach was similar to that used in the Bird Species of Special Concern (Shuford and Gardali 2008). Specifically, taxa that had intermediate scores but had a combination of exceedingly small range size, extreme ecological specialization, and high projected impacts were included as Species of Special Concern. In essence, this approach weights the combination of these factors more heavily in order to meet the last of the four criteria for inclusion as a Species of Special Concern, "small populations and/or range size and exhibits high susceptibility to risk from any factor(s), that if realized, could lead to declines that would qualify it for state Threatened or Endangered status" (Cormack et al. 2008).

We further ranked Species of Special Concern into three priority categories based on the severity and immediacy of threats affecting each taxon. Priority 1 Species of Special Con-

cern are those taxa that are likely to experience severe future declines and/or extirpation without immediate conservation actions. Priority 2 Species of Special Concern require substantial conservation and management actions, although the threats facing them are less immediate and severe than those in Priority 1. Finally, Priority 3 Species of Special Concern are clearly at risk but likely are not experiencing a substantial and immediate threat of extirpation, although the potential for this threat to develop exists if no management actions are undertaken. One of the primary goals of the Species of Special Concern designation is to identify taxa for which managers can undertake relatively small scale and achievable conservation actions that will negate the need for more costly and serious listings at a later date. Priority 3 taxa are prime candidates for such efforts.

Watch List and Additional Taxa in Need of Research and Monitoring

Taxa that were previously considered Species of Special Concern but are no longer included comprise a Watch List (Appendix 3). Appendix 3 includes an explanation for each taxon's change in status and discusses future conservation concerns regarding Watch List taxa. In Appendix 4, we discuss several other taxa in need of research and monitoring that did not warrant inclusion as Species of Special Concern. Some of these were taxa that had scores indicating a lower, but still substantial, amount of risk. Although we decided that they were at a lower priority than the Priority 3 Species of Special Concern and therefore should not be so designated, they formed a group of species to reevaluate in the future. We were also missing important information for some taxa that would have allowed us to make more informed judgments about conservation status. We devote a paragraph to each of these additional taxa in need of research and monitoring in Appendix 4, briefly describing the threats facing each and outlining research and management needs.

Species Accounts

We prepared a species account for each Species of Special Concern that summarized our findings and the relevant aspects of the taxon's biology. We also provided management and research recommendations for each taxon. These accounts follow a standardized format containing each of the following sections.

Status summary. The status summary is a short explanation of each animal's current and former status as a California Species of Special Concern, including its priority level. In the first version of the Amphibian and Reptile Species of Special Concern monograph, Jennings and Hayes (1994a) categorized each taxon according to whether they felt it was a Species of Special Concern or met the criteria for listing as Threatened or Endangered under the California Endangered Species Act. However, this strategy led to some potential confusion because the Jennings and Hayes (1994a) Threatened and Endangered categories did not correspond to actual state listing categories, nor had taxa they described as Threatened or Endangered undergone the rigorous status evaluation required to assess status under the California Endangered Species Act. To avoid this confusion, we used Priority categories (1, 2, or 3) to convey similar information on relative severity of threat as represented in the ranking of Species of Special Concern. This section also contains the overall metric score.

Identification. The identification section summarizes and explains the diagnostic characters for each animal, providing a guide for identifying it in the field. This section also explains how to differentiate each taxon from similar species with which it may be confused. Several taxa within the state are members of morphologically similar species complexes that have been identified primarily based on molecular data. In some of these cases, accurate identifications using morphological characters alone are difficult or impossible, and we generally recommend that biologists rely on geographic range. We also provide references to the

taxonomic literature to guide the reader to the more thorough and technical descriptions of morphology that are beyond the scope of this document.

Taxonomic relationships. In addition to identification information, we provide a summary of the taxonomic status of each animal. This section contains information on current controversies over scientific names, at either the species or higher taxonomic levels. It also summarizes our current understanding of phylogenetic relationships, intraspecific variation, and species boundaries among closely related taxa.

Life history. This section summarizes the current state of knowledge for each taxon's life history, which broadly includes ecology, natural history, and breeding biology. As an exhaustive review of life history information would be enormous for some taxa, we focused on information that is most relevant to current and future management actions and to the risk metrics. Specifically, we concentrated on information that relates to timing and duration of reproductive activity, daily and seasonal activity, and dietary information. Because management efforts for many taxa could be greatly enhanced by a better understanding of life history, we attempted to point out the areas that require further study rather than speculating about the details of life history where the data are weak. We emphasized data from California populations, but used data from other areas of the range or similar species when those were the best available data. We note when we used data from non-California populations and why we believed that the data could be accurately applied.

Habitat requirements. This section focused on the current state of knowledge concerning habitat use, preferences, and requirements. We attempted to distinguish between habitat *preferences*, the habitats in which the taxon is most frequently found, and habitat *requirements*, which are the characteristics of the habitat that the taxon requires for survival over long timescales.

Distribution. This section describes each animal's current distribution and makes an

assessment of changes that have occurred throughout its documented history in the state. We focused primarily on the known distribution within the state, although we also discussed the distribution outside of California if applicable. Finally, to stimulate additional fieldwork, we point out areas where the distribution is poorly known or there is a high probability of significant new localities being discovered.

Trends in abundance. This section reviews information relating to changes in abundance throughout each taxon's documented history. For current population status, we used quantitative population-level analyses where available. However, these kinds of data are rare. Historical data tend to be spotty and incomplete for amphibians and reptiles, and much of the historical information comes from nonquantitative sources, including field reports and personal communications from experienced field biologists.

Nature and degree of threat. This section contains a detailed description of the principal threats that each taxon faces. We highlighted both the nature and severity of different threat sources, while discussing any uncertainty and conflicting data in the literature associated with these threats. We evaluated the weight of evidence and discussed what threats might be playing the largest role(s) in causing declines.

Status determination. This section connects the information on different sources of threat to the metric scores and Species of Special Concern priority categories. We explained the rationale for our determination and the seriousness of the different major threats facing each taxon.

Management recommendations. This section makes recommendations aimed at achieving sound, biologically based management and status improvement for each Species of Special Concern. Wherever possible, we made these recommendations both taxon-specific and action-oriented to allow conservation resources to be put directly into management efforts, rather than into further development of management strategies. We did, however, recom-

mend further research and strategy development as a prerequisite to effective management for taxa that lacked necessary data.

Monitoring, research, and survey needs. This section outlines the additional information necessary to achieve effective management and status improvement. In general, information needed to inform management actions falls into the general areas of monitoring, research, or surveys, and we discuss each as appropriate.

Maps. We developed locality maps to complement the distribution information in the text for each taxon by compiling data from museum collections, state agency databases (e.g., California Natural Diversity Database), and other online databases (e.g., North American Field Herping Association) (Table 1). Data from the CDFW's California Natural Diversity Database and the Biogeographic Information and Observation System were assessed up through April 2012. Museum locality data from HerpNet and the Global Biodiversity Information Facility were assessed through February 2012. Our goal was to develop a set of annotated and geo-referenced localities that accurately describe each taxon's range. Records that appeared to be possibly erroneous (i.e., those that occurred in unexpected areas) were checked individually and excluded in those instances where no supporting information could be found or where the specimens were misidentified (see individual species accounts). We attempted to verify all records coming from online databases and the public by requesting, minimally, photo vouchers or detailed field notes to substantiate the record. The California Natural Diversity Database contains localities that lack this information, so we followed up on questionable records by attempting to contact the individual(s) that initially reported the record. We submitted most new localities that we gathered to the California Natural Diversity Database to make them available for future workers. In a few cases, we could not obtain permission to include localities in the database, so these were included in the maps in this volume, but

TABLE 1
List of museum collections and other data sources that were queried for locality records

Museum Collections	Other Sources
American Museum of Natural History	Cal Photos
Arizona State University	California Biogeographic Information and Observation System
Brigham Young University	California Natural Diversity Database
California Academy of Sciences	Field Notes
California Academy of Sciences, Stanford University Collection	Literature Records
California State University, Chico	Mendocino Redwood Company
Carnegie Museum of Natural History	North American Field Herping Association
Cincinnati Museum Center	Our Own Surveys
Cornell University Museum of Vertebrates	Public Input/Personal Communications
Humboldt State University	US Forest Service
Los Angeles County Museum	US Geological Survey
Museum of Comparative Zoology, Harvard University	
Museum of Vertebrate Zoology, University of California, Berkeley	excluded from the database. The complete geospatial dataset and associated metadata from this project are accessioned in the CDFW's Biogeographic Information and Observation System (BIOSds644).
National Museum of Natural History	After removing erroneous and questionable records from the data, we developed point locality maps with our CDFW Geographic Information System specialist by projecting all localities for each taxon to the California (Teale) Albers projection (figure 1). We used the California Wildlife Habitat Relationships (http://www.dfg.ca.gov/biogeodata/cwhr) mapping protocol to develop range maps for each taxon using these localities. California Wildlife Habitat Relationships is a comprehensive information system for the state's terrestrial vertebrates that seeks to integrate data on species life history, habitat needs, and ranges.
Royal Ontario Museum	To develop species range estimates, we selected the full set of US Department of Agriculture ecoregion subsections that contained at least one locality and used these as a starting point for range maps (figure 2). We then overlaid existing range maps from California Wildlife Habitat Relationships, as well as data layers for habitat types, watersheds, elevation, land use, and urbanization. Using these draft maps,
San Diego Natural History Museum	
Santa Barbara Museum of Natural History	
Slater Museum of Natural History	
Sternberg Museum of Natural History	
University of Alberta Museum of Zoology	
University of Arizona Museum of Natural History	
University of California, Davis – Zoology Collection	
University of California, Santa Barbara	
University of Colorado Museum of Natural History	
University of Michigan Museum of Zoology	
University of Nevada Reno	
University of Texas at El Paso	
Yale Peabody Museum	
Zoological Institute of the Russian Academy of Sciences	

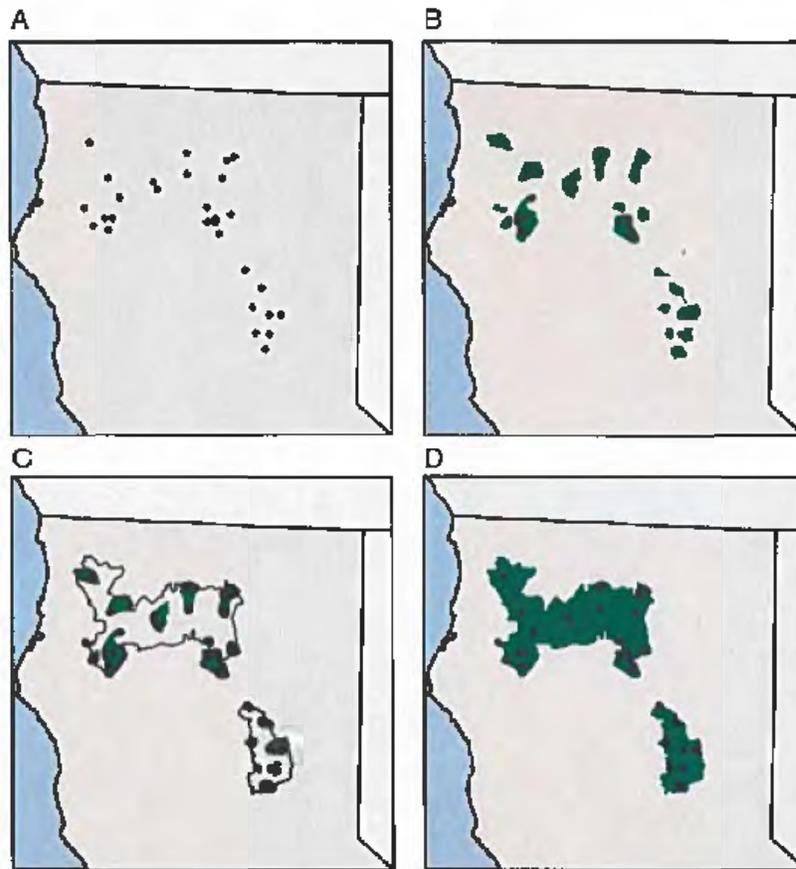


FIGURE 1 Development of range maps for each species. We began by plotting localities on a base map in a geographic information system (A). We then selected the intersection of these localities with an objective geographic object such as US Department of Agriculture (USDA) Ecoregion subsection boundaries, elevational boundaries, or watershed boundaries (in this example, watershed boundaries were used). The particular geographic object that we used varied according to the biology of the taxon (e.g., watershed boundaries for stream-dwelling amphibians, elevation for high-elevation taxa) (B). We then interpolated between the geographic objects that had known localities using expert opinion to develop an approximate range boundary (C). The approximate range boundary and known localities were then drawn together to produce a map for this document (D).

we restricted range boundaries based on ecoregion subsection, watersheds, and other data layers to a more biologically realistic species range. In accordance with the California Wildlife Habitat Relationships guidelines, our goal was to define the current maximum geographic extent of the species within the state, where maximum geographic extent is defined as the area within the range boundary where the species can potentially be expected to occur given suitable habitat conditions. We delineated the range boundaries to minimize errors of omission,

even to the extent of allowing some commission error. For certain species, significant fractions of the range are potentially extirpated (see the species accounts for additional detail). No range shading is included for the species that are presumed extirpated in California (see individual species accounts).

In most cases, we defined the edges of species ranges by selecting meaningful landscape characteristics to set a boundary, such as elevation, rivers, or watershed boundaries. Our goal was to identify specific places on the landscape

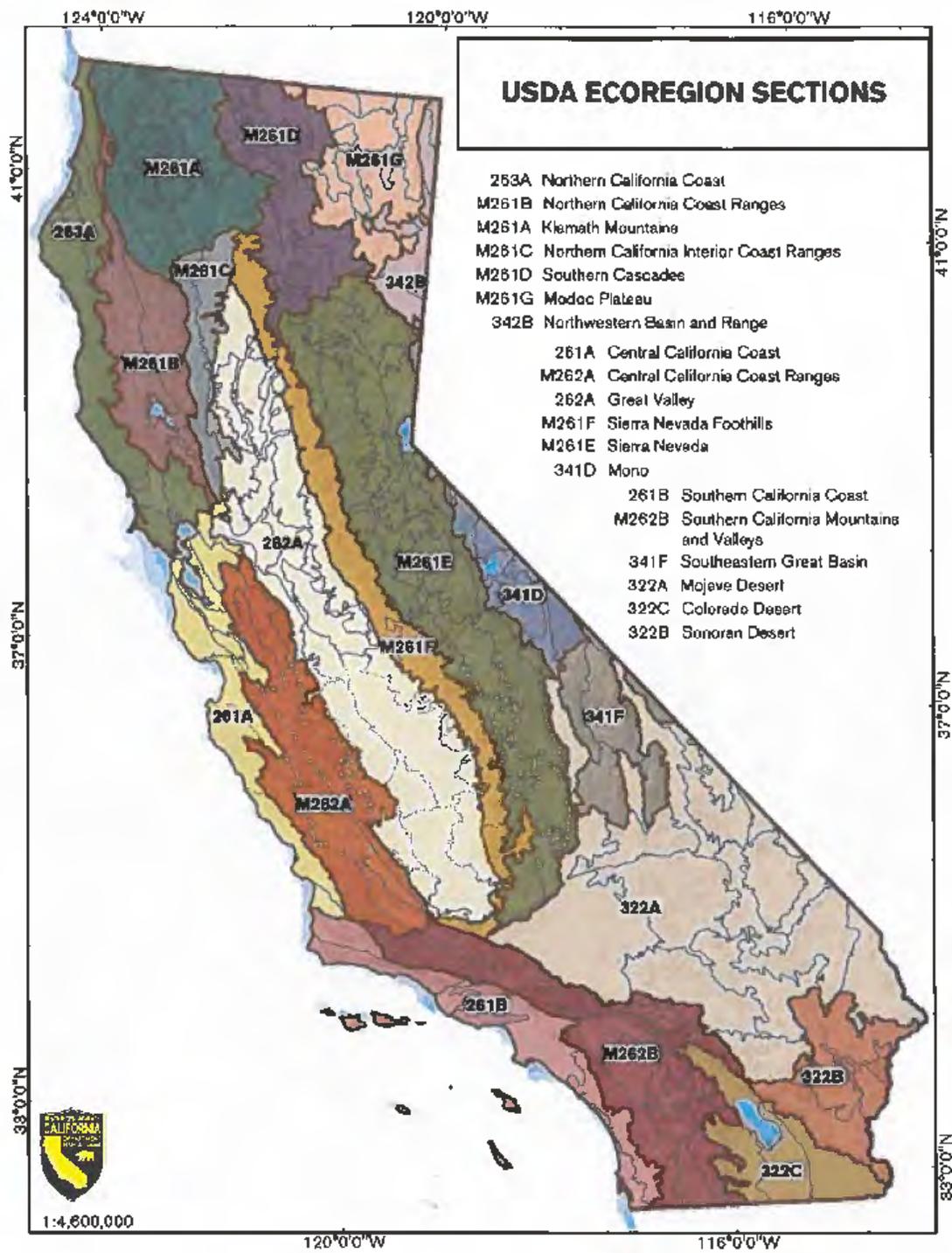


FIGURE 2 United States Department of Agriculture (USDA) Ecoregion subsections which were used in developing range maps.

where future surveys could be conducted to further characterize the species' range. Range maps that lack specific and objective boundaries provide only generalized starting points for such surveys. In total, our range maps present comprehensive estimates based on currently available species locality data and represent our best effort to use these data to approximate a species range, fully recognizing that such ranges are hypotheses to be tested rather than fixed entities.

Review Process

All phases of this project were reviewed by the three authors, the Technical Advisory Committee, and the CDFW. Most parts of the project were also subject to a wider review from members of the herpetological conservation community. For each taxon, we asked at least two experts to review the species account, including the maps and any appendix information. Finally, the Technical Advisory Committee, the CDFW, biologists from state and federal land management agencies, and other interested parties reviewed the finished manuscript as a whole.

RESULTS

Status Lists

We identified 217 native species, subspecies, and distinct population segments that are, or are suspected to be, present in California (Appendix 1). Seventy-three of these taxa were considered nominee Species of Special Concern and underwent evaluations using the risk metrics. Four additional taxa were initially considered for evaluation but were subsequently state listed and removed from further consideration (see Watch List). Of the 73 candidates, we determined that 28 did not merit special status at this time and 45 met our criteria for Species of Special Concern status (figures 3 and 4 and Table 2). Three of these species qualified for Species of Special Concern status by definition because they were

listed under the Federal, but not the California, Endangered Species Act (the arroyo toad, *Bufo californicus*; the California red-legged frog, *Rana draytonii*; and the Yosemite toad, *B. canorus*). We conducted the scoring separately for the two subspecies of the western pond turtle (*Emys marmorata marmorata* and *E. m. pallida*) because the severity of threats facing one population appeared to be larger than those facing the other. However, both populations merited inclusion as Species of Special Concern, resulting in a single species account where threats to each population are discussed separately.

We ranked the Species of Special Concern taxa according to the magnitude of risks that they face, with the two pond turtle populations receiving separate Priority scores. This resulted in 16 taxa categorized as Priority 1, 14 as Priority 2, and 12 as Priority 3. Three additional species clearly qualify as Species of Special Concern, although the scarcity of field records precludes their accurate prioritization at this time: the regal ring-necked snake (*Diadophis punctatus regalis*), Cope's leopard lizard (*Gambelia copeii*), and the Gila monster (*Heloderma suspectum*). In these three cases, we have not assigned a priority score pending additional fieldwork.

Performance of Metrics

Spearman's rank correlations among the eight risk metrics indicated that approximately two-thirds (18/28) of the possible pairwise correlations among metrics were significant (Table 3). Some metrics were not highly correlated with other metrics (e.g., endemism was not correlated with any other metrics), while other metrics were correlated with four or five other metrics (e.g., distribution trend, population concentration/migration, and population trend). Some pairs of correlations indicated that there was considerable overlap in the scores received across taxa. The strongest correlation among metric scores was between distribution trend and population trend ($\rho = 0.66$, $p < 0.001$), indicating that animals that have

TABLE 2
List of California amphibian and reptile Species of Special Concern and priority designations
 Three species qualify as Species of Special Concern, although the scarcity of data precludes their accurate prioritization at this time (see text for further discussion)

Scientific Name	Common Name	Priority
<i>Ambystoma macrodactylum sigillatum</i>	Southern long-toed salamander	2
<i>Aneides flavipunctatus niger</i>	Santa Cruz black salamander	3
<i>Anniella pulchra</i>	California legless lizard	2
<i>Arizona elegans occidentalis</i>	California glossy snake	1
<i>Ascaphus truei</i>	Coastal tailed frog	2
<i>Aspidoscelis tigris stejnegeri</i>	Coastal whiptail	2
<i>Batrachoseps campi</i>	Inyo Mountains salamander	3
<i>Batrachoseps minor</i>	Lesser slender salamander	1
<i>Batrachoseps relictus</i>	Relictual slender salamander	1
<i>Bufo alvarius</i>	Sonoran Desert toad	1
<i>Bufo californicus</i>	Arroyo toad	1
<i>Bufo canorus</i>	Yosemite toad	1
<i>Coleonyx variegatus abboti</i>	San Diego banded gecko	3
<i>Crotalus ruber</i>	Red diamond rattlesnake	3
<i>Diadophis punctatus regalis</i>	Regal ring-necked snake	Undefined
<i>Dicamptodon ensatus</i>	California giant salamander	3
<i>Elgaria panamintina</i>	Panamint alligator lizard	3
<i>Emys marmorata marmorata</i>	Northern western pond turtle	3
<i>Emys marmorata pallida</i>	Southern western pond turtle	1
<i>Gambelia copeii</i>	Cope's leopard lizard	Undefined
<i>Heloderma suspectum</i>	Gila monster	Undefined
<i>Kinosternon sonoriense</i>	Sonora mud turtle	1
<i>Masticophis flagellum ruddocki</i>	San Joaquin coachwhip	2
<i>Masticophis fuliginosus</i>	Baja California coachwhip	3
<i>Phrynosoma blainvillii</i>	Coast horned lizard	2
<i>Phrynosoma mcallii</i>	Flat-tailed horned lizard	2
<i>Rana aurora</i>	Northern red-legged frog	2
<i>Rana boylei</i>	Foothill yellow-legged frog	1
<i>Rana cascadae</i>	Cascades frog	2
<i>Rana draytonii</i>	California red-legged frog	1
<i>Rana pipiens</i>	Northern leopard frog	1
<i>Rana pretiosa</i>	Oregon spotted frog	1
<i>Rana yavapaiensis</i>	Lowland leopard frog	1
<i>Rhyacotriton variegatus</i>	Southern torrent salamander	1
<i>Salvadora hexalepis virgulata</i>	Coast patch-nosed snake	2
<i>Scaphiopus couchii</i>	Couch's spadefoot	3
<i>Spea hammondi</i>	Western spadefoot	1
<i>Taricha rivularis</i>	Red-bellied newt	2

<i>Taricha torosa</i> , Southern populations	Coast range newt	2
<i>Thamnophis hammondi</i>	Two-striped garter snake	2
<i>Thamnophis sirtalis</i> , Southern populations	Common garter snake	1
<i>Uma notata</i>	Colorado Desert fringe-toed lizard	2
<i>Uma scoparia</i>	Mojave fringe-toed lizard	3
<i>Xantusia gracilis</i>	Sandstone night lizard	3
<i>Xantusia vigilis sierrae</i>	Sierra night lizard	3

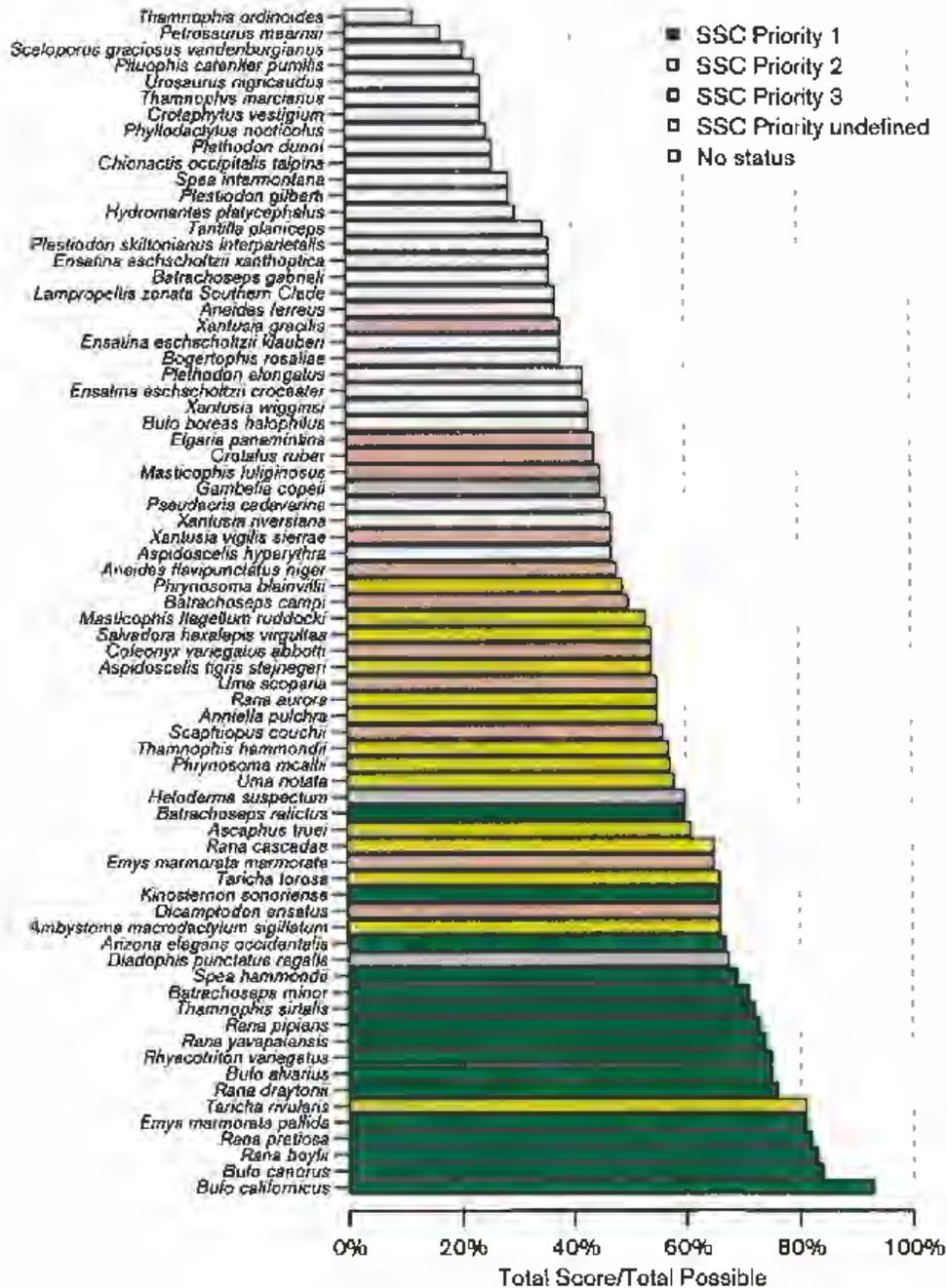


FIGURE 3 Total Score/Total Possible for 73 taxa evaluated for Species of Special Concern status.

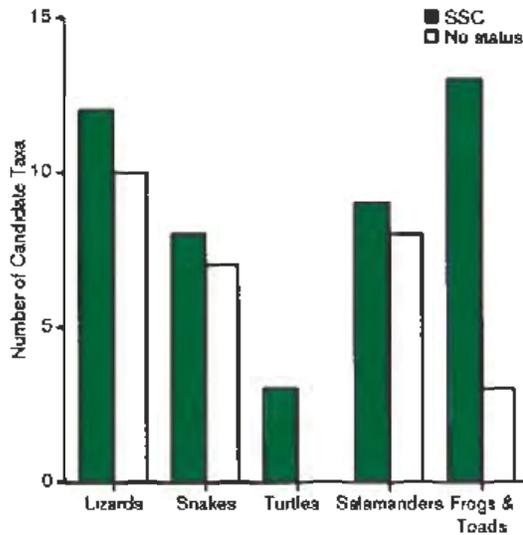


FIGURE 4 Number of taxa in each status category among the 73 nominee taxa by taxonomic group. Species of Special Concern (SSC) are represented by filled bars. Open bars are nominee taxa that did not receive SSC status.

been extirpated from historic localities tended to also be undergoing declines in abundance in currently occupied sites. Taxa experiencing high levels of extirpation also tended to have vulnerable life stages (correlation between distribution trend and population concentration/migration) and be more at risk from future threats (correlation between distribution trend and projected impacts). Those with vulnerable life stages also tended to be declining in abundance (correlation between population concentration/migration and population trend) and were more vulnerable to climate change (correlation between population concentration/migration and vulnerability to climate change).

All but two metrics (range size and endemism) were significantly positively correlated with Total Score/Total Possible (Table 3). Distribution trend and population trend were a priori given the greatest weight (each had a maximum score of 25 vs. a maximum score of 10 for all other metrics), and they were also the most highly correlated with Total Score/Total Possible ($\rho = 0.77$ and 0.87 , respectively). Projected

impacts, population concentration/migration, and vulnerability to climate change also stood out as contributing to risk, although the relationships were not as strong ($\rho = 0.57$ – 0.68).

Principal components analysis of the metric scores for the 73 evaluated taxa showed that the first two principal component axes accounted for about half (54%) of the total variation. Distribution trend, population trend, and projected impact of threats loaded most strongly on the first principal component axis, and Species of Special Concern taxa tended to have positive values for this axis (80% of Species of Special Concern taxa positive; figures 5 and 6). Ecological tolerance and range size loaded most strongly on the second PC axis. However, there is little correlation with special concern status along this axis (figure 6).

Patterns in the Metric Scores

The Total Score/Total Possible ratios for the Species of Special Concern taxa were normally distributed with a mean of 63%, ranging from 38% to 93% (Shapiro Wilk test for normality, $W = 0.98$, $p = 0.58$). Three of the Species of Special Concern taxa are also federally listed as endangered or threatened, and all of these taxa (California red-legged frog, *Rana draytonii*; arroyo toad, *Bufo californicus*; Yosemite toad, *B. canorus*) had a Total Score/Total Possible greater than 75%, occurring in roughly the top 20% of Species of Special Concern (figure 3). The top 20% of taxa were amphibians, with the exception of the western pond turtle (*Emys marmorata pallida*) (figure 3). In contrast, the lowest scoring 20% of Species of Special Concern taxa were all reptiles with the exception of the Santa Cruz black salamander (*Aneides flavipunctatus niger*) (figure 3). On average, turtles and frogs and toads had the highest scores among the five major taxonomic groups (frogs and toads, salamanders, lizards, snakes, and turtles; figure 7).

We were unable to score certain metrics due to a lack of data. Population trend had the largest number of deficiencies with 26% (19/73). Distribution trend was data deficient for 8% of

TABLE 3
Spearman's rank correlations (ρ) among the eight ranking criteria scores
 Values below the diagonal are for the 73 candidate taxa. Values above the diagonal are for the 45 Species of Special Concern taxa

	RS	DT	PCM	EN	ET	PT	CC	PI	TS/TP
Range Size (RS)	—	-0.31*	-0.06	-0.16	0.29	-0.24	0.02	-0.07	-0.04
Distribution Trend (DT)	-0.27*	—	0.30	-0.29	-0.41**	0.46**	0.05	0.28	0.56***
Population Concentration/Migration (PCM)	-0.27*	0.41***	—	-0.12	-0.08	0.49**	0.39*	0.00	0.73***
Endemism (EN)	-0.13	-0.10	-0.04	—	0.26	-0.14	-0.15	-0.40**	0.02
Ecological Tolerance (ET)	0.21	0.00	0.09	0.15	—	-0.41*	0.12	-0.25	0.03
Population Trend (PT)	-0.31*	0.66***	0.57***	-0.01	0.02	—	0.39*	0.33*	0.79***
Vulnerability to Climate Change (CC)	-0.09	0.22	0.50***	0.01	0.30*	0.40**	—	0.08	0.47**
Projected Impact of Threats (PI)	-0.07	0.61***	0.23	-0.15	0.26*	0.65***	0.25*	—	0.25
Total Score/Total Possible (TS/TP)	-0.12	0.77***	0.66***	0.14	0.39***	0.87***	0.57***	0.68***	—

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

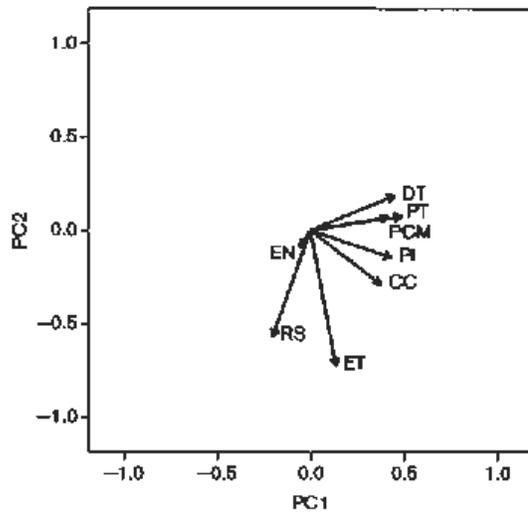


FIGURE 5 Vectors of PCA loading coefficients on first two PC axes. These two axes explain approximately half of the variation in metric score among the 73 nominee taxa. Distribution trend (DT), population trend (PT), population concentration/migration (PCM) loaded strongly onto PC1. Range size (RS) and ecological tolerance (ET) loaded strongly onto PC2. Climate change (CC) loaded equally and moderately on both axes, and endemism (EN) did not load strongly onto either axis.

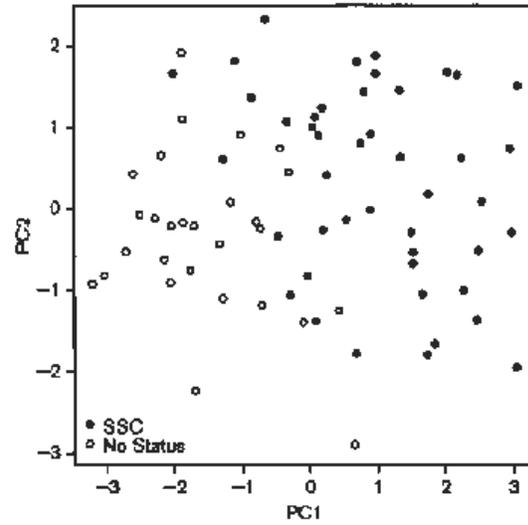


FIGURE 6 Distribution of all 73 taxa evaluated for Species of Special Concern (SSC) status along PCA axes 1 and 2. Most SSC taxa are positive for PC1 and most taxa with "No Status" are negative for PC1. There is little separation among taxa along PC2. SSC are represented by filled symbols. Open symbols are nominee taxa that did not receive SSC status.

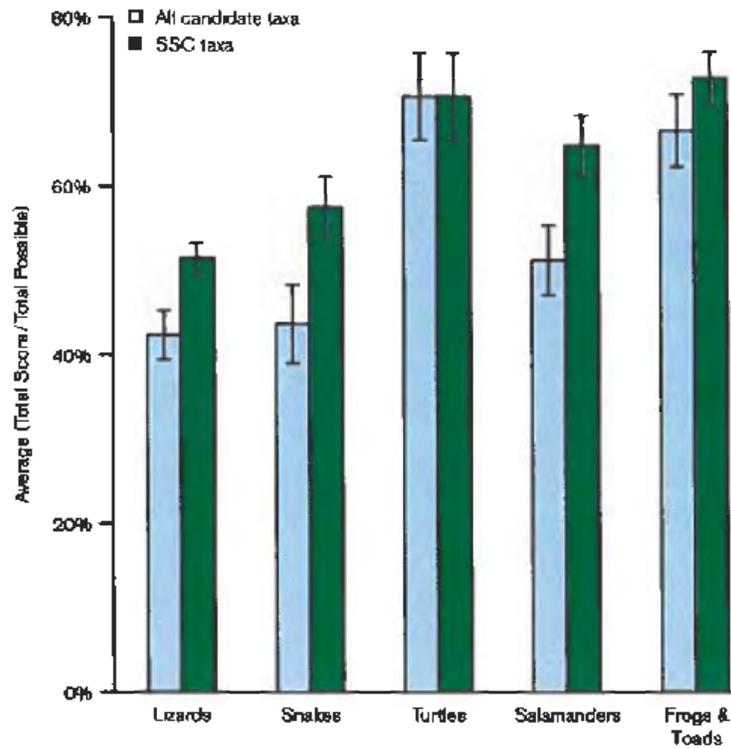


FIGURE 7 Average Total Score/Total Possible by taxonomic group. Filled bars are averages across the Species of Special Concern (SSC) taxa. Open bars are averages across all 73 nominee taxa. Error bars are standard errors.

taxa (6/73), and only a few taxa lacked data on vulnerability to climate change (2/73), projected impacts (3/73), and population concentration/migration (2/73). Among the Species of Special Concern, nine species were data deficient for the critically important population trend metric: Cope's leopard lizard (*Gambelia copeii*), coast patch-nosed snake (*Salvadora hexalepis virgultea*), regal ring-necked snake (*Diadophis punctatus regalis*), California giant salamander (*Dicamptodon ensatus*), Gila monster (*Helerma suspectum*), Sonora mud turtle (*Kinosternon sonoriense*), lowland leopard frog (*R. yavapaiensis*), Sonoran Desert toad (*B. alvarius*), and red-bellied newt (*Taricha rivularis*). Southern populations of the common garter snake (*Thamnophis sirtalis*) were data deficient for population concentration/migration, and the Oregon spotted frog (*R. pretiosa*) was data deficient for vulnerability to climate change. The Gila monster (*H. suspectum*) was data deficient for three metrics (distribution trend, population trend, and projected impacts), and the regal ring-necked snake was data deficient for the same three metrics plus population concentration/migration.

Certain geographic areas of the state emerged as experiencing a high degree of conservation risk, measured by the number of Species of Special Concern contained within them. At least two important geographic trends emerged from our analysis (figure 8). First, California ecoregions north of San Francisco Bay tended to have far fewer at-risk taxa than those from southern California (figure 8). In particular, the Southern California Coast, Southern California Mountains and Valleys, and the Mojave Desert ecoregions all contained a large number of Species of Special Concern (figures 2 and 8). Second, the geographic pattern of risk varied between amphibians and reptiles. Overall, reptiles experienced the highest risk in the three previously mentioned ecoregions as well as the Colorado Desert, while the northern ecoregions generally had only a single reptile Species of Special Concern (western pond turtle, *E. m. marmorata*). However, amphibian Species of Special Concern

taxa were more evenly distributed among ecoregions across the state, with a slight peak in the mountains surrounding the Central Valley and in northern coastal California (generally 7–8 species) and a slight drop-off in the southern ecoregions (generally 5–6 species; figure 8).

To assess possible correlations between habitat type and conservation risk, we scored all 73 nominee taxa as predominantly terrestrial or aquatic, based largely on where reproduction takes place. Our categorization of aquatic versus terrestrial was not identical to that used in Jennings and Hayes (1994a), although it is broadly similar. We categorized amphibians based on their breeding biology—those that lay aquatic eggs and have free-living aquatic larvae were considered aquatic, whereas those with terrestrial eggs and direct development were considered to be terrestrial. Under these criteria, all frogs and toads were scored as aquatic, as well as the salamander genera *Ambystoma*, *Dicamptodon*, *Rhyacotriton*, and *Taricha*. Terrestrial salamander genera were all from the family Plethodontidae, and included *Aneides*, *Batrachoseps*, *Ensatina*, *Hydromantes*, and *Plethodon*. All lizards and snakes, including the semi-aquatic garter snakes (*Thamnophis*) were considered terrestrial, since all either lay terrestrial shelled eggs or are live-bearing, and all spend the majority of their time on land. All of the turtles were considered to be aquatic since they spend the vast proportion of their lives, including all feeding and mating activities, in freshwater aquatic habitats. Categorizing taxa in this manner shows that there is an overall effect of habitat on Total Score/Total Possible (One-way Anova, $p < 0.0001$; figure 9). The same pattern was true for aquatic versus terrestrial salamanders (figure 9).

Public Comment

The formal public comment period lasted for 60 days over the summer of 2009, although we continued to solicit and incorporate feedback after this period closed. During the public comment phase of the project, the website was visited 886 times by visitors from 17 countries. The majority

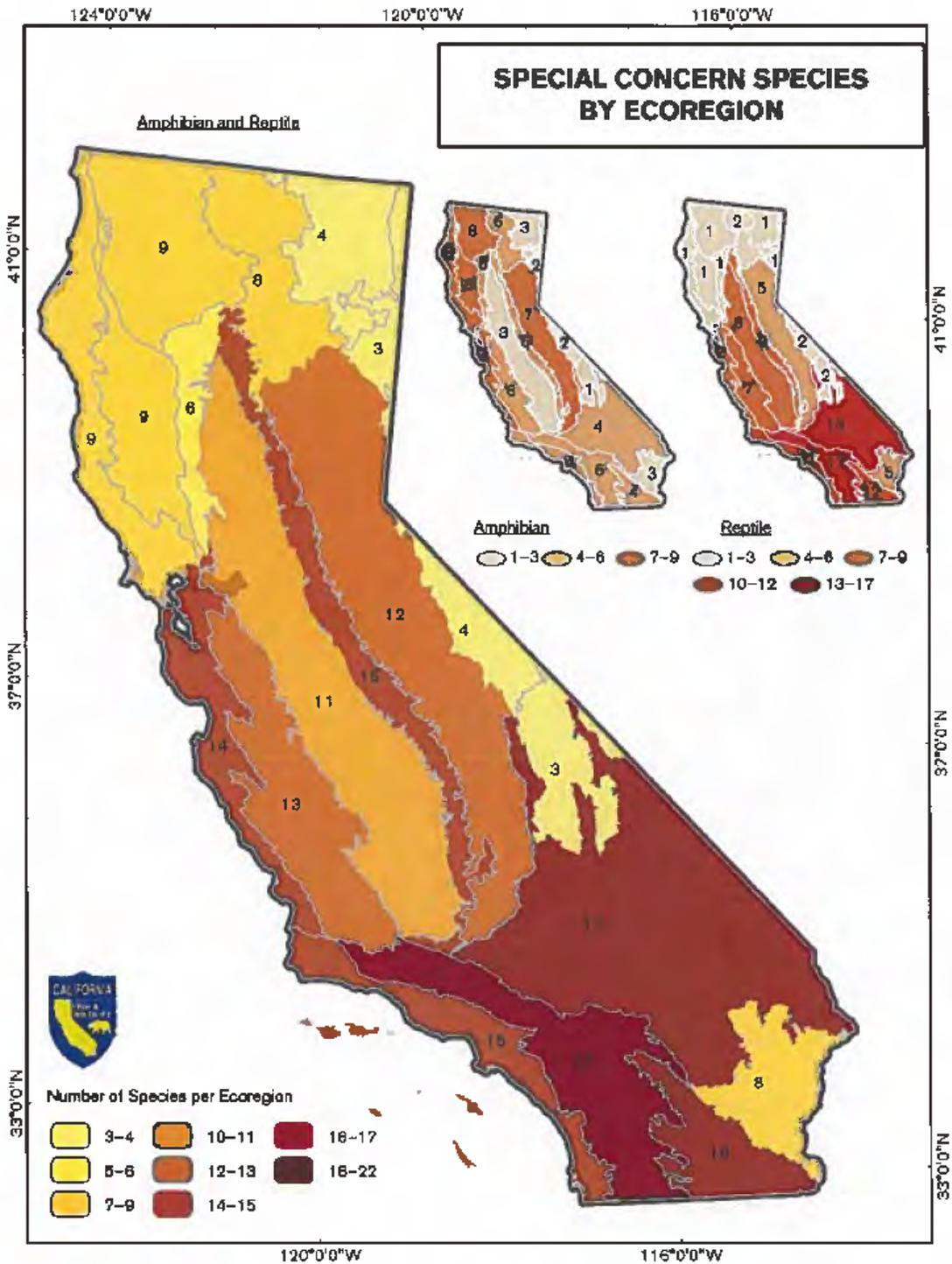


FIGURE 8 The number of Species of Special Concern that occurs within each US Department of Agriculture (USDA) Ecoregion section.

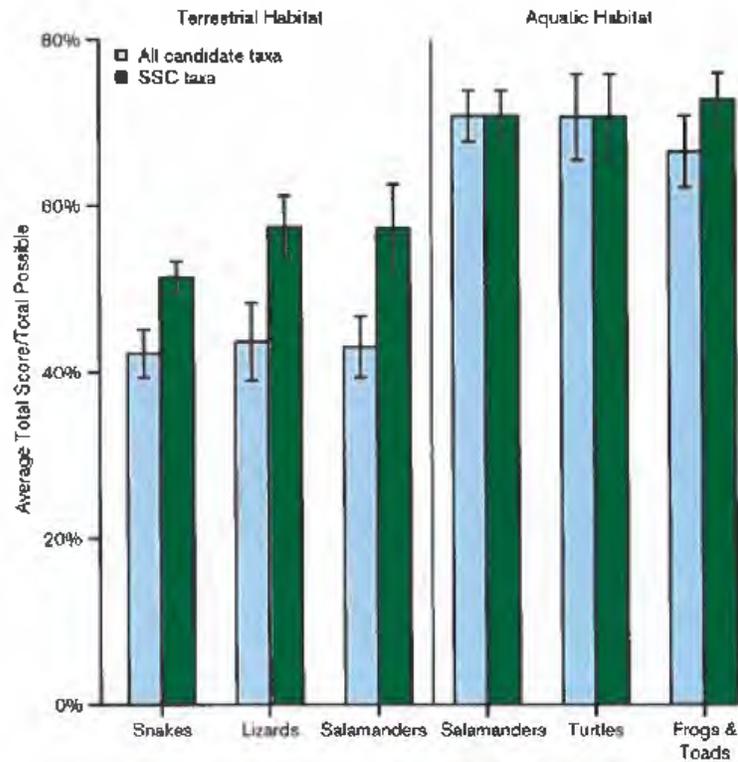


FIGURE 9 Average Total Score/Total Possible by aquatic or terrestrial habitat type. Filled bars are averages across the Species of Special Concern (SSC) taxa. Open bars are averages across all 73 nominee taxa. Error bars are standard errors

of visitors (575) were from California, followed by visitors from neighboring states (Washington: 32; Oregon: 28; Arizona: 26). We received feedback from a wide variety of conservation professionals, academics, and enthusiasts. Because much of this feedback came from informal conversations on the telephone or at workshops, meetings, and conferences, we cannot precisely quantify the number of data contributors to this project. However, we received substantial contributions in the form of unpublished data, reprints, field notes, and/or localities during the public comment period from approximately 45 individuals (see Acknowledgments).

DISCUSSION

Risk Metrics

Overall, the metrics performed well, successfully identifying taxa that herpetologists gener-

ally consider to be at risk across the state, such as ranid frogs. Similarly, scores for the Species of Special Concern that are federally listed suggested that the metrics were performing well. Evaluating all taxa within a metric framework also facilitated identification of patterns among the metric scores that revealed insights into the geographic and ecological factors associated with declines. As emphasized by Shuford and Gardali (2008) for birds, no single set of metrics can capture the intricacies of the natural world fully. The strengths of our approach were that the eight metrics covered a wide range of factors that indicate declines and established a repeatable and transparent baseline for the evaluation of Species of Special Concern. During the initial public input phase of the project, we observed firsthand how a metric-based framework facilitated incorporation of feedback into conservation decisions, regardless of disagreements over the particular metrics used.

That is, when disagreements arose, the metrics allowed us to discuss conflicting scores for individual taxa, focusing discussions on specific issues and questions.

Our metrics covered four basic categories that spanned the diversity of conservation issues faced by any species: geography of declines, changes in population biology over time, key ecological attributes associated with risk, and estimates of future impacts. Metric scores within these categories were often correlated, capturing real patterns in how declines occur. For example, the high correlation between distribution trend and population trend reflects the fact that populations tend to become smaller and smaller as they become isolated and fragmented over time. This general shrinking of populations for many taxa with naturally extensive metapopulations will lead to a high score for population trend. However, as this trend continues over time, those isolated, declining populations experience much greater demographic stochasticity (Lande 1988), leading to more frequent extirpations of local populations and thus high scores for distribution trends. Thus, although these two metrics could be decoupled in principle, our assessments indicate that they tend to be associated in natural systems, and the metrics reflect this association rather than a redundancy in the approach. They also highlight the importance of measuring population connectivity as a research goal and of maintaining or reestablishing it as a management objective.

The correlation among metric scores may help explain why the rankings were robust to data deficiencies. This feature of the rankings is critical when evaluating reptile and amphibian taxa that can be cryptic, rare, and for which survey data are often lacking. We ranked taxa using the ratio of the total score to the total possible, rather than just the total score, to account for the different possible total scores for each species arising from data deficiencies. An implication of this approach is that each species' score is based on the data available and that the metrics differentially influenced scores

depending on data availability. For example, population size is difficult to estimate with precision and generally requires extensive multi-year field studies. As a result, we could not score population trend for eight Species of Special Concern. If such data deficiencies were biasing our results, then this would be reflected in a different distribution of Priority 1, 2, 3 and Undefined scores for data-deficient taxa compared to the overall set of Species of Special Concern, but this was not the case ($\chi^2 = 5.4$, $df = 3$, $p = 0.14$). We acknowledge that data deficiencies in key metrics, such as distribution and/or population trend, could allow for taxa to achieve high Total Score/Total Possible ratios based on having only moderate scores for the remaining metrics. Although this was rarely an issue in our analyses, we also believe that this captures a realistic axis of risk. Taxa that have life histories indicating some amount of risk, particularly small range size and high ecological specialization, but for which we have no data on trends in abundance or distribution, are prime candidates both for unnoticed declines and for further research or monitoring. By scoring them as data deficient and having their overall score only on available data, we explicitly upweight the importance of those metrics for which we do have information, appropriately bringing them to the attention of biologists and resource managers.

The metric scores were informative for broadly categorizing risk, with generally accepted high-risk taxa receiving the highest scores (e.g., arroyo toad, *Bufo californicus*) and clearly low-risk taxa receiving the lowest scores (e.g., northwestern garter snake, *Thamnophis ordinoides*). If a few strongly correlated risk metrics were uniformly high for at-risk taxa, this could have produced a sharp break point in overall score for Special Concern taxa, but this was not the case. Instead, the risk metric scores formed a smooth continuum from very low to extremely high Total Score/Possible Score values, indicating that a wide variety of combinations of metric scores characterized different taxa (figure 3). This smooth continuum in

scores made it difficult to use metric scores alone to decide on special concern status, particularly for the lower-ranking taxa. It also forced us to focus on the specific biology of taxa with lower metric scores in evaluating whether they should or should not be Species of Special Concern. For example, the yellow-blotched ensatina (*Ensatina eschscholtzii croceater*) has much of its small range on private land, and concerns regarding the management and development of that land was a primary motivation for its previous designation as a Species of Special Concern (Jennings and Hayes 1994a). However, more recent planning efforts have emphasized the importance of retaining much of the yellow-blotched ensatina's habitat as unfragmented space (e.g., Tejon Ranch Conservancy 2008). This shift to regional conservation planning addressed the concerns about habitat loss for this species as described in the previous amphibian and reptile Species of Special Concern document (Jennings and Hayes 1994a), so we placed it on the Watch List. However, we identified the sandstone night lizard (*Xantusia gracilis*), which has a lower metric score, as a Species of Special Concern because of its tiny range size and associated potential for extinction.

The same was generally true for assigning priority rankings to individual taxa. Once again, there are no clear cut-offs in ranking scores among Species of Special Concern taxa in figure 3, making the identification of unambiguous criteria for priority score difficult. If the correlation between ranking and priority were perfect (or if we defined priority based solely on ranking), then all Priority 1 (green) taxa would be at the bottom of figure 3, Priority 2 (yellow) would be next, Priority 3 (peach) next, followed by taxa with No Status (white) at the top of the figure. This is close to, but not identical with, our priority ranking scheme.

We could have simply imposed priority-level cut-offs using the metric scores themselves rather than trying to add information that goes beyond a ranking based entirely on metrics. We did not do so because we felt that this would

amount to a statement that all relevant biological information for each species was captured in the metric data. For example, the red-bellied newt (*Taricha rivularis*) ranked in the top 20% of taxa but is considered a Priority 2 Species of Special Concern. This decision was made because the ecological and population size data for this taxon are limited in scope, such that it was not possible to conclude that severe future declines and/or extirpation are likely without immediate conservation actions. Overall, we view the metrics as a useful but necessarily approximate guide for informing conservation decisions, not a complete replacement for careful consideration of the biology of each taxon on a case-by-case basis.

Taxonomic Patterns in Metric Scores

Taxonomic patterns among the Species of Special Concern can be measured as the total number of taxa, the fraction of the total number of species in the state that are Species of Special Concern, or as the average numerical metric score (Total Score/Total Possible) for different taxonomic groups. Each is informative, and together they provide a more complete overall picture of the status of the amphibian and reptile fauna of California than does any single measure.

When viewed in the context of all 217 taxa that are known to naturally occur in California (Appendix 1), turtles and amphibians are the most at-risk taxonomic groups. Among the candidate taxa, turtles and frogs had similar average metric scores (71% and 67%, respectively; figure 7), and many of these taxa are Species of Special Concern. All of California's nonmarine turtles are at risk at the Species of Special Concern or State Threatened level (figure 10). This pattern mimics the situation for turtles and tortoises globally; according to the IUCN, turtles have the highest fraction of Red List taxa among any major group (39% of all species and 62% of the currently evaluated species; Rhodin et al. 2010). While very few turtle species occur in the state, half of California's frogs and loads

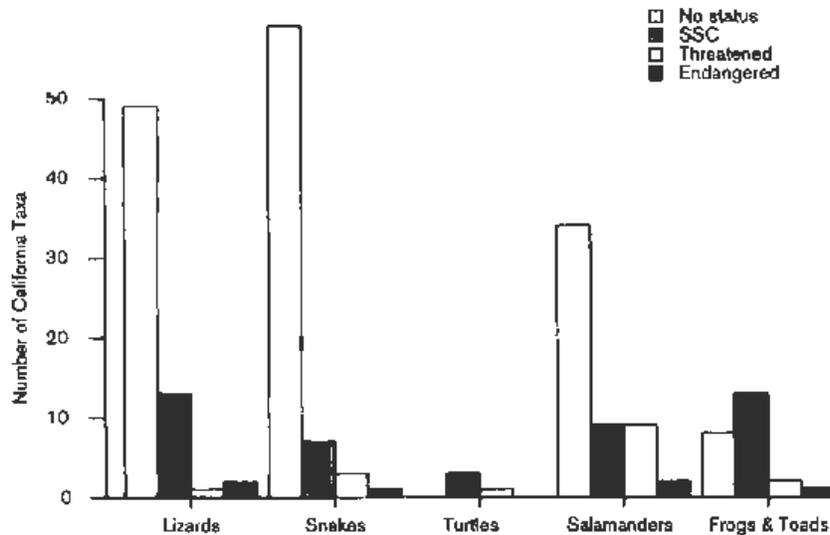


FIGURE 10 Percent of California reptile and amphibian taxa ($n = 217$ by state protected status: Endangered, Threatened, Species of Special Concern [SSC], No Status).

are included as Species of Special Concern. The state's other amphibian group, salamanders, has the next highest fraction of included taxa, with squamates (lizards and snakes) being least at risk at the state level (figure 10). These patterns are consistent with global concerns about amphibian declines in recent decades (Lannoo 2005). No frogs or toads were included in the additional taxa in need of research and monitoring category (Appendix 4), which confirms that a disproportionately large research effort has focused on this globally imperiled group compared to other taxa (Stuart et al. 2004).

Ecological Patterns in Metric Scores

Although taxa can be categorized along a variety of ecological axes, one clear distinction is between aquatic and terrestrial primary habitat requirements. The most striking overall pattern is the higher Total Score/Total Possible scores for aquatic (all frogs and toads, aquatic salamanders, turtles) compared to terrestrial (terrestrial salamanders, lizards and snakes) taxa. Jennings and Hayes (1994a) suggested that taxa having aquatic life stages were more extinction prone than terrestrial taxa, and our analysis supports this conclusion. However,

phylogenetic and ecological patterns are confounded in this analysis because all frogs and turtles that we scored are also aquatic and all of the lizards and snakes were terrestrial. Thus, it is not clear whether frogs, toads, and turtles as taxonomic groups are at risk or whether obligatorily aquatic taxa are at risk. Salamanders provide some insight into this issue, as both aquatic and terrestrial taxa occur in California. The Total Score/Total Possible metric scores for Species of Special Concern in these two groups are strikingly different (terrestrial salamanders 57%, aquatic salamanders 71%) and consistent with the interpretation that aquatic taxa are, on average, at greater risk than terrestrial ones. Even within salamanders, however, phylogeny is still a confounding variable because all salamanders in the family Plethodontidae are terrestrial, whereas all of the other California salamanders are aquatic. While the overall pattern of higher scores for aquatic taxa is clear, it is not possible to infer causality from this analysis.

Concluding Thoughts on Metric Score Patterns

Two general conclusions emerge from our analyses of metric scores across taxa. First, regard-

less of whether the pattern is driven by evolutionary relatedness or some intrinsic feature of aquatic ecosystems, aquatic species are at greater risk than terrestrial ones. Second, amphibians overall are at greater risk than reptiles. Both of these conclusions may stem from the ecology of aquatic and terrestrial taxa, particularly in the relatively arid landscape that dominates much of California. Although amphibians have been characterized in the past as harbingers of habitat deterioration due to their permeable skin and sensitivity to environmental chemicals, recent work suggests that this may be less of a general conclusion than was previously thought (Kerby et al. 2010). However, what is clear is that water is a limiting resource over most of California, and climate change predictions for the next 50–100 years indicate that this limitation will only increase in the future. Aquatic habitats in California have also been particularly negatively impacted by nonnative fish, amphibian, and invertebrate introductions (see discussion below), and managing and preventing future introductions is a major challenge to conserving aquatic habitats. Aquatic invasive predators, combined with water modification and overutilization, have led taxa that rely on water, be it a mountain stream or vernal pool, to more precipitous declines than purely terrestrial taxa.

The fact that aquatic taxa are more at risk does not, however, indicate that terrestrial taxa are uniformly secure, now or in the future. The greatest biodiversity hot spot for terrestrial lizards and snakes in the state is in southern California (Parisi 2003; figure 8). Much of this region has experienced heavy development which has led to major conservation concerns. Coastal taxa that are diurnally active and highly mobile (e.g., coast patch-nosed snake, *Salvadora hexalepis virgulata*; coastal whiptail, *Aspidoscelis tigris stejnegeri*) are particularly at risk, in part because habitat fragmentation and heavy road traffic, interactions with humans, their commensals (e.g., raccoons, skunks, rats, crows), and pets (dogs and cats), as well as general problems with fragmented habitat and a

loss of metapopulation dynamics. In addition, some of the greatest areas of urban growth in California are in the relatively sparsely populated inland xeric regions, where remote conditions and lack of easily developed water and infrastructure have thus far protected many species. As these regions become more heavily populated and more fragmented by roads and urban centers, we predict a shift in endangerment patterns over the next several decades.

To help avoid future population declines, listings, and extinctions, amphibian and reptile Species of Special Concern are sometimes considered in both urban and large-scale planning efforts. Large-scale efforts originate at both the state (Natural Community Conservation Plan [NCCP]) and federal (Habitat Conservation Plan [HCP]) levels and involve cooperation between the two jurisdictions and other public and private partners. For example, five amphibian or reptile Species of Special Concern are included in the heavily populated planning area covered by the San Diego Multiple Species Habitat Conservation Plan (<http://www.wildlife.ca.gov/Conservation/Planning/NCCP/Plans/San-Diego-MSCP>). As of December 2013, nine approved NCCPs were being implemented, some of which include amphibian and reptile taxa, and 16 NCCPs were in the planning phase. Of the nine plans undergoing implementation, 1.5 million acres (0.6 million hectares) have been committed to reserve lands. The total planning area for the 25 NCCPs covers over 33 million acres (13.3 million hectares) (<http://www.dfg.ca.gov/habcon/nccp/>). As of 25 June 2014, there are 147 approved Federal HCPs in California (http://ecos.fws.gov/conserv_plans/). HCPs are primarily focused on federally listed species, so any benefit to ARSSC taxa is typically incidental to the plan.

Other large-scale wildlife planning efforts include a statewide assessment of essential habitat connectivity sponsored by the CDFW and the California Department of Transportation. The effort identified large remaining blocks of intact habitat or natural landscape and linkages between them that need to be

maintained, particularly as corridors for wildlife (<http://www.dfg.ca.gov/habcon/connectivity/>).

Peripheral Populations and Endemic Taxa

At least 10 of the 45 Species of Special Concern are best considered peripheral in California. For these species, the bulk of their range occurs outside of the state, where they may be abundant and in little danger (e.g., Couch's spadefoot, *Scaphiopus couchii*), of relatively uncertain status (e.g., regal ring-necked snake, *Diadophis punctatus regalis*), or declining and protected (e.g., Oregon spotted frog, *Rana pretiosa*). Particularly for those taxa that are common range-wide, a reasonable question to ask is whether they should be protected in California, where they may occur in marginal habitat at the edge of their ranges. From a biological perspective, conditions beyond the state's borders are clearly relevant to range-wide conservation risk. However, from a political and jurisdictional perspective, managing populations outside of California is not the state's responsibility. We consider peripheral taxa as valid Species of Special Concern because the CDFW's mission is to "maintain native fish, wildlife, plant species and natural communities for their intrinsic and ecological value and their benefits to people [...] include[ing] habitat protection and maintenance in a sufficient amount and quality to ensure the survival of all species and natural communities" that naturally occur in California (<http://www.dfg.ca.gov/about>). Therefore, peripheral populations are similar to taxa whose entire range occurs within the state in that they are established, natural components of the biodiversity of California; whether they require special conservation measures should be based on their current status in the state. Two of our metrics, range size and endemism, take the peripheral nature of populations into account, at least indirectly. Range size generally upweights these populations, since they have small ranges within the state. Countering this, endemism measures the fraction of the species' overall range that occurs in California, which

tends to downweight such taxa. Each had a maximum score of 10, so they had equal impacts in the total score for each taxon.

Endemic taxa, by contrast, are clearly one of the state's most important conservation responsibilities (Table 4). Because they occur nowhere else, these taxa make up a critical component of California's unique amphibian and reptile fauna, so conservation successes or failures within the state are likely to have much larger impacts on these species than taxa that range more widely.

Geographic Patterns in Species of Special Concern

Range maps are an important resource in delimiting changes in the distribution of taxa. However, range is also difficult to determine precisely for many reptiles and amphibians due to their naturally low population densities, cryptic natural history, and the paucity of survey data. In constructing these range maps, we included, rather than excluded, regions where the likelihood of occurrence was high but no specimens have been documented to date. Our reasons for doing so were twofold. First, by setting boundaries that may be too large, we hope to encourage field researchers to expand their geographical horizons when searching for new localities. Second, since the taxa are at-risk, we want to err on the side of potential habitat inclusion for conservation purposes. We used previously established units (watershed boundaries, ecoregions, etc.) rather than arbitrary polygons around localities to provide objective boundaries from which future surveys can work. For instance, where we drew a species as being present in one watershed but absent in the next, this provides a very straightforward way to focus additional surveys. Surveyors can ask the question, "Is the taxon present in the adjacent watershed?" and focused efforts can answer that question, refining range boundaries in an organized, efficient manner.

These maps also highlight an important, frequently overlooked point: we need a mecha-

TABLE 4
Endemic and Near Endemic Species of Special Concern

Endemic	
<i>Aneides flavipunctatus niger</i>	Santa Cruz black salamander
<i>Batrachoseps campi</i>	Inyo Mountains salamander
<i>Batrachoseps minor</i>	Lesser slender salamander
<i>Batrachoseps relictus</i>	Relictual slender salamander
<i>Bufo canorus</i>	Yosemite toad
<i>Dicamptodon ensatus</i>	California giant salamander
<i>Elgaria panamintina</i>	Panamint alligator lizard
<i>Masticophis flagellum ruddocki</i>	San Joaquin coachwhip
<i>Taricha rivularis</i>	Red-bellied newt
<i>Taricha torosa</i> , Southern populations	Coast Range newt
<i>Thamnophis sirtalis</i> , Southern populations	Common garter snake
<i>Xantusia gracilis</i>	Sandstone night lizard
<i>Xantusia vigilis sierrae</i>	Sierra night lizard
Near endemic	
<i>Aniella pulchra</i>	California legless lizard
<i>Bufo californicus</i>	Arroyo toad
<i>Emys marmorata marmorata</i>	Northern western pond turtle
<i>Emys marmorata pallida</i>	Southern western pond turtle
<i>Phrynosoma blainvillii</i>	Coast horned lizard
<i>Rana boylei</i>	Foothill yellow-legged frog
<i>Rana draytonii</i>	California red-legged frog
<i>Spea hammondi</i>	Western spadefoot
<i>Uma scoparia</i>	Mojave fringe-toed lizard

nism, including a curated database, that tracks documented absence as well as documented presence data. Documenting, and even defining, absence is often a very difficult problem, but these efforts can be helped by collating survey results (including both positive and negative occurrence data) into a publically available and easily accessible format. Locality data from the past couple of decades tend to come from sight records, survey data, and other field research that does not result in the collection of museum specimens (figure 11). While museums are increasingly making their data acces-

sible through online databases, there is currently no centralized way to collate locality data from other sources across all California reptiles and amphibians. The California Natural Diversity Database is an important means by which the state collates status and location information for Species of Special Concern and those listed under the federal and California Endangered Species Acts. Currently, this resource does not document absence data for sites where only negative surveys have occurred and focuses solely on those taxa on California's Special Animals list. Expanding the scope of this

Museum Specimens 1950–1969



1970–1989



1990–2013



Other Sources 1950–1969



1970–1989



1990–2013



FIGURE 11 Distribution of Species of Special Concern locality records over time. Data from other sources include records from the California Natural Diversity Database and the Biogeographic Information and Observation System, both of which contain some museum records, though the majority of records plotted are from survey data.

database or adding an additional database to capture negative occurrence data, as well as survey data from other taxa, would help the state's efforts to improve estimates of species ranges.

When we plot the number of at-risk species contained within each ecoregion, geographic patterns in conservation risk emerge (figure 8). The southern California coast and mountains and the Mojave Desert have the largest number of at-risk species overall, although this pattern is due largely to trends among reptiles. This important area of conservation risk is driven

along the south coast by habitat loss and degradation arising from the massive land use changes that this area has experienced over the last century. The Mojave Desert, conversely, is often viewed as being less disturbed and protected by reserves, parks, and military reservations. Our analysis highlights that this is not entirely true. The Mojave Desert has experienced some degree of habitat degradation and loss, although, to date, not as strongly as that which has occurred along the coast where extensive urbanization has effectively removed large areas of habitat. However, the Mojave

Desert, as well as the Great Basin, Colorado, and Sonoran Deserts, and some of the southern Sierra Nevada and associated foothills constitute the 22.5 million acre planning area for future renewable energy development (wind, solar) in southern California. In addition, many of the at-risk species in the Mojave Desert use specialized and rare resources that have experienced a disproportionate amount of habitat degradation relative to other areas of the desert. For example, the fringe-toed lizards of the genus *Uma* exclusively use sand dune habitats, which also disproportionately attract off-highway vehicle use even in some protected areas (see species accounts for additional details). The Mojave Desert is also home to a large number of narrowly distributed or rare taxa that may exist at the edge of their physiological tolerance and persist in small, often isolated areas (e.g., Gila monster, *Heloderma suspectum*). These species may be at particular risk of further declines as climate change occurs. Importantly, it is not the case that all desert species are declining equally, since the Great Basin and Sonoran ecoregions have relatively few at-risk reptiles, while an intermediate number occur in the Colorado Desert.

For amphibians, the areas of largest conservation risk are the mountainous areas surrounding the Central Valley and the forested regions of central and northern California (figure 8). These areas have not experienced massive land use change per se, although they have experienced considerable habitat fragmentation and modification stemming from water diversions, timber harvest, and nonnative species (Bunn et al. 2007, <http://www.wildlife.ca.gov/SWAP>). Some studies indicate that agriculture in the Central Valley has had an impact on some species in the Sierra Nevada and Cascades Range via increased exposure to pesticide drift from the Central Valley (e.g., Davidson et al. 2002, Davidson 2004, Lind 2005). In addition, many of these regions are heavily exploited for timber harvest, and this has also had an impact on both stream-dwelling and terrestrial amphibians (e.g., Olson et al. 2007, Welsh and

Hodgson 2008). An emerging threat in northern California is marijuana cultivation, which can degrade both terrestrial and aquatic amphibian habitat (CDFW 2013). Increased sedimentation, dewatering of headwater streams, and application of agricultural chemicals are all potential negative effects of marijuana growing, and these effects should be monitored and potentially regulated. High elevation mountainous areas are expected to experience large impacts from climate change through the altered timing and amount of snowmelt (Cayan et al. 2008b), and this future risk probably affects amphibians to a greater extent than co-occurring reptiles (figure 8). Increasing temperatures associated with climate change may also lead to phenological shifts in several species, which could interact with several of the existing threats (Todd et al. 2011). This pattern in both amphibians and reptiles is driven to some extent by species richness of the respective groups. Southern California and the deserts have the highest richness of reptile diversity, whereas the Sierra Nevada and northern Coast Ranges are home to greater amphibian species richness (Parisi 2003, Stebbins 2003).

Finally, for all taxa we note that the distribution of locality data is uneven and patchy across the state (figure 12). At first glance, it appears that the areas with the greatest human impacts and populations (southern coastal California, the Bay Area) are also the areas with the greatest number of locality records, and it may be that these are simply the areas that have received the greatest efforts from field biologists. Unfortunately, we cannot unambiguously say whether the sparse locality records, for example, from the Mojave Desert reflect sparse fieldwork, underreporting of data, or a genuine low density of animals in the region. Our sense is that all of these factors are contributing to the distribution of locality records. That is, it is almost certainly the case that there has been much more intensive sampling effort, and consequently a larger number of records, in San Diego County than in the eastern Mojave

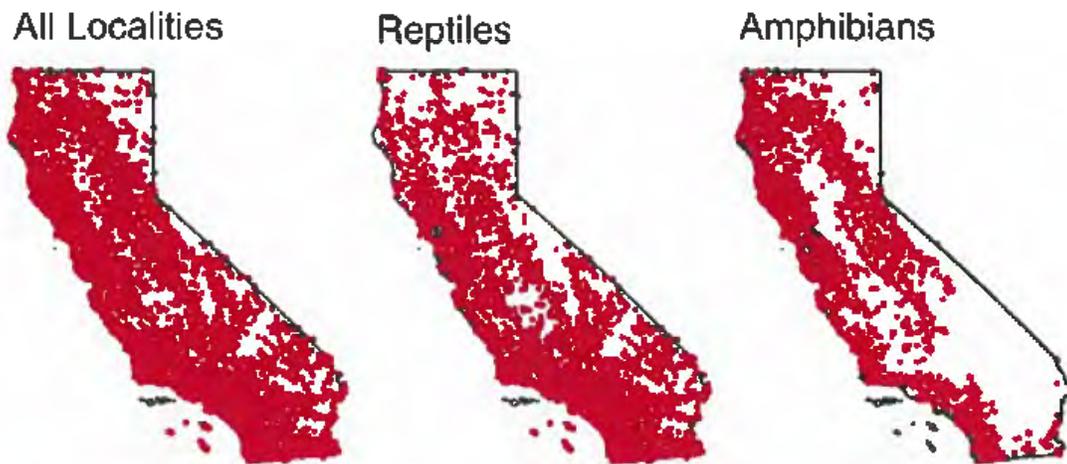


FIGURE 12 Occurrence of Species of Special Concern taxa locality records throughout the state. Regions with few occurrence records may represent areas with few SSC taxa, low sampling effort, or both.

(figure 11). However, it is also true that both reptiles and amphibians are sparsely represented in the eastern Mojave (compare reptile and amphibian maps in figure 12), even though this is a region of high abundance and species richness for reptiles. However, the large number of sensitive species (figure 8) and the recent, intensive development in San Diego County cause many environmental impact assessments to be undertaken under the California Environmental Quality Act, and this has likely contributed to the larger number of records compared to the deserts of southern California.

Differences between This Document and Jennings and Hayes (1994a)

Species priority assessments for conservation purposes are subject to revision over time as factors that affect risk, including habitat protection, invasive species, and scientific knowledge change. Although the number of species identified as being of concern was similar (49 vs. 45), a number of differences exist between the current and previous assessments. Jennings and Hayes (1994a) based their assessment on a combination of their own knowledge and that of a large group of leading experts on individual species; we follow a similar procedure here but summarize the available data using a metric-

based approach. Jennings and Hayes (1994a, p.183) felt that for no species of amphibian or reptile was there compelling evidence to “downgrade” status from more threatened to less threatened, whereas we removed several taxa from the Species of Special Concern designation. In total, 34 taxa occur on both lists; we added 11 taxa that were not included by Jennings and Hayes (1994a) and excluded 15 taxa that were previously included (Table 5, Appendix 3).

The status of 43% (26/60) of Species of Special Concern taxa has changed between 1994 and the present. Of the 26 species that changed status, approximately half were upgraded and half were downgraded: 58% (15/26) of the taxa were on the previous list but not the current one, and 42% (11/26) were upgraded from having no formal status to Species of Special Concern (Table 5). These changes reflect differences in approach between these two compilations, insights gained from an additional 20 years of field and systematic research, and real changes that have occurred in the abundance of species. However, on face value, it appears that the past two decades have not been a completely negative period for amphibian and reptile biodiversity in California.

Several factors contribute to these changes. In Table 5, we broadly categorized reasons for changes into three categories. “Listing status”

TABLE 5
 Comparison of Species of Special Concern between this publication and Jennings and Hayes (1994a)
 Gray cells denote species designated by both publications (see text for additional details)

Taxon	Jennings and Hayes	Thomson et al.	Reason
<i>Ambystoma californiense</i>	X		Listing status
<i>Ambystoma macrodactylum sigillatum</i>		X	New data
<i>Aneides flavipunctatus niger</i>		X	New data
<i>Aniella pulchra</i>	X	X	
<i>Arizona elegans occidentalis</i>		X	New data
<i>Ascaphus truei</i>	X	X	
<i>Aspidoscelis hyperythra</i> ¹	X		New data
<i>Aspidoscelis tigris stejnegeri</i>		X	New data
<i>Batrachoseps</i> sp. "Breckenridge" ²	X	X	
<i>Batrachoseps campi</i>	X	X	
<i>Batrachoseps minor</i>		X	Taxonomy
<i>Batrachoseps relictus</i>	X	X	
<i>Bogertophis rosaliae</i> ³	X		New data
<i>Bufo alvarius</i>	X	X	
<i>Bufo californicus</i> ⁴	X	X	
<i>Bufo canorus</i>	X	X	
<i>Coleonyx variegatus abbotti</i>		X	New data
<i>Crotalus ruber</i>	X	X	
<i>Diadophis punctatus regalis</i>		X	New data
<i>Dicamplodon ensatus</i>		X	New data
<i>Elgaria panamintina</i>	X	X	
<i>Emys marmorata marmorata</i> ⁵	X	X	
<i>Emys marmorata pallida</i> ⁴	X	X	
<i>Ensatina eschscholtzii croceater</i>	X		New data
<i>Ensatina eschscholtzii klauberi</i>	X		New data
<i>Gambelia copeii</i>		X	New data
<i>Heloderma suspectum</i>	X	X	
<i>Hydromantes platycephalus</i>	X		New data
<i>Hydromantes</i> sp. "Owens Valley"	X		Taxonomy
<i>Kinosternon sonoriense</i>	X	X	
<i>Lampropeltis zonata parvirubra</i>	X		New data
<i>Lampropeltis zonata pulchra</i>	X		New data
<i>Masticophis flagellum ruddocki</i>	X	X	
<i>Masticophis fuliginosus</i>		X	Taxonomy
<i>Phrynosoma blainvillii</i> ⁷	X	X	
<i>Phrynosoma mcallii</i>	X	X	

(continued)

TABLE 5 (continued)

Taxon	Jennings and Hayes	Thomson et al.	Reason
<i>Pituophis catenifer pumilis</i> ⁸	X		New data
<i>Plestiodon skiltonianus interparietalis</i> ⁹	X		New data
<i>Plethodon elongatus</i>	X		New data
<i>Rana aurora</i>	X	X	
<i>Rana boylei</i>	X	X	
<i>Rana cascadae</i>	X	X	
<i>Rana draytonii</i> ¹⁰	X	X	
<i>Rana muscosa</i>	X		Listing status
<i>Rana pipiens</i>	X	X	
<i>Rana pretiosa</i>	X	X	
<i>Rana sierrae</i> ¹¹	X		Listing status
<i>Rana yavapaiensis</i>	X	X	
<i>Rhyacotriton variegatus</i>	X	X	
<i>Salvadora hexalepis virgulea</i>	X	X	
<i>Scaphiopus couchii</i>	X	X	
<i>Spea hammondi</i> ¹²	X	X	
<i>Taricha rivularis</i>		X	New data
<i>Taricha torosa</i> (Southern populations)	X	X	
<i>Thamnophis hammondi</i>	X	X	
<i>Thamnophis sirtalis</i> ssp.	X	X	
<i>Uma notata</i>	X	X	
<i>Uma scoparia</i>	X	X	
<i>Xantusia gracilis</i>	X	X	
<i>Xantusia vigilis sierrae</i>	X	X	

1. Evaluated under the name *Cnemidophorus hyperythrus beddingi* in Jennings and Hayes (1994a).

2. Now included within *Batrachoseps relictus*.

3. Evaluated under the name *Elaphe rosaliae* in Jennings and Hayes (1994a).

4. Evaluated under the name *Bufo microscaphus californicus* in Jennings and Hayes (1994a).

5. Evaluated as a single species, *Clemmys marmorata*, in Jennings and Hayes (1994a).

6. Evaluated as a single species, *Clemmys marmorata*, in Jennings and Hayes (1994a).

7. Evaluated as two subspecies, *Phrynosoma coronatum blainvillii* and *Phrynosoma coronatum frontale* in Jennings and Hayes (1994a).

8. Evaluated under the name *Pituophis melanoleucus pumilis* in Jennings and Hayes (1994a).

9. Evaluated under the name *Eumeces skiltonianus interparietalis* in Jennings and Hayes (1994a).

10. Evaluated under the name *Rana aurora draytonii* in Jennings and Hayes (1994a).

11. Evaluated as part of *Rana muscosa* in Jennings and Hayes (1994a).

12. Evaluated under the name *Scaphiopus hammondi* in Jennings and Hayes (1994a).

applies to a few taxa, like the California tiger salamander (*Ambystoma californiense*), that are no longer considered Species of Special Concern because they were listed under the California Endangered Species Act between 1994 and

2014. These taxa are still considered to be at risk, but their state listing precludes inclusion as a Species of Special Concern. "Taxonomy" is more difficult to categorize because many taxa have had name changes between the two lists.

However, in Table 5 we highlight taxonomic changes that led to either the recognition of a new at-risk taxon or the elimination of a previously recognized taxon that is no longer considered valid. An example of the former is the Baja California coachwhip (*Masticophis fuliginosus*), which was considered a part of the widespread and relatively common coachwhip (*M. flagellum*) in 1994, but has since become more widely recognized as a distinct species (Grismer 2002). We note taxonomic changes in Table 5 that did not impact special concern status, like the elevation of the arroyo southwestern toad (*Bufo microscaphus californicus*) (Jennings and Hayes 1994a) to the arroyo toad (*B. californicus*) (current document) as footnotes. The remaining taxa changed special concern status because of new data. This category covers a variety of factors, ranging from better and more extensive field survey data which has revised our understanding of the severity of threats (e.g., the Mount Lyell salamander, *Hydromantes platycephalus*) to new threats that have been identified since 1994 (e.g., predation by introduced fishes for the southern long-toed salamander, *Ambystoma macrodactylum sigillatum*). Some of the difference in threat evaluation stems from our choice of metrics. For example, climate change is currently a particularly important aspect of conservation risk that was not previously considered. In some cases, the availability of suitable habitat has changed, either positively or negatively. Habitat may be set aside for conservation (e.g., Tejon Ranch appears to be setting aside considerable land that will benefit the yellow-blotched ensatina, *Ensatina eschscholtzii croceater*) but is usually lost (e.g., coastal scrub habitat for the California glossy snake, *Arizona elegans occidentalis*). Finally, we note that the factors listed in Table 5 are an over-simplification of the reasons behind our decisions. An explanation for each of the 15 taxa that appeared on the previous list but not on the new list is also included in Appendix 3.

Ultimately, the comparison of the two Species of Special Concern documents emphasizes what can be learned by periodically updating

and evaluating the conservation status of taxa on a regular basis. For the 34 taxa that have remained Species of Special Concern, we can and should ask what more can be done to improve their status. Some of the taxa that are no longer Species of Special Concern may inform the kinds of positive changes that can be brought about by management, research, or both. For example, additional surveys and taxonomic research on the Mount Lyell salamander (*H. platycephalus*) have shown that the species is more widespread than previously thought and clarified the taxonomic status of populations in Owens Valley, which were previously suspected of being distinct and of conservation concern. Finally, the challenges of incompletely known taxonomy that were emphasized by Jennings and Hayes (1994a) still pose a major challenge to effective management; if we do not have a complete catalogue of the taxa that occur in California, we cannot even enumerate what may need protection to maintain biodiversity.

Management Recommendations for California Amphibians and Reptiles

While effective management of the Species of Special Concern will generally require development of specific management strategies tailored to the biology of individual taxa, several general recommendations have emerged from this document.

1. *Protect aquatic habitats.* The metric scores indicate that aquatic species are at greater risk than terrestrial ones, suggesting that remaining aquatic habitats with native amphibian and turtle populations should be high conservation priorities. California's aquatic habitats have been highly modified from a faunal perspective. As of 2002, there were 51 nonnative freshwater fishes in California, the majority of which were deliberately introduced to enhance recreational fisheries (Moyle 2002). Nonnative fishes now predominate in many California waterways, raising concerns about increased competition, predation, habitat interference,

disease, and hybridization with native species (CDFG 2008). A large body of ecological research has demonstrated a negative effect of introduced fishes and bullfrogs (*Rana catesbeiana*) on California's native anurans (e.g., Hayes and Jennings 1986, Tyler et al. 1998, Knapp and Matthews 2000, Vredenburg 2004, Knapp 2005, Leyse 2005, Welsh et al. 2006, Pope et al. 2008). As a result, predatory salmonids, centrarchids, catfishes, and other nonnative species should be eradicated wherever feasible and should not be introduced into remaining native amphibian or reptile habitat. Maintaining appropriate water flow regimes for stream-dwelling taxa is also critical, as are broad riparian buffers to maintain lotic habitats and reduce siltation (e.g., Lind et al. 1996, Yarnell 2005, Hancock 2009).

Specific management recommendations include the following:

- Control, or eliminate where possible, invasive aquatic species, particularly predatory fishes, crayfish, and bullfrogs. For widespread, established invasives, plans should be developed with actions that reflect those identified in the California Aquatic Invasive Species Management Plan (CDFG 2008). For bullfrogs in particular, plan Objectives 5 and 6 apply; Education and Outreach and Long-Term Control and Management. Invasive species in the early stages of colonization (e.g., *Nerodia fasciata*, *N. sipedon* and *N. rhombifer*) should be eradicated as soon as possible to prevent further spread. Known to be present in California since the 1990s, coordinated efforts have yet to effectively coalesce to make significant progress toward eradicating *Nerodia*, though educational (<http://biology.unm.edu/mmfuller/WebDocs/HTMLfiles/nerodia.html>) and occasional agency efforts occur.
- Eliminate, limit, or mitigate effects of dams, water diversions, and other hydrological disturbances to breeding streams whenever possible, and particularly during breeding seasons.
- When biologically appropriate, enhance connectivity and continuity of streams to allow free movement of aquatic species. Conversely, the potential for increasing connectivity to facilitate the spread of invasive species or disease should be considered on a species-by-species basis.
- Maintain riparian vegetation buffers and adjacent upland habitat.
- Eliminate roads within buffer zones and mitigate their effects in high-use amphibian migration areas whenever possible to avoid siltation and road mortality.
- Restrict use of heavy equipment on dirt roads and upland habitats, particularly during the breeding season when eggs and small larvae may be most affected by siltation.
- Maintain culverts under roads adjacent to breeding streams to reduce siltation.

2. *Protect integrity and connectivity of large terrestrial habitat patches.* The size of habitat patches necessary to support healthy populations of most species may be larger than previously recognized (Prugh et al. 2008). The amount and configuration of habitat clearly has a strong impact on the overall extirpation and recolonization dynamics of adjacent populations, and ultimately, of entire species. Besides the general conclusion that more intact habitat is always desirable, specific requirements will always need some level of study on a species-by-species basis. For example, ongoing work on the state and federally endangered California tiger salamander (*Ambystoma californiense*) suggests that this species routinely moves long distances (up to 2 km) away from breeding ponds, suggesting that the extent and quality of upland habitat is likely to have a strong impact on the species' long-term persistence (Trenham and Shaffer 2005, Searcy and Shaffer 2008, Searcy and Shaffer 2011). Several diurnally active and wide-ranging reptile species in southern California appear to be sensitive to habitat fragmentation and disappear from patches of small suit-

able habitat (e.g., coastal whiptail, *Aspidoscelis tigris stejnegeri*; coast patch-nosed snake, *Salvadora hexalepis virgulata*). Habitat fragmentation is a strong driver of declines for many species, and we recommend that land managers pay particular attention to preserving extensive habitat blocks where possible (see Mitrovich et al. 2009, for a well-worked example).

Although the individual conservation needs of species vary, formal conservation planning occurs on a broader scale that considers large areas of habitat for many species simultaneously. Because of many aspects of their shared biology, amphibians and reptiles are often considered as a group, and some excellent, general guidelines for their management have been developed (see, e.g., the Partners in Amphibian and Reptile Conservation habitat management guidelines <http://www.parcplace.org/parcplace/publications/habitat-management-guidelines.html>). In addition, the biology of amphibian and reptile species needs to be jointly considered within the framework of larger conservation initiatives. The California Natural Community Conservation Planning program is one such initiative that takes an area-wide approach to conservation planning, simultaneously considering conservation of many plant and animal species as well as potential land use activities (see Fish and Game Code Section 2800-2840). These broadscale, integrative approaches to conservation planning promise to be among the more effective strategies for achieving habitat protection and should become an increasingly central mechanism for conservation planning in California. Preserving linkages between adjacent habitat patches is also a key priority in these landscape-level conservation initiatives. Biologically, these linkages maintain metapopulation connectivity and habitat corridors that are often essential for long-term conservation. The California Essential Habitat Connectivity Project seeks to identify corridors between large remaining blocks of intact habitat and is one step in this direction (Spencer et al. 2010). Projects such as these are critically important for maintaining gene flow

and migration among localized populations and should continue to be considered as landscape-level conservation initiatives move forward in the state.

Specific management recommendations include the following:

- All Species of Special Concern and the taxa discussed in Appendices 3 and 4 should be considered in Habitat Conservation Plans, Natural Community Conservation Plans, and other local and regional habitat management planning efforts.
- Develop species-specific ecological and landscape genetic datasets to determine the most important habitat corridors for protection and management of amphibian and reptile Species of Special Concern on specific landscapes.
- Identify and either eliminate or mitigate land uses that interrupt connectivity across habitat blocks that have been set aside for conservation. These might include roads, grazing, mining, timber harvest, and many other land uses and activities.

3. *Mitigate the effects of roads as a source of mortality and habitat fragmentation.* Roads have two primary effects: mortality and fragmentation (Fahrig et al. 1995, Gibbs and Shriver 2002, Mazerolle 2004, Gibbs and Shriver 2005; see also review in Andrews et al. 2008). The overall impact of road mortality on amphibian and reptile populations varies across road types, from species to species, geographically, temporally, and seasonally, and road-associated mortality levels interact with the movement patterns and seasonal migrations of individual taxa. In other parts of the country, roads have been documented to significantly contribute to fragmentation and reduced gene flow, interrupting normal metapopulation dynamics (Fahrig et al. 1995, Hels and Buchwald 2001, Langen et al. 2009, Clark et al. 2010, Sutherland et al. 2010), and the same presumably occurs in California. For example, surveys of 21 roads for migrating, federally endangered

California tiger salamander (*A. californiense*) in Sonoma County suggest widespread mortality that has increased over time as traffic volume has increased. For surveys of one 1200-ft section of Stony Point Road conducted from 2001 to 2010, 160 of 262 salamanders (61%) found were road mortalities, suggesting that vehicular traffic is a substantial form of death in this extremely endangered species (D. Cook, unpublished data). Langen et al. (2009) identified predictors of hot spots of amphibian and reptile road mortality for use when planning roads or when conducting surveys on existing roads to locate priority areas for mitigation.

Although they have been employed infrequently in California, tunnels that assist amphibian and reptile movements can be an effective management tool that should be more actively investigated (for a comprehensive summary of published and unpublished literature, see Caltrans 2012). Two important aspects of migration tunnels are that they must have some capacity to funnel individuals into the tunnels (drift fences, concrete walls, or other similar structures), and they must be actively maintained. Without regular, scheduled maintenance, tunnels fill with debris, drift fences become covered with leaves, runoff soil, trash, and woody debris, and the tunnel quickly ceases to function. Tunnels may also play a role in the deserts of southern and eastern California, particularly as vehicular traffic increases, and roads fragment previously contiguous habitat. For additional recommendations regarding herpetofauna and roads, see Schmidt and Zumbach (2008).

Specific management recommendations include the following:

- Limit traffic, and consider road closures, during amphibian breeding migrations on sensitive public lands.
- Use signage (e.g., "Newt Crossing" warning signs) to warn vehicular traffic that they are in key migration areas.
- Develop standards for and install, maintain, and monitor usage of tunnels, underpasses

or other passage mechanisms to reduce road-related mortality.

- Use various media resources for public education campaigns.

4. *Translocate animals only when biologically appropriate.* A general management strategy, variously referred to as relocation, repatriation, or translocation (Germano and Bishop 2009), is the practice of moving animals across landscapes, often from a site destined for development to a protected site. These efforts have become increasingly common as partial or complete mitigation for development projects that affect amphibians and reptiles. Several key biological issues need to be considered before animals are translocated. Disease transmission is an important problem that has had devastating consequences for several species (Jacobson 1993). The well-known upper respiratory tract infection that has decimated desert tortoise (*Gopherus agassizii*) populations is thought to be derived from released captive animals (Jacobson 1993). Genetic consequences of relocation programs should also be considered. Increasingly, genetic data are allowing researchers to elucidate fine-scaled genetic structure among populations, and the insights gained from nonlethal genetic sampling allow insight into biological parameters that are relevant for conservation including population subdivision, gene flow, migration corridors, and population sizes. However, the overall extent and functional consequence of this variation is still poorly understood for most organisms.

Moving individuals around the landscape has the potential for deleterious effects, either by diluting or eliminating unique historical lineages or by disrupting genetic variation that may be an important component of local adaptation. As emphasized in a recent review (Germano and Bishop 2009), homing and poor habitat quality are two of the primary reasons why translocation efforts may fail, and they should be carefully studied on a case-by-case basis. A recent document providing guidelines for translocations for the California tiger sala-

mander (Shaffer et al. 2009) may serve as a model for some other taxa as well. It emphasizes that translocations should only be attempted into unoccupied habitat, and only after the threats that caused the initial declines have been effectively removed. It also emphasizes that sufficient research must have been conducted to provide compelling evidence that the potential damages that can be done to existing conspecific and heterospecific taxa do not outweigh the potential gains to the animals and populations being relocated.

In some cases, headstarting programs may represent a suitable alternative to repatriation or translocation, particularly if the headstarting is done under seminatural conditions. Many species experience the most severe mortality during early life stages. Raising individuals in captivity from a given site to the size or age where they are past this initial peak of mortality and then releasing them at the site where they were initially collected may avoid many of the potential issues associated with translocations while also providing a temporary boost to populations that are in decline. Headstarting is only appropriate, however, where suitable unoccupied habitat exists, or where introduction of individuals will not create problems for existing species at the introduction site.

Specific management recommendations include the following:

- Only translocate animals when other alternatives do not exist.
- Only translocate animals into situations where other animals at the translocation site will not be adversely affected by the introduced animals.
- Only translocate animals when the ecological requirements of the species exist in the new habitat.
- Utilize methods to increase the likelihood that translocations will be successful. These potentially include “soft” translocations (i.e., moving young animals rather than adults with established home ranges) and moving a

sufficiently large number of individuals to ensure that a successful breeding population can establish (Germano and Bishop 2009).

Research, Survey, and Monitoring Needs

Both new research and continuing, long-term monitoring are integral parts of the science-driven protection and recovery of sensitive species. For California amphibians and reptiles, our level of basic knowledge on natural history is frequently so fragmentary that even rudimentary information is lacking, and increasing our understanding of these animals is critical for effective management. Many of the particular research needs are discussed in individual species accounts under the “Monitoring, research, and survey needs” section; here, we highlight several basic research and monitoring needs that are common to virtually all taxa.

Distribution

A statewide survey for all amphibians and reptiles is essential to establish baseline data for ongoing status determination and monitoring. Survey efforts are particularly needed for those Special Concern taxa whose population status or range size are a high priority for clarification. These surveys should employ standardized and repeatable methods, with the data emerging from these efforts made widely and easily accessible (Heyer et al. 1994). The Partners in Amphibian and Reptile Conservation Inventory and Monitoring guide (Graeter et al. 2013) serves as an important resource in the detailed design of these distributional surveys. Greatest need taxa include (1) those that may be recently extirpated, but for which comprehensive surveys have yet to be conducted (e.g., the Sonora mud turtle, *Kinosternon sonoriense*); (2) recently discovered taxa that are currently known from relatively small ranges, which may also be tied to specific narrow habitat types, that have yet to be thoroughly surveyed (e.g., the regal ring-necked snake, *Diadophis punctatus regalis*); (3) at-risk taxa that are difficult to

detect or that have ranges that are poorly understood because they occur in remote, difficult-to-survey areas (e.g., the Gila monster, *Heloderma suspectum*); and (4) taxa that may occur only on private land where gaining access can be challenging (e.g., the Oregon spotted frog, *Rana pretiosa* or the western spadefoot, *Spea hammondi*). In addition, surveys of virtually all Species of Special Concern, particularly at their hypothesized range edges, would greatly enhance our knowledge of range boundaries for most taxa.

Natural History

Basic natural history and ecology information is the foundation for effective management, and for most amphibian and reptile Species of Special Concern, it is either fragmentary or completely lacking. Home range sizes, habitat suitability analyses, food habits, the effects of invasive plants and animals, compatibility with grazing and agriculture, the effects of human activities including forestry, recreation, and water diversions are unknown for many of the taxa considered here. For some questions and species, this probably is not a pressing problem—calling the southern long-toed salamander (*Ambystoma macrodactylum sigillatum*) a “generalist predator” is, to the best of our knowledge, correct, and filling in the precise details of which invertebrates are the most important prey in specific situations may not be an urgent management issue. However, in other cases, filling in at least some of this basic ecology is absolutely critical. For example, of the 19 species of pond/stream breeding Species of Special Concern amphibians, we do not have a well-tested, clearly understood model of terrestrial habitat use for a single taxon. For example, we have little idea of whether the southern long-toed salamander (*A. m. sigillatum*) requires 10, 1000, or 10,000 m radius habitat patches around breeding ponds. Filling in these fundamental information gaps, hopefully across a range of habitat types, constitutes the highest priority conservation-related research need for Species of Special Concern.

Climate Change

Climate change is likely to have a number of effects on the California landscape that are relevant to amphibian and reptile conservation. While the impact that climate change has on California’s landscape is undergoing extensive study (reviewed by Cayan et al. 2008a) and is a CDFW focus (<http://www.wildlife.ca.gov/Conservation/Climate-Science>), the impact that these effects will have on amphibian and reptile species requires additional study. The Association of Fish and Wildlife Agencies has initiated work on this problem in the southeastern United States, and the CDFW, in collaboration with the Southwest Climate Science Center, initiated a detailed investigation of future climate impacts on amphibians and reptiles across California (Wright et al. 2013). A major focus of these projects, and one that requires additional research effort, is to model a full range of future climate change predictions and their impacts on both common and rare amphibian and reptile taxa.

Importantly, the interplay between conservation risks that climate change presents and competing factors that will arise needs careful examination. For example, many climate projections forecast a decrease in the snowpack in the Sierra Nevada, as well as a shift in the speed and timing of snowmelt to be both more rapid and earlier in the year (Maurer and Duffy 2005, California Climate Action Team 2006, Maurer 2007). Even for the lowest carbon emissions scenarios and relatively conservative estimates of increasing temperatures, current models predict a 30–60% decrease in Sierra Nevada snowpack (Cayan et al. 2006). This is likely to have important, direct impacts on amphibians that rely on snowmelt-fed streams and lakes for their breeding habitat. In addition, it is likely to further stress California’s already overburdened water resources, setting the stage for further conflicts between the ecological needs of at-risk species and municipal and agricultural demands for increasingly limited water.

The combined impacts of changes in climate on biological diversity are likely to be

strong. Several studies have documented ongoing (Walther et al. 2002, Parmesan and Yohe 2003, Root et al. 2003, Root et al. 2005, Parmesan 2006, Pounds et al. 2006) and expected (Hughes 2000) implications of climate change, with some estimates predicting 35% or more (Harte et al. 2004, Thomas et al. 2004) of species being “committed to extinction” under mid-range warming scenarios. These effects will likely be especially pronounced for amphibians, which generally exhibit limited dispersal and are already experiencing severe declines (Stuart et al. 2004, Lawler et al. 2010). The uncertainties involved with estimating specific effects that will occur on landscapes, species’ responses to these changes, and the interplay of factors that will result from climate change (e.g., agricultural and municipal water needs vs. amphibian breeding habitat needs, alternative energy development in the desert vs. reptile habitat needs) clearly indicate that this topic requires further study. An important step in this direction is a recent initiative by the US Fish and Wildlife Service (USFWS) to fund the California Landscape Conservation Cooperative, an interdisciplinary program to facilitate research and planning across scientific and management agencies in the state (<http://californialcc.org/about-us>). Results of the CDFW and Southwest Climate Science Center collaboration mentioned above should be integrated into the California Landscape Conservation Cooperative process.

Threats from Disease

Diseases in amphibian and reptile populations have become an issue of global significance. In particular, the pathogenic chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), has been linked to precipitous declines in several amphibian species in the state (e.g., the Sierra Nevada yellow-legged frog, *Rana sierrae*) and globally (Stuart et al. 2004). At the present time, no broadly effective management strategies for controlling or mitigating the effects of this pathogen are known, and this is a critical, active research area. Proposed management

strategies that would benefit from further study include altering population dynamics to minimize disease outbreaks, treating individual amphibians and habitats to control the prevalence or spread of disease, biological control of *Bd* using the zooplankter *Daphnia magna*, and in the most dire cases, maintenance of captive assurance colonies followed by repatriation with assisted selection (Buck et al. 2011, reviewed by Woodhams et al. 2011). Efforts to develop management strategies should not focus exclusively on strategies for the short term, such as direct control of *Bd* in the wild or captive breeding. Rather, management strategies that allow susceptible amphibians to persist in the wild in the presence of *Bd* are needed for long-term conservation of sensitive species (Woodhams et al. 2011).

The extent and type of interactions that *Bd* may have with other threats, such as climate change, pesticide exposure, or other pathogens, are also key research needs. A growing body of work on *Bd* indicates that it has negative consequences on at-risk species of amphibians in California (Davidson et al. 2007, Morgan et al. 2007, Andre et al. 2008, Lacan et al. 2008, Padgett-Flohr 2008, Briggs et al. 2010), that synergistic interactions with pesticides may have strong biological effects (Davidson et al. 2007), and that terrestrial amphibians may serve as vectors for the disease (Schloegel et al. 2009, Weinstein 2009). Other emerging diseases, particularly those that have their origins in human pets or are a result of human-mediated movements and relocations of animals are also high-priority research targets. Important examples include ranaviruses and iridoviruses, both of which have also been linked to amphibian declines (e.g., Picco et al. 2007, Schloegel et al. 2009).

Phylogeography and Landscape Genetics

Another important research need, and one that may be easier to fill than comprehensive ecological studies, is genetic analyses for most species. Some limited phylogeographic and landscape genetic work has been completed for a

few California amphibians and reptiles (or their close relatives), and these analyses have provided key insights into the importance of drainages on stream- and pool-breeding amphibians and reptiles (Shaffer et al. 2000, Spinks and Shaffer 2005, Dever 2007, Wang 2009b, Lind et al. 2011), corridors of land use (Wang et al. 2009), the importance of environmental variables in structuring populations (Savage et al. 2010), and a variety of other problems (e.g., the provenance of introduced populations; Johnson et al. 2010). At a broader, regional-to-range-wide scale, phylogeographic studies have been conducted for several Species of Special Concern, in many cases indicating either that previous subspecies (which often serve as proxies for genetic lineages) are non-diagnosable and correspond poorly to genetic patterns (Rodríguez-Robles et al. 1999b) or that unappreciated lineage diversity is stronger than previously suspected (Shaffer et al. 2004, Leavitt et al. 2007, Parham and Papenfuss 2009). We are aware of phylogeographic work for roughly half of the Species of Special Concern (although many of those studies rely on a single mitochondrial gene and need data from additional nuclear gene analyses), and we strongly encourage the research community to gather these data for the remaining taxa.

Monitoring

To establish that a species or population is declining or recovering requires long-term monitoring. Such efforts can take many forms, each with strengths and weaknesses. Ideally, monitoring data would be generated by intensive, multiyear mark-recapture-based studies that follow the fate of individuals through time, leading to a detailed inventory of population increases and decreases (Heyer et al. 1994). Such monitoring is not difficult conceptually, but it requires time, effort, and often substantial financial resources. However, this is also an area that is undergoing renewed methodological development. Monitoring methods now exist that require less recapture effort and that can incorporate detection probabilities in a rig-

orous manner, both of which can help to effectively monitor rare and/or cryptic taxa (reviewed by Mazerolle et al. 2007). One such example is the emerging techniques to monitor rare or cryptic taxa via detection of persistent DNA in environmental samples (Ficetola et al. 2008, Dejean et al. 2011).

Techniques to survey amphibians and reptiles vary, depending on the taxon, habitat, and life stage involved. Although standardized survey protocols are essential to proper inventory and monitoring, relatively few have been developed, representing an ongoing research need, particularly for rare taxa or taxa that are difficult to detect. Some of this standardization is beginning to take place and a few excellent resources are available or forthcoming (Heyer et al. 1994; the ongoing Amphibian Research and Monitoring Initiative being undertaken by the US Geological Survey, and the Partners in Amphibian and Reptile Conservation Inventory and Monitoring guides are such examples). In the absence of detailed, multiyear monitoring, we advocate at least two potential approaches that have received relatively little attention to date for amphibian and reptile taxa. The first is single-pass monitoring via population surveys conducted on public lands. Such surveys can be incredibly informative, yet only require a few field days per year to monitor a large number of species and sites (e.g., Thomson et al. 2010). A recent example for 75 ponds from the East Bay Regional Park District provided multiyear data for five species of pond-breeding amphibians and two species of semiaquatic garter snakes, and demonstrates the kind of data that can be collected even with very cursory efforts for each site (S. Bobzien, unpublished data; M. Ryan, unpublished data). A critical goal of such monitoring efforts should be to publish the results in the peer-reviewed literature and/or deposit in a publically available, curated dataset. Our sense is that a great deal of valuable monitoring data exists, but is not easily accessible because it has never been published or made publically accessible. Another type of single-pass “monitoring” can be genetic monitoring. By collecting non-

destructive, but vouchered, tissue samples, reasonable estimates of the effective population size (Wang 2009a, Wang et al. 2011), historical population increases or decreases (Piry et al. 1999), and ongoing movement between existing populations (Wilson and Rannala, 2003) can be applied to many populations and species. Although each of these genetic approaches has its own set of assumptions and caveats, together they form a powerful addition to traditional field-based studies of population monitoring.

A second approach to monitoring falls under the more general category of "citizen science" (Bonney et al. 2009, Dickinson et al. 2010). Although often less rigorous and more error prone than more formal monitoring, the interested public comprises a large network of knowledgeable, committed individuals who will often willingly contribute to overall monitoring efforts. These efforts can help identify general patterns of population increases and decreases, as has been amply demonstrated by the very successful Breeding Bird Surveys (Sauer et al. 2011) and Christmas Bird Counts (National Audubon Society 2011) conducted for North American birds. Several programs for citizen-science-based frog and toad monitoring programs are in place in other parts of the United States (e.g., the FrogWatch USA program, <http://www.aza.org/frogwatch>), and they have provided valuable data on breeding time, duration, and population sizes for frogs and toads based on their audible calls at breeding sites. Road surveys (Coleman et al. 2008) can also provide valuable data on population sizes, although the confounding effects of mortality induced by vehicular traffic is always a concern in such studies. That said, documentation of road mortality, particularly during key migration seasons, is an ideal topic of additional citizen science initiatives. California has recently initiated at least two citizen-science web-based projects focusing on southern California reptiles and amphibians (RASCals; see <http://www.nhm.org/site/activities-programs/citizen-science/rascals>, and the California

chapter of the Field Herp Forum <http://www.fieldherpforum.com>), both of which seek to increase communication and the dissemination of distributional information on California amphibians and reptiles.

Finally, because monitoring provides the basic information upon which much of conservation rests, a temptation naturally arises to "over-monitor." By this, we mean that additional monitoring becomes favored over the implementation of management actions. Monitoring efforts constitute the most important strategy for measuring the effectiveness of conservation actions. However, monitoring also carries a cost, because these efforts require valuable conservation resources that otherwise might be spent on direct management efforts. Monitoring efforts should have clearly defined goals and well-characterized statistical power, including an assessment of the added benefit to be gained from future monitoring efforts. Monitoring efforts should be clearly documented, and results should be readily accessible. In some cases, the optimal strategy may be limited, but consistent, monitoring combined with direct conservation actions, rather than evermore detailed monitoring with fewer actions. The implementation of effective management in the face of imperfect knowledge about the status of populations is one of the greatest challenges facing the conservation of many amphibian and reptile species.

Species of Special Concern Conservation Recommendations

To promote the conservation of amphibian and reptile Species of Special Concern in California, we make the following recommendations:

- Maintain a Species of Special Concern Technical Advisory Committee with explicit expertise covering the taxonomic and geographic scope of taxa in California. We recommend that membership on this committee be of relatively limited term (e.g., 10 years) to ensure that new voices and fresh

problem-solving strategies are available. We especially encourage that committee composition include some early career scientists, particularly those with strong statistical and technical skills. This group should meet periodically in order to update and revise the status information on the Species of Special Concern.

- Develop and implement a web-based mechanism whereby the Species of Special Concern document can be more easily updated and improved, creating a “living document” that is responsive to changing conditions and new data.
- In conjunction with efforts to facilitate future revisions of this document, support the development of a database that collates species occurrence data. This database should house information on both positive and negative occurrence data and not be limited to species that are already designated as Species of Special Concern.
- Increase wildlife agency capacities to address management needs of California’s amphibians and reptiles, as funding and staffing allow.
- Establish both a priority list and a funding stream for critical research needs for Species of Special Concern.
- Continue to promote strong collaborations between wildlife agencies and the university/research communities throughout California to ensure that the strongest possible science is brought to bear on important management needs and that the state’s research priorities are being pursued.
- Use forthcoming analyses of predicted road usage and construction as a management guide for conservation planning for Species of Special Concern. Included in this analysis should be ways to use tunnels or other constructs to minimize the effects of new and existing roads on Species of Special Concern.
- Create a coordination network for localities, voucher specimens, and tissue samples for amphibian and reptiles from throughout California. Roadkill specimens are a particularly valuable source of information, since they represent vouchered specimens and, in some cases, sources of DNA for genetic research and life history data (diet, body condition, etc.) for ecological studies.
- Create a mechanism by which both professional biologists and concerned citizens can contribute locality, natural history, and other data types that might help detect or quantify conservation risk for Species of Special Concern. Improve data sharing and communication among wildlife agencies, amphibian and reptile conservation groups, and organizations in the avocational herpetological community.
- To facilitate data collection, streamline the process for appropriate permitting for research by professionals, and in the case of citizen science projects, the public.
- Encourage publication of data arising from these efforts in the peer-reviewed literature to increase access to management-relevant findings, particularly for government reports and studies conducted by private consultants.
- Integrate information from this document, as appropriate, with that of an upcoming analysis of the existing regulatory situation for all of California’s amphibians and reptiles and their general conservation needs.

SPECIES ACCOUNTS





COASTAL TAILED FROG

Ascaphus truei Stejneger 1899

Status Summary

Ascaphus truei is a Priority 2 Species of Special Concern, receiving a Total Score/Total Possible of 61% (67/110). During the previous evaluation, it was also considered a Species of Special Concern (Jennings and Hayes 1994a).

Identification

Ascaphus truei is a small (2.5–5.0 cm SVL) dark frog with an olive, brown, gray, or reddish dorsum and lighter colored ventral surface. Other color characters include a pale triangular blotch on the snout and a dark eye stripe. This species has rough, granular skin, and the outermost toes on the hind feet are broad. Males have a unique tail-like copulatory organ that is unmistakable. This frog is nocturnal and adults have vertical pupils (Stebbins 2003).

Larvae grow up to 6.0 cm in TL and are adapted to life in fast-flowing streams. They have dorsoventrally flattened bodies and large sucking mouthparts that extend nearly halfway down their head-body on the ventral surface.

These morphological traits allow larvae to attach to rock substrates (Altig and Brodie 1972, Nussbaum et al. 1983, Welsh and Hodgson 2011). Larvae often have a light-colored tail tip with a proximal dark band (Stebbins 2003).

Coastal Tailed Frog: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	15
iii. Population concentration/ migration (10)	0
iv. Endemism (10)	0
v. Ecological tolerance (10)	10
vi. Population trend (25)	15
vii. Vulnerability to climate change (10)	10
viii. Projected impacts (10)	7
Total Score	67
Total Possible	110
Total Score/Total Possible	0.61

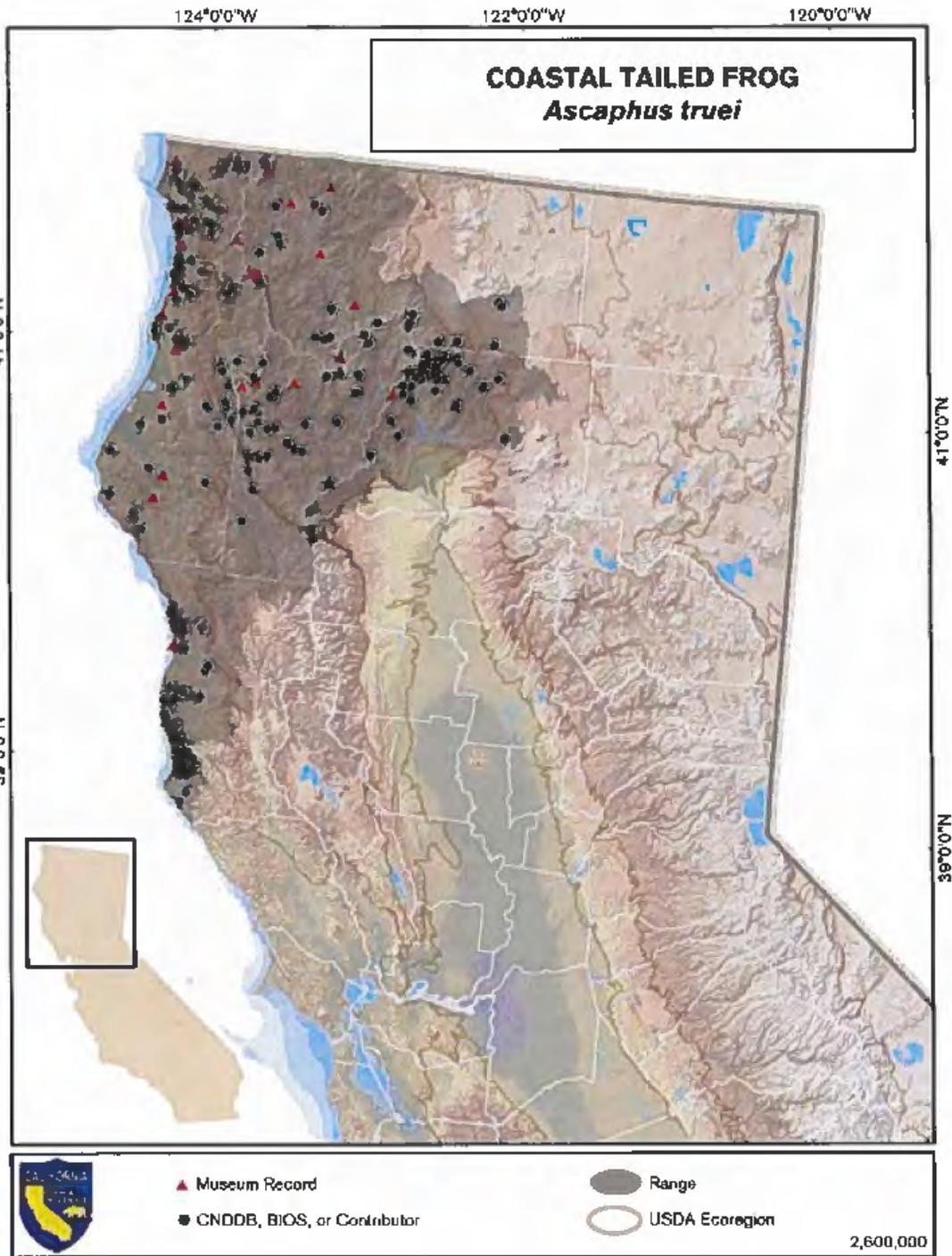


PHOTO ON PREVIOUS PAGE: Coastal tailed frog, Del Norte County, California. Courtesy of Rob Schell Photography.

In California, metamorphosed *A. truei* may be confused with co-occurring foothill yellow-legged frogs (*Rana boylei*). *Rana boylei* have horizontal pupils, more robust hind legs, and males lack enlarged toes and “tails” (Stebbins 2003). In addition, the enlarged mouthparts of *A. truei* tadpoles are distinctive.

Taxonomic Relationships

The formerly monotypic genus *Ascaphus* was recently split into a coastal (*A. truei*) and an inland species (*A. montanus*), but California populations remain *A. truei* (Nielson et al. 2001, Nielson et al. 2006). The two species of *Ascaphus* comprise the family Ascaphidae. This family forms the sister group to all other anurans either alone or in combination with the New Zealand endemic Leiopelmatidae (Roelants et al. 2007). In either case, it is from one of the oldest and most phylogenetically distinctive extant anuran lineages.

Life History

Ascaphus truei exhibits substantial geographic variation in life history. Here, we focus on data from California populations where possible. Breeding occurs primarily in the spring and summer in coastal populations (Sever et al. 2001, Burkholder and Diller 2007), but there are reports from Trinity County of animals found in breeding condition in the fall (J. Garwood, pers. comm., in Burkholder and Diller 2007). Females likely breed in alternate years (Burkholder and Diller 2007) and can store viable sperm for up to a year (Nussbaum et al. 1983, Sever et al. 2001). Eggs begin developing in the fall, and oviposition occurs the following summer between July and September in California populations (Sever et al. 2001, Karraker et al. 2006). Egg diameter is 4 mm on average (Brown 1977), and clutch size averages around 40 for the species with a range of 28–89 eggs per clutch documented in California populations (Karraker et al. 2006). Egg masses can be difficult to find in the field (Karraker et al. 2006). Recent surveys in coastal California have found single and multiple clutches, with

the timing of the surveys (late August–early September) likely the most important factor for detecting eggs (R. Bourque, pers. comm.). Clutches are pearl-like strings of eggs and have been found attached to the underside of cobble or boulder substrates in riffles and pools (Karraker et al. 2006).

Time to metamorphosis in lowland coastal California populations (elevation <200 m) is 1–2 years (Wallace and Diller 1998, Bury and Adams 1999). Longer developmental times have been observed in montane populations (e.g., 4 years to metamorphose in a Washington population at ~1500 m elevation; Brown 1990). In a population in Humboldt County, California, females reached sexual maturity 2.5–3 years after metamorphosis, while males were sexually mature 1.5–2 years after metamorphosis (Burkholder and Diller 2007). Post-metamorphic frogs grow year-round, with growth rates fastest in the summer (Burkholder and Diller 2007).

Adults and post-metamorphic juveniles are generalist invertebrate predators (Bury 1970b). Larvae are generalist grazers and scrapers, consuming diatoms and other periphyton (observations from *A. montanus*; Metter 1964).

Landscape genetic studies have detected different patterns of connectivity among populations in California and Washington. In four watersheds in Mendocino County at the southern range limit of the species, high population structure among watersheds suggested limited long-distance gene flow, and movements within watersheds were inferred to occur along waterways (Aguilar et al. 2013). By contrast, a study in Washington concluded that some animals engage in long-distance dispersal through terrestrial habitats, and these movements do not rely on stream connectivity (Spear and Storfer 2008). These differences may be due to regional variation in climate and forest type, though additional studies are needed.

Habitat Requirements

Ascaphus truei requires cold, permanent, swift-flowing streams with coarse (e.g., cobble,

boulder, bedrock) substrates. Some populations may persist in streams that occasionally dry depending on the length of the larval period (Wallace and Diller 1998). *Ascaphus truei* tends to be more common in mature and old-growth forest relative to younger stands, in terms of both presence and abundance (Bury and Corn 1988, Corn and Bury 1989, Welsh 1990, Gomez and Anthony 1996, Welsh and Lind 2002, Welsh et al. 2005, Ashton et al. 2006).

Several studies have examined the relationship between *A. truei* presence and abundance and environmental variables at different scales. Larvae are positively associated with low stream temperatures, high water velocity, steep gradients, and the presence of riffles, waterfalls, and cobble and boulder substrates (Hawkins et al. 1988, Bury et al. 1991, Welsh and Ollivier 1998, Diller and Wallace 1999, Adams and Bury 2002, Welsh and Lind 2002, Wahbe and Bunnell 2003). Larvae are negatively associated with fine sediment load (i.e., embeddedness), pools, and slow-flowing stream habitat (Hawkins et al. 1988, Corn and Bury 1989, Welsh and Ollivier 1998, Diller and Wallace 1999, Welsh and Hodgson 2008). Steep gradients allow for flushing of fine sediments, although gradient effects may be more pronounced in harvested compared to primary forest habitat (Corn and Bury 1989). Adults are positively associated with high rainfall, moist forest habitats, and pool habitat, and negatively associated with fine sediment loads (Welsh and Lind 2002, Ashton et al. 2006). Adults and larvae in the Mattole Watershed were restricted to headwater channels, and canopy closure was the best single predictor of *A. truei* presence (Welsh and Hodgson 2011). *Ascaphus truei* were never detected in streams where canopy closure was less than 83% (Welsh and Hodgson 2011).

Some researchers have suggested a positive association between *A. truei* and the presence of harder, more consolidated parent geologies because they produce less sediment (Diller and Wallace 1999, Dupuis et al. 2000, Wilkins and Peterson 2000). However, *A. truei* does occur in streams with unconsolidated geologies, such

as those derived from marine sediments, particularly in areas not subjected to recent or historical anthropogenic disturbance (e.g., Adams and Bury 2002, Welsh and Lind 2002, Ashton et al. 2006). The absence of *A. truei* from some streams with unconsolidated geologies may be because the presence of easily erodible substrates exacerbates the impacts of habitat disturbance, which can have long-lasting effects (Adams and Bury 2002, Welsh and Lind 2002, Ashton et al. 2006).

Ascaphus truei is extremely sensitive to warm temperatures at all life stages. Eggs have a temperature tolerance range from 5°C to 18.5°C (Brown 1975a). The critical thermal maximum range for larvae is 28.9–30.1°C, and larvae avoided temperatures above 22°C in laboratory trials (de Vlaming and Bury 1970). First-year larvae collected from Del Norte County selected temperatures below 10°C along a thermal gradient in the laboratory, while second-year larvae selected temperatures closer to 15°C (de Vlaming and Bury 1970). The critical thermal maxima for adults ranged on average from 27.6°C to 29.6°C (data from *A. montanus*; Clausen 1973). Field temperatures at occupied sites are usually well below these limits, with larvae occurring in streams with a mean of 11.6°C (range 5.7–15.8°C; Welsh and Hodgson 2008).

In addition to narrow thermal tolerances, *A. truei* is also extremely sensitive to desiccation (Brattstrom 1963), which may limit adult use of upland habitat to periods of wet weather conditions (Nussbaum et al. 1983). One mark-recapture study in Humboldt County documented movements of only 0–30 m along the stream channel over a two-year period (Burkholder and Diller 2007). However, recapture probabilities were low, and some animals may have moved beyond the study area. Longer distance movements have been documented from populations outside of California, from tens of meters up to 400 m into upland habitat (McComb et al. 1993, Gomez and Anthony 1996, Vesely 1996, Wahbe et al. 2004, Matsuda and Richardson 2005). Seasonal variation in adult location in managed forests in Washing-

ton was hypothesized to be a localized breeding migration, with downstream movements for oviposition and a return upstream in late summer (Hayes et al. 2006). It is unknown whether similar movements also occur in older, less disturbed forests in the area. In an *A. montanus* population in Montana, seasonal movements may be due to behavioral thermoregulation (Adams and Frissell 2001).

Distribution (Past and Present)

Ascaphus truei ranges from British Columbia to northern California, mostly west of the Cascades Mountains (Stehbins 2003). California is the southern limit of the range, with *A. truei* occurring south from the Oregon border along the coast to Mendocino County and east to Shasta County (Grinnell and Camp 1917, Mittleman and Myers 1949, Salt 1952, Bury et al. 1969, Welsh 1985). *Ascaphus truei* ranges from near sea level in Humboldt County up to 2150 m in the Trinity Alps (J. Garwood, pers. comm.).

Random sampling of streams has documented higher occupancy rates for *A. truei* in unmanaged or older forests compared to managed or younger stands (Welsh 1990). We therefore assume that some historically occupied localities are no longer occupied due to disturbance. In one study in the Mattole Watershed in Mendocino and Humboldt counties, *A. truei* was present in 71% of streams in old and mature forests, but was not found in second growth forests (Welsh et al. 2005). Further studies in the Mattole Watershed have found *A. truei* in 67% (14/21) of streams in unmanaged forests, but only in 4% (1/28) of streams in managed stands (H. Welsh and G. Hodgson, unpublished data). Streams with mixed harvest histories in the South Fork of the Trinity River had an intermediate level of occupancy, with 28% of streams occupied (17/60; Welsh et al. 2010). Studies from outside of California also indicate that *A. truei* is present in a greater proportion of streams in unmanaged forests (Bury and Corn 1988, Corn and Bury 1989, Hayes et al. 2006). A survey of streams in private, man-

aged timber lands all less than 80 years old along the northern California coast found stream occupancy rates of 37% (18/49) at the level of 30 m sampling reaches and 76% (54/72) at the level of entire stream reaches (Diller and Wallace 1999). The relatively high occupancy rates in these young forests are thought to be due to the ameliorating effect of maritime climate, as most sites were within 30 km of the coast (Bury 1968, Diller and Wallace 1999).

Trends in Abundance

Ascaphus truei tends to be lower in abundance in managed compared to unmanaged forest stands (Bury and Corn 1988, Corn and Bury 1989, Welsh 1990, Gorncz and Anthony 1996, Welsh and Lind 2002, Ashton et al. 2006). Clear-cuts can have immediate effects on abundance. Larval densities were higher in late-succession and old-growth forests compared to adjacent clear-cuts lacking streamside buffers in Oregon and British Columbia (Dupuis and Steventon 1999, Biek et al. 2002). Upland pit-fall trapping in clear-cuts and mature forests in British Columbia found similar total numbers of *A. truei* in both forest types, but very few adults in clear-cuts, suggesting that immature frogs in clear-cuts are transients or incur high mortality rates (Matsuda and Richardson 2005). Several researchers have predicted declines or continuing declines if anthropogenic disturbances continue (e.g., Corn and Bury 1989, Dupuis and Steventon 1999, Welsh and Lind 2002, Ashton et al. 2006, Olson et al. 2007).

Nature and Degree of Threat

Declines and local extirpations to date are largely due to land management including timber harvesting and road construction (Welsh and Ollivier 1998, Welsh et al. 2005). Marijuana cultivation and climate change are also emerging as potential threats to this taxon.

The mechanisms underlying declines and extirpations due to timber harvesting and road construction are primarily increased

sedimentation, increased stream temperatures, and fragmentation. While the initial impacts of road construction may be relatively short-lived, longer-term impacts are caused by sedimentation due to runoff from poorly maintained dirt and gravel roads (L. Diller, pers. comm.). Reduced canopy cover does not seem to increase temperatures as much at high-elevation sites, and *Ascaphus truei* may be more resilient to timber harvesting in areas where stream temperature is cooler due to overall climate (e.g., Diller and Wallace 1999, Wahbe and Bunnell 2003). Reductions in canopy or riparian vegetation that result in increased light levels may cause shifts in the algal community (i.e., from diatoms to filamentous green algae) that negatively affect the quality and abundance of larval food (L. Diller, pers. comm.). Landscape genetic studies in Washington suggest that significant overland dispersal occurs through terrestrial habitat, with gene flow detected between populations on a scale of 25–30 km (Spear and Storer 2008). While timber harvests have some initial effect on gene flow, it may take multiple generations before the effects of fragmentation on population genetic structure can be detected.

An emerging threat to *A. truei* is large-scale marijuana cultivation, though little data is currently available due to limited accessibility of private lands. Similar to timber harvesting, marijuana cultivation requires clearing land and building roads which can increase sedimentation. Contamination from pesticides used on marijuana grows has been documented to negatively affect mammals in the field (Thompson et al. 2014), and amphibians are likely to be susceptible as well because of their permeable skin. Of particular concern for headwater amphibians like *A. truei* is the dewatering of waterways that are diverted for irrigation (CDFG 2013).

Climate change poses potential risks to *A. truei* through increased temperatures, changes in hydrology, changes in fire regime, and vegetation shifts. Mean annual temperatures are expected to increase throughout northwestern California (reviewed in PRBO 2011). The fre-

quency of extremely hot days is projected to increase, with roughly nine additional days over 32.2°C (Bell et al. 2004). Such temperatures exceed the critical thermal maxima for all life stages of *A. truei*, though water temperatures, microhabitat structure, and behavioral thermoregulation may ameliorate these effects. For coastal populations, upwelling is expected to intensify, which may increase fog development and contribute to cooler, moister conditions (Snyder et al. 2003, Lebassi et al. 2009). Coastal areas may therefore continue to provide more favorable climatic conditions than areas farther inland. Potential changes in precipitation are less clear, with some models predicting modest increases, some modest decreases, and some reductions in rainfall of up to 28% (reviewed in PRBO 2011). Warmer temperatures will result in less precipitation stored as snow, and reductions of 30–80% are predicted for snowpack accumulation in northwestern California (Snyder et al. 2004, Cayan et al. 2008b). The timing of spring snowmelt has shifted later in the spring in this region over the last 50 years (Stewart et al. 2005), though the timing of future shifts is unknown. Reductions in water availability due to reduced snowpack and possibly reduced precipitation will affect the timing and magnitude of stream flows and may lead to a mismatch between the timing of breeding and appropriate stream conditions. How fire regime will be affected by climate change in northwestern California is not well understood. Some models predict little change in fire regime or even decreases in area burned along the northern coast (Fried et al. 2004, Lenihan et al. 2008). Increases in area burned have been predicted for the southern coast of northwestern California (Lenihan et al. 2008). Westerling et al. (2011) projected a 100% increase in area burned in northwestern California under some scenarios. Direct mortality of adults and larvae due to fire has been documented in *A. montanus* populations (P. Van Eimeren, pers. comm., in Pilliod et al. 2003, Hossack et al. 2006). Short-term impacts of fire may be due to warmer temperatures

and/or increased ammonia levels or other changes to water chemistry (Pilliod et al. 2003), but long-term impacts are understudied. Vegetation communities are expected to shift from moist conifer to drier mixed evergreen forest, with reductions in Douglas fir and redwood forest in particular (Lenihan et al. 2008, PRBO 2011). It is unclear what effect these shifts may have on *A. truei* because stream conditions and forest age seem to be more important indicators of habitat quality than forest type.

Status Determination

Ascaphus truei is a specialist of cold, headwater stream habitats in old and mature forests, a habitat type that incurs substantial disturbance from land management activities. Declines in distribution and abundance have been documented in response to anthropogenic disturbances, and climate change has the potential to further negatively impact this species. These factors all contribute to a Priority 2 designation for this species.

Management Recommendations

Remaining old and mature forest habitats should be protected, with a focus on managing the entire stream network (Olson et al. 2007, Welsh 2011). Retaining streamside buffers on managed lands can help mitigate the effects of logging and roadbuilding, but more research is needed to determine buffer prescriptions, particularly how to preserve stream network processes (Olson et al. 2007). One model recommends riparian management zones 40–150 m wide and patch reserves along headwater streams to accommodate upland habitat use and promote connectivity among drainages (Olson et al. 2007). The ecological effects of buffer protections may vary across habitat types, and narrower buffers may be effective in more mesic coastal habitat compared to more xeric inland sites in the California range of *Ascaphus truei*.

Construction of new roads should be minimized or avoided in areas where protecting *A. truei* is a high conservation priority. To reduce the sedimentation impacts of runoff from roads,

forest roads should be disconnected from stream systems (e.g., through the use of ditch-relief culverts). Use of heavy equipment should be avoided or restricted on forest roads when larvae are present in nearby aquatic habitat. Road management strategies should be applied to all forest roads, not just those used for timber harvest.

Ascaphus truei management would benefit from greater legal clarity regarding state and federal law on marijuana cultivation in California. Currently, some cultivation is legal under state law but prohibited under federal law, which may be hampering regulation of cultivation sites. Greater enforcement of existing environmental and land use laws is needed, and development of additional regulations should consider environmental impacts on *A. truei*.

Monitoring, Research, and Survey Needs

The presence of uncut streamside buffers on the entire channel network can ameliorate the impacts of land management on *Ascaphus truei* populations, but more research is needed into optimum buffer widths as they relate to different life history requirements and different portions of the catchment network. Studies from *A. truei* populations in British Columbia and Oregon have found positive effects of buffers 5–60 m wide (Bull and Carter 1996, Dupuis and Steventon 1999, Stoddard and Hayes 2005, Pollett et al. 2010). Experiments to determine optimal buffer widths in California habitats are needed. We recommend, at a minimum, that comparative data from coastal Mendocino County (the southern limit of the species range), coastal Humboldt/Del Norte Counties (the northern limit of the species range in California), and inland Trinity County are needed to assess the minimum forest buffer on industrial timber lands to retain key temperature and stream clarity conditions for *A. truei*.

Much of the research on *A. truei* has focused on stream-breeding habitat and presence/absence studies. While more difficult, monitoring efforts to document abundance and population dynamics are needed to gain insight into declines that cannot be inferred from presence/

absence surveys (Welsh 2011). Such studies could also determine which life history stages limit population growth in this species. When possible, population estimates in managed forests should be compared to *A. truei* abundance in nearby undisturbed mature forest stands (i.e., reference populations) to assess the impacts of disturbance (Welsh 2011).

More studies are needed on use of upland habitats by adults and dispersing animals. Such studies should be targeted at identifying terrestrial habitat corridors, if present, which can then be protected to maintain connectivity

among populations (Olson et al. 2007, Olson and Burnett 2009). Landscape genetic analyses from replicate California populations may be particularly informative, given that recent studies from different parts of the range reach different conclusions about population connectivity (Spear and Storfer 2008, Spear and Storfer 2010, Aguilar et al. 2013).

Field research on impacts of marijuana cultivation on amphibian populations would contribute to development of environmental regulations for this growing industry and inform management strategies in cultivated areas.



SONORAN DESERT TOAD

Bufo alvarius Girard 1859

Status Summary

Bufo alvarius is a Priority 1 Species of Special Concern, receiving a Total Score/Total Possible of 75% (64/85). During the previous evaluation, it was also designated as a Species of Special Concern (Jennings and Hayes 1994a). The species has not been found in California since 1955 (but see the "Distribution" section).

Identification

Bufo alvarius is a large (10.1–19.0 cm SVL) olive, brown, or gray toad with prominent cranial crests and large elongate paratoid glands (Stebbins 2003). The skin is smoother than in other North American toads, with few warts along the dorsum. *Bufo alvarius* has large warts on the hind limbs and prominent white warts at the corners of the mouth (Stebbins 2003). The call is a low-pitched bleat or screech (Elliott et al. 2009).

This species is unlikely to be confused with any other anuran within its California range. All other true toads (family Bufonidae) in the

region have extensive warts over the entire dorsal surface and lack large warts on the hind legs. The spadefoots (*Scaphiopus* and *Spea*, family Scaphiopodidae) are much smaller as adults

Sonoran Desert Toad: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	20
iii. Population concentration/migration (10)	10
iv. Endemism (10)	0
v. Ecological tolerance (10)	7
vi. Population trend (25)	Data deficient
vii. Vulnerability to climate change (10)	7
viii. Projected impacts (10)	10
Total Score	64
Total Possible	85
Total Score/Total Possible	0.75

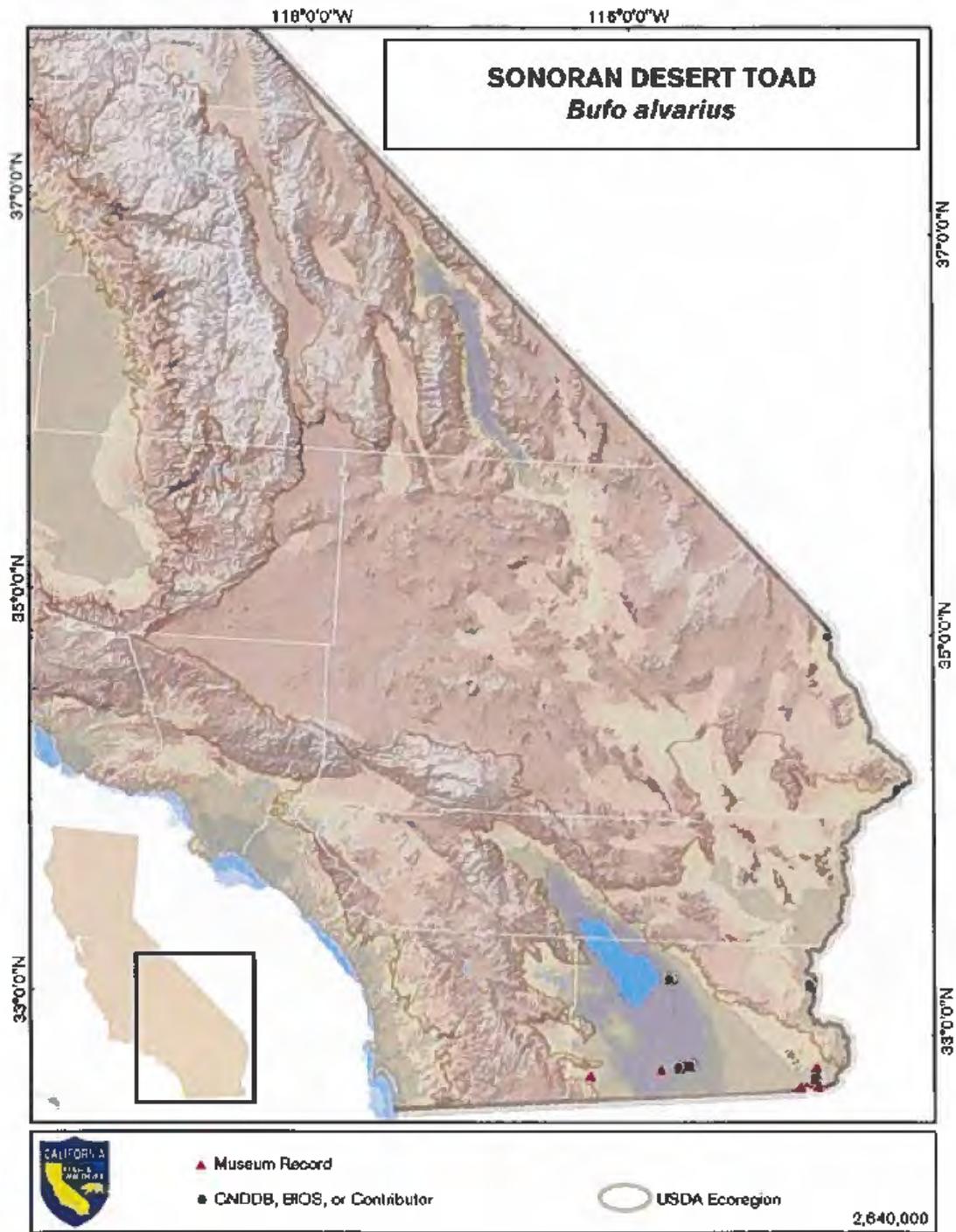


PHOTO ON PREVIOUS PAGE: Sonoran Desert toad, Cochise County, Arizona. Courtesy of Rob Schell Photography.

and have a conspicuous black keratinized spade on the ventral surface of the rear feet.

Taxonomic Relationships

The validity of this taxon has never been questioned, although confusion about the type specimen and locality has been discussed (Fouquette 1968). Osteological and genetic data, as well as call characteristics, suggest that it is related to Central American bufonids (Tihen 1962, Martin 1972, Sullivan and Malmos 1994, Pauly et al. 2004, Frost et al. 2006a).

Frost et al. (2006a) suggested a taxonomic revision that placed this species in the genus *Cranopsis*. Based on subsequent discoveries of older available names, the genus name for this taxon was later revised to *Ollotis* (Frost et al. 2006b) and then *Incilius* (Frost et al. 2009b, Pauly et al. 2009). We retain the older taxonomy both for taxonomic stability and because the analyses supporting the original rearrangement are controversial (Crother 2009, Frost et al. 2009a, Pauly et al. 2009).

Life History

The life history of this species in California is unknown, and we base the following discussion on observations from other areas. *Bufo alvarius* spends much of the year underground, presumably in rodent burrows (Degenhardt et al. 1996). *Bufo alvarius* is primarily nocturnal and becomes active before summer rains. It is more strongly aquatic than most North American toads (Stebbins 1951). Breeding behavior appears to be generally associated with summer rains (Sullivan and Malmos 1994), although amplexus has been reported in stock ponds before rains have occurred (Degenhardt et al. 1996). Several years may pass between breeding events depending on the presence of sufficient rainfall (Sullivan and Fernandez 1999). The species sometimes congregates in large numbers for breeding, with nearly all reproduction of a local breeding population occurring in a single night (Degenhardt et al. 1996). The time required for hatching and metamorphosis is unknown but may be less

than a month (notes of Thornber, reported in Ruthven 1907 and Storer 1925). This species appears to be a dietary generalist, feeding on any live arthropod or small vertebrate prey that it can successfully capture (Stebbins 1951, Cole 1962). Poison secreted by the skin and paratoid glands is particularly toxic and has caused death and paralysis in dogs and is a potent hallucinogen in humans (Musgrave 1930, Stebbins 1951, Stebbins 2003).

Habitat Requirements

The habitat requirements for *Bufo alvarius* in California are unknown. In arid habitats of Arizona and New Mexico, the species can be found in and around a variety of water sources used for breeding, including springs, stock ponds, washes, river bottoms, and irrigation ditches (Stebbins 1951, Stebbins 1972), though it is occasionally found at great distances (>1 mi) from water (Slevin 1928). Upland habitat surrounding known aquatic breeding localities elsewhere in the range include mesquite-creosote desert lowland, arid grassland, rocky riparian zones, oak-sycamore-walnut assemblages in mountain canyons, and montane pine-oak-juniper plant communities (Stebbins 2003, Fouquette et al. 2005).

Distribution (Past and Present)

There are no known extant populations in California. Historically, the species ranged in California along the Lower Colorado River and into the Imperial Valley (Grinnell and Camp 1917, Stebbins 1951, Jennings and Hayes 1994a), likely ranging as far north as the southern tip of Nevada (Cooper 1869). It is not known if records in the Imperial Valley are a natural part of the historic range or whether they represent recent range expansion following the development of irrigation (Stebbins 1951).

The last verified record (LACM 87044) from California dates to 31 July 1955, 7 km north of Winterhaven. More recent surveys have failed to detect the species (King and Robbins 1991, Jennings and Hayes 1994b). Sporadic records continue to be reported on the Arizona side of

the Colorado River, however. Several individuals were found near the Cibola National Wildlife Refuge in 1980 (Anderson and Ohmart 1982; B. Anderson, pers. comm.), and a single individual was found at the refuge itself in 1986 (J. Rorabaugh, pers. comm.). On 1 July 2004, a large individual was found "by the golf course on the Parker Strip," La Paz County, Arizona (J. Rorabaugh, pers. comm.). On 29 July 2009, an amplexing pair was found along the Bill Williams River at Planet Ranch, Mohave County, Arizona, and the species is reportedly "fairly common" 24–32 km above the confluence of the Gila and Colorado Rivers, Yuma County, Arizona (J. Rorabaugh, pers. comm.). A single, unverified record of a calling *Bufo alvarius* was reported near Bard, California, in the spring of 2007 or 2008, though the time of year was unexpected and the observer was inexperienced with the species (J. Rorabaugh, pers. comm.).

Outside of California, *B. alvarius* ranges across southern Arizona to the southwestern corner of New Mexico and south into Sonora and the northern edge of Sinaloa, Mexico. The known elevational range extends from near sea level to 1615 m (Cole 1962).

Trends in Abundance

Though the paucity of records from California makes assessing former abundance difficult, *Bufo alvarius* was apparently common at Yuma, Arizona, on the California border, along the Lower Colorado River, and in parts of the Imperial Valley (Slevin 1928, Klauber 1934). As no populations are currently known in these areas, declines leading to probable population extirpations or extremely low population sizes have clearly occurred. The species is also known to be declining in New Mexico (Degenhardt et al. 1996). Throughout the rest of the range the species appears to be stable and abundant at many localities (Fouquette et al. 2005, Lazaroff et al. 2006), though some have suggested that declines are occurring throughout the range (B. Brattstrom, R. Ruibal, and C. Schwalbe, pers. comms., reported in Jennings and Hayes 1994a).

Nature and Degree of Threat

The causes of declines, and therefore the threats to this species, are poorly understood. Declines occurred before any studies were carried out in California, though it is likely that landscape modification and pesticide applications that occurred with the growth of agriculture in the Imperial Valley contributed to declines (Ohmart et al. 1988, Jennings and Hayes 1994a). Bufonids are generally very susceptible to amphibian declines (Stuart et al. 2004). In California, toad declines have been linked to habitat loss and pesticide use (Davidson et al. 2002) and pathogenic fungi (Green and Kagarise Sherman 2001).

Status Determination

The declines and possible extirpation of *Bufo alvarius* in California are the primary concerns for this taxon. The species may require permanent aquatic environments making it a moderate ecological specialist, given the arid environments that characterize its range. This also makes the taxon sensitive to the effects of climate change, particularly changes in hydrology and the increasing year-to-year variation in precipitation that have been projected (Cayan et al. 2008b). Finally, because little understanding of the causes of declines in California exists, we are poorly positioned to protect any remaining populations should they be found in future surveys.

Management Recommendations

The development of an effective management strategy for *Bufo alvarius* in California is not possible without further distributional and ecological information. As no populations are currently known, the first management priority should be to undertake comprehensive surveys, as described below, aimed at identifying remaining fragmentary California populations. Habitat protection and enhancement would then become the critical management tools to build these populations to larger and viable sizes. Simultaneous ecological research is also needed on habitat use, home range size, life

history, and population connectivity before more complex management programs focused on reestablishing the species are considered.

Monitoring, Research, and Survey Needs

A critical first step toward developing a comprehensive management plan for this species is to undertake comprehensive surveys of remaining potential habitat in southeastern California. These surveys should take place during the summer rains and should involve biologists who are familiar with *Bufo alvarius*' breeding behavior. If any remaining populations are found, a population-monitoring program should rapidly be established to determine both geographical extent and population size. As little is known about this species in California, this monitoring program should take place in conjunction with a study of the species' life history and habitat use, in California and/or adjacent Arizona. These surveys should specifically target the remaining moist areas of the southwest California deserts that are known to support other water-dependant vertebrate species, such as the desert mule deer (*Odocoileus hemionus crooki*). Using existing survey data from other, and better known, species may help to guide toad survey efforts

toward the wettest areas or most consistent water supplies, thereby increasing odds of detection.

A second critical priority is to work with wildlife managers in Arizona to survey for and study the nearest remaining populations on the Arizona side of the Lower Colorado River. These populations are likely the most ecologically similar to the former California populations and should therefore provide information valuable to the eventual development of management programs in California. Genetic samples from both California and Arizona should be collected to help inform managers about levels of genetic differentiation, and therefore the appropriateness of possible reintroduction of Arizona animals to California.

As any populations that remain in California are likely isolated, study of these populations is unlikely to yield information on the metapopulation dynamics that we presume are key in sustaining this species elsewhere. Reestablishing these dynamics would form an important part of a comprehensive management program in California, and research focused on better understanding these dynamics will also need to take place outside of California, preferably in adjacent Arizona.



ARROYO TOAD

Bufo californicus Camp 1915

Status Summary

Bufo californicus is a Priority 1 Species of Special Concern, receiving a Total Score/Total Possible of 93% (102/110). During the previous evaluation, it was also considered a Species of Special Concern (Jennings and Hayes 1994a), and it has been listed as federally Endangered since 1995.

Identification

Bufo californicus is a small to medium-sized (4.6–8.6 cm SVL), light-gray to tannish-brown toad that often has some greenish or olive and dark-brown mottling on the back and sides (Camp 1915, Stebbins 2003). The underside is buff or dirty white and usually unmarked (Stebbins 2003). A light middorsal stripe is rarely present (Jennings and Hayes 1994a, Stebbins 2003). Weak cranial crests are often present and the paratoids are oval-shaped and widely separated (Stebbins 2003). The advertisement call of this species is a musical trill that lasts 3–10 s. The pitch of the call rises quickly and is held constant for the

remainder of the call, which ends abruptly (Stebbins 2003, Elliott et al. 2009). Like most toads, the tadpoles are small and black early in life. However, several weeks post-hatching they develop a cryptic tan coloration that closely

Arroyo Toad: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	25
iii. Population concentration/ migration (10)	10
iv. Endemism (10)	7
v. Ecological tolerance (10)	10
vi. Population trend (25)	20
vii. Vulnerability to climate change (10)	10
viii. Projected impacts (10)	10
Total Score	102
Total Possible	110
Total Score/Total Possible	0.93

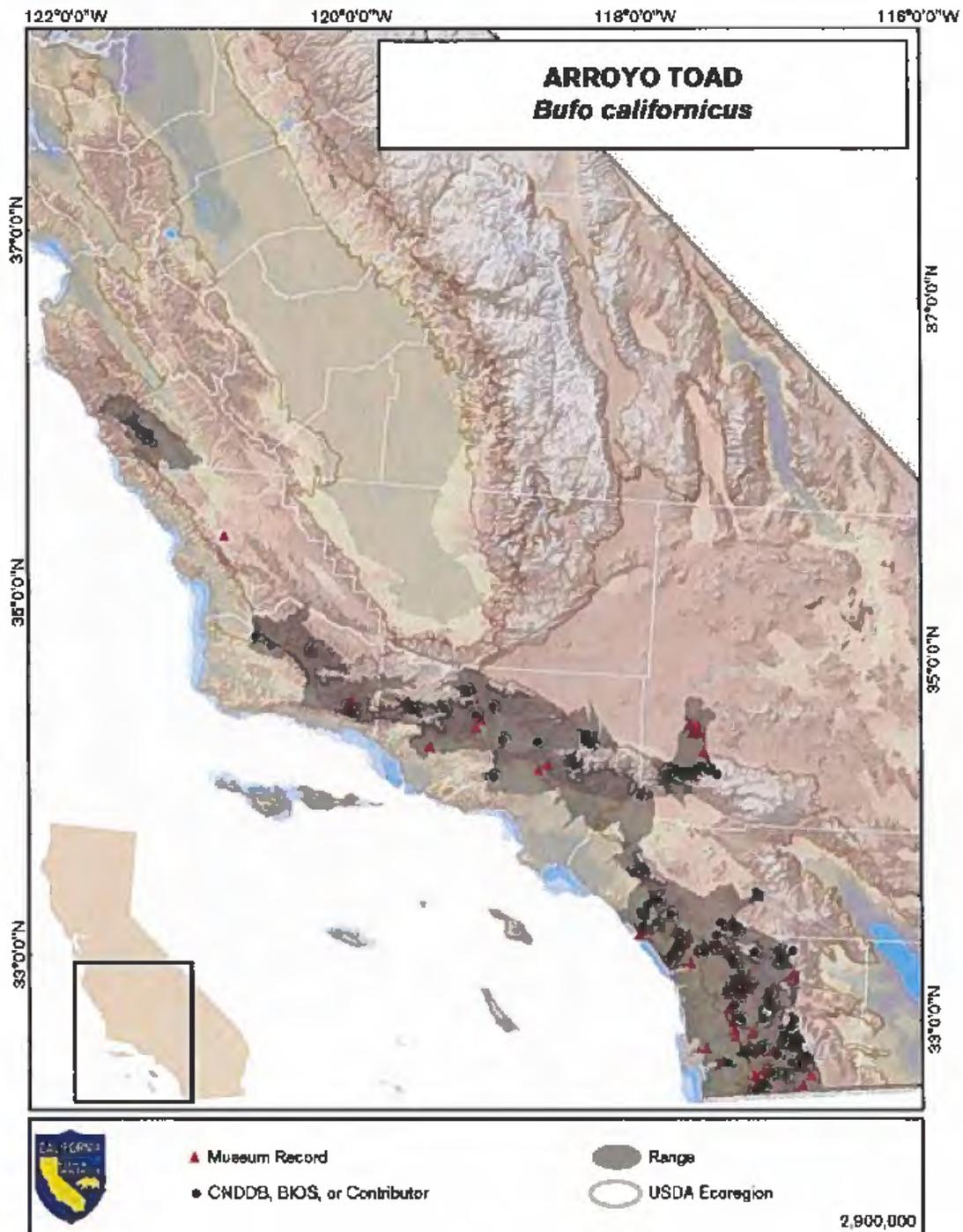


PHOTO ON PREVIOUS PAGE: Arroyo toad, Baja California, Mexico. Courtesy of Rob Schell Photography.

matches the substrate (Sweet 1992, Hancock 2009).

Metamorphosed individuals of this species may be confused with the western toad (*B. boreas*), which is the only sympatrically occurring toad. *Bufo boreas* has a prominent white or cream dorsal stripe and lacks cranial crests (Stebbins 2003). Young tadpoles that still retain the black coloration are difficult to distinguish from *B. boreas*, but older tadpoles are readily distinguishable.

Taxonomic Relationships

Until recently, *Bufo californicus* was considered a subspecies of the Arizona toad (*B. microscaphus*) (Price and Sullivan 1988), although recommendations to recognize it as a full species date back to Myers (1930). Frost and Hillis (1990) recognized this species as distinctive based on the general observation that few allopatrically distributed polytypic species represent single genetically cohesive units, as is implied by retaining *B. californicus* as a subspecies under *B. microscaphus*. Later analyses of allozyme data confirm that *B. californicus* is a distinct lineage, providing support for its recognition as a full species (Gergus 1998). Additional analyses of advertisement calls indicated a substantial amount of variation within the species complex, although the results were equivocal with respect to species status (Gergus et al. 1997). Lovich (2009a) analyzed data from two mitochondrial genes and found additional evidence that *B. californicus* is a distinct species. This work also identified clades within *B. californicus* that roughly correspond to parts of the range north and south of the Los Angeles Basin, respectively.

Frost et al. (2006a) recommended placing this species and many other North American bufonids in the genus *Anaxyrus*, although this proposal and the analyses that support it are controversial (Crother 2009, Frost et al. 2009a, Pauly et al. 2009). We choose not to follow this recommendation at the present time, pending further analyses, and to maintain taxonomic stability.

Life History

Bufo californicus is primarily nocturnal and feeds predominantly on nocturnally active ant species (Cunningham 1962, Sweet 1992, Sweet 1993, Mahrtdt et al. 2002). Adults typically emerge from retreats approximately 30–40 min after sunset, remaining active down to temperatures of around 13°C on dry nights and 10°C on rainy nights, with nocturnal activity increased during wet periods (Cunningham 1962, Sweet 1992, Sweet 1993).

Males begin calling at varying times of the year depending on local conditions and elevation, although calling activity appears to initiate when water temperatures reach or exceed 11–13°C (Myers 1930, Sweet 1992). Choruses generally begin in late February in coastal populations and late March or April at higher elevation inland sites, and they may continue into July (Sweet 1992, Sweet 1993, Stebbins 2003, Hancock 2009). Eggs are laid near the male's calling site on a substrate of mud, sand, or gravel, away from vegetation and other submerged debris (Sweet 1992). Hatching occurs after 4–6 days at typical water temperatures (12–16°C), although the larvae remain associated with the egg mass for an additional 5–6 days. Metamorphosis can occur in as few as 65 days, although typically 72–80 days are required (Sweet 1992, Hancock 2009). Larger males and females are more sedentary and tend to breed in the same pools throughout the reproductive season and from year to year (Sweet 1993, Hancock 2009, Mitrovich et al. 2011). The seasonal activity period for adults extends roughly from the beginning of the breeding season to late June or July, after which most toads become inactive (Cunningham 1962, Sweet 1993, Hancock 2009). Juveniles may remain active into October or later following rains (Sweet 1993).

Bufo californicus usually attain reproductive condition in their second (males) or third (females) year. The species is relatively short-lived, with few toads living beyond 5 years of age. In the absence of nonnatural disturbances, survivorship of adult toads is high during the active season, but decreases markedly during

the inactive season. Sweet (1993) documented that toads experience ~55% per year mortality mostly during the winter, though other estimates suggest even higher mortality (D. Holland and N. Sisk, unpublished data, reported in Sweet and Sullivan 2005). Eggs and young larvae are apparently unpalatable to most predators, although garter snakes and nonnative fishes prey upon older tadpoles (Sweet 1992). Juvenile toads that have not yet adopted the nocturnal activity pattern characteristic of adults also experience high predation pressure (Hancock 2009). Adult toads experience intense predation from introduced bullfrogs in areas where that species occurs (Miller et al. 2012, R. Fisher pers., comm.). In the absence of bullfrogs, adult toads experience much lower predation intensity (Sweet 1993, Hancock 2009).

Habitat Requirements

Along with its close relative *Bufo microscaphus*, *B. californicus* may have the most specialized habitat requirements of any North American anuran (Stebbins 2003). This species requires shallow, slow-moving stream and riparian habitat. In some areas they may occupy first-order streams, although most populations inhabit second- to sixth-order streams that have extensive braided channels and sediment deposits of sand, gravel, or pebbles that are occasionally reworked by flooding (Sweet and Sullivan 2005). These toads will use either permanent or seasonal streams, although seasonal streams must flow for a minimum 4–5 months for successful reproduction and recruitment (Sweet and Sullivan 2005). At inland sites, radiotelemetry studies indicate that this species rarely moves beyond the immediate upland margin of streams, although in coastal sites arroyo toads appear to occasionally use and disperse across hotter and drier upland sites (Sweet 1992, Sweet 1993, Griffin and Case 2001, Hancock 2009, Mitrovich et al. 2011). Mitrovich et al. (2011) found that radio-tracked toads actively selected channel and terrace stream habitats, and largely avoided surrounding scrub, grassland, and forest. On average, males were found

in closer proximity to flowing sections of stream than females, possibly to maximize reproductive opportunity (Mitrovich et al. 2011). *Bufo californicus* is known to occasionally use and breed in human-made habitats, such as artificial stream terraces and ponds (Price and Sullivan 1988, Mahrtdt et al. 2002). It is unknown whether the species can persist in these habitats.

Distribution (Past and Present)

Bufo californicus historically occurred in coastal drainages from the San Antonio River, Monterey County, California, southward through the Transverse and Peninsular Ranges to the vicinity of Arroyo San Simón in Baja California Norte, Mexico (Price and Sullivan 1988, Gergus et al. 1997, Grismer 2002, Lovich 2009a). Almost all populations occur along the coast or on the coastal slopes of the southern California mountains. Six localities were previously recognized from the desert slopes of Los Angeles, Riverside, San Bernardino, and San Diego Counties, California (Patten and Myers 1992, Jennings and Hayes 1994a). Desert slope populations are known to occur at Little Rock Creek, Los Angeles County, and the Mojave River, San Bernadino County. Populations at Whitewater River, Riverside County, Borrego Springs (listed as San Felipe Creek in Jennings and Hayes 1994a), Vallecito Creek, and Pinto Canyon, San Diego County, are probably in error and are the result of misidentifications (Ervin et al. 2013). The known elevational range extends from near sea level to approximately 1000 m (Stebbins 2003; S. Sweet, pers. comm.).

The present distribution of *B. californicus* is considerably smaller than it once was. Jennings and Hayes (1994a) estimated that this species had disappeared from 76% of its former range in California, although more recent estimates place this loss at 65% (Sweet and Sullivan 2005).

Trends in Abundance

In addition to the extirpations discussed above, extensive declines in abundance have been

documented in most *Bufo californicus* populations that do survive. Extensive collections from the 1930s, largely stemming from the work of L.M. Klauber, suggest that this species was formerly present at much higher densities (S. Sweet, pers. obs., reported in Sweet and Sullivan 2005).

Nature and Degree of Threat

A recent 5-year review of the status of *Bufo californicus* thoroughly discusses the ongoing threats to this taxon (USFWS 2009). We follow the findings of that document and recommend that readers consult it for additional detail.

The greatest threat facing this taxon is loss and degradation of habitat that stems from modifications to hydrology from reservoir construction, roads, flood control, development, recreational activity, and mining (USFWS 2009). In addition, declines are occurring even in areas that are not subject to development and direct habitat degradation from human activities (Hancock 2009). These additional declines stem largely from introduced predators (primarily bullfrogs and green sunfish) and introduced plants, which degrade habitat and/or decrease survivorship of toads (Sweet 1992, Hancock 2009, USFWS 2009, Miller et al. 2012). Off-highway vehicle use has also caused both habitat degradation and direct mortality in this species (Ervin et al. 2006)

Status Determination

Major declines in both distribution and abundance, coupled with several ongoing threats, combine to warrant a Priority 1 Species of Special Concern status for *Bufo californicus*.

Management Recommendations

Management efforts for *Bufo californicus* should mirror those outlined by the USFWS recovery

plan and 5-year review for this taxon (USFWS 1999, USFWS 2009). The recent 5-year review suggests that management efforts to date have been effective, and the outlook for this species has improved somewhat since it was initially listed (USFWS 2009). The most important management strategy is to preserve existing stream habitat that supports this species and to restore additional habitat that can support self-sustaining populations. Restoration efforts should include dam removal to allow streams to meander and rebuild sand and gravel bars, and removal of exotic plants and vertebrate predators.

Monitoring, Research, and Survey Needs

Monitoring, research, and survey needs are covered in depth in the USFWS recovery plan for this taxon and the recent 5-year review. We refer the reader to these documents for additional detail (USFWS 1999, USFWS 2009). Monitoring efforts should focus on recovering populations, particularly those in newly restored habitat. It is particularly important to continue monitoring through drought and El Niño cycles given that this is a short-lived species and several years of consistent drought could be extremely damaging to recovering populations.

In addition, research aimed at characterizing variation in this species' life history in different parts of its range should be undertaken, as these differences might have an impact on future management efforts. For example, the two desert slope populations may differ substantially in several aspects of life history relative to the coastal slope populations. Additional research into the prevalence and potential impacts of *Bd* fungus on this species is also particularly important. Finally, molecular analyses of population size and connectivity might be particularly valuable in this taxon.



YOSEMITE TOAD

Bufo canorus Camp 1916a

Status Summary

Bufo canorus is a Priority 1 Species of Special Concern, receiving a Total Score/Total Possible of 84% (92/110). During the previous evaluation, it was also considered a Species of Special Concern (Jennings and Hayes 1994a). This species is also listed as Threatened under the US Endangered Species Act.

Identification

Bufo canorus is a moderately sized (1.0–7 cm SVL) sexually dichromatic toad (Camp 1916a, Grinnell and Storer 1924, Kagarise Sherman 1980, Stebbins 2003). Females and juveniles have tan or brown dorsal coloration with extensive dark blotches over the dorsal surface and legs that are edged with white or cream. Males are pale green-yellow or olive green above without, or with only minimal, dark blotching or flecking (Camp 1916a, Stebbins 2003). A pale, very thin middorsal line is often present in juveniles and young females, but is usually lost in males and older females (Camp 1916a). The paratoid glands

are large, flat, and circular, and are separated by a space less than or equal to their diameter (Camp 1916a). The advertisement call of this species is a musical trill lasting 3–9 s (Elliott et al. 2009). The specific epithet “*canorus*” (Latin for

Yosemite Toad: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	15
iii. Population concentration/ migration (10)	10
iv. Endemism (10)	10
v. Ecological tolerance (10)	10
vi. Population trend (25)	20
vii. Vulnerability to climate change (10)	10
viii. Projected impacts (10)	7
Total Score	92
Total Possible	110
Total Score/Total Possible	0.84

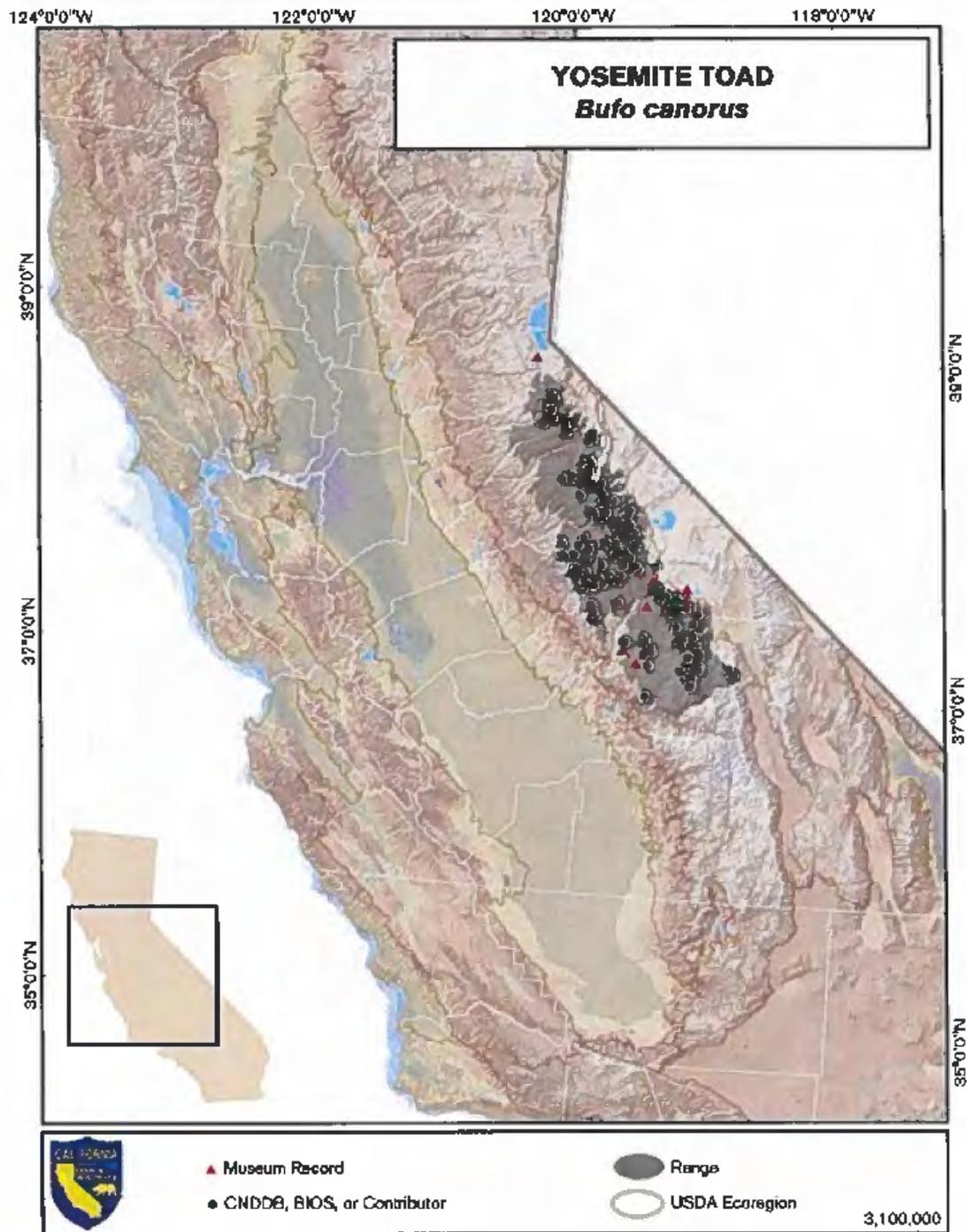


PHOTO ON PREVIOUS PAGE: Yosemite toad, Mono County, California. Courtesy of Rob Grasso.

“tuneful”) refers to the melodic quality of the call (Camp 1916a, Karlstrom 1962).

This species may be confused with high-elevation populations of the western toad (*B. boreas*). *Bufo boreas* often has a conspicuous light middorsal stripe and smaller, more widely spaced paratoid glands that are separated by a space approximately twice their diameter (Stebbins 2003). *Bufo boreas* also has more extensive webbing on the hind feet than *B. canorus* (Camp 1917). Populations of *B. boreas* that occur in the Sierra Nevada do not produce advertisement calls; thus, toad breeding choruses are diagnostic for *B. canorus* (Mullally 1956). Juveniles of the two species (<20–30 mm) are very similar to one another, and identifications of this size class should be made with caution (Karlstrom 1962).

Taxonomic Relationships

Bufo canorus was initially described on the basis of coloration and morphology (Camp 1916a). Its status as a distinct species has gone largely unquestioned since this time. Subsequent genetic analyses based on mitochondrial data suggest that this taxon is a close relative of *B. boreas* (Shaffer et al. 2000, Pauly et al. 2004). In addition, mitochondrial DNA data suggest that *B. canorus* may be paraphyletic with respect to the black toad, *B. exsul*, and some lineages of *B. boreas* (Graybeal 1993, Shaffer et al. 2000, Goebel et al. 2009). These relationships have not been corroborated with nuclear sequence data, and thus it is unclear whether cryptic diversity exists within the taxon or if this is a case of mitochondrial introgression. Unpublished genetic data suggest that mitochondrial introgression associated with past or ongoing hybridization may explain these results (G. Pauly, unpublished data). Some morphological variation has been observed in size and degree of melanism in eggs and larvae of this taxon (Karlstrom and Livezey 1955, Karlstrom 1962). Whether this is plasticity in response to elevation and/or the local environment or genetic differentiation has not been investigated further. Mitochon-

drial data also indicate that some intraspecific variation and isolation by distance may exist within the taxon (Shaffer et al. 2000, Pauly et al. 2004, Goebel et al. 2009), although sample sizes in these studies were small. Wang (2012) collected data from 10 microsatellites for toads from 24 populations in Yosemite National Park and found significant variation in the amount of genetic distance between populations. This analysis concluded that environmental factors such as slope and precipitation were associated with genetic structure.

Frost et al. (2006a) recommended placing this species and many other North American bufonids in the genus *Anaxyrus*, although this proposal and the analyses that support it are controversial (Crother 2009, Frost et al. 2009a, Pauly et al. 2009).

Life History

Bufo canorus is primarily a diurnal toad that occasionally exhibits crepuscular or nocturnal activity on warm days (Mullally 1956, Martin 2008). Males emerge from hibernation as soon as snowmelt pools form along the margins of preferred high-elevation meadow habitat and quickly form breeding choruses (Karlstrom 1962). As in many high-elevation amphibians, the timing of emergence is correlated with elevation, and generally occurs in May and June (Karlstrom 1962, Kagarise Sherman 1980). Males are territorial and often maintain interindividual spacing of 7–14 m (Karlstrom 1962, Kagarise Sherman 1980). Fighting occurs between males that encroach on one another's territory (Kagarise Sherman and Morton 1984). Breeding activity and egg-laying commence soon after males begin calling, with females depositing eggs along shallow edges of pools and streams in meadows (Karlstrom 1962, Kagarise Sherman 1980). Hatching occurs in as few as 3–4 days at relatively high water temperatures (20–23°C) or up to 10–14 days at lower temperatures (16–17°C) (Karlstrom 1962, Kagarise Sherman 1980). Metamorphosis occurs approximately 40–60 days after oviposition, again depending on temperature and

elevation (Karlstrom 1962, Kagarise Sherman 1980, Kagarise Sherman and Morton 1984). The seasonal activity period extends into late September and early October, after which toads hibernate in rodent burrows, crevices under rocks, and root tangles (Kagarise Sherman 1980). Adult toads do not begin to breed until they are 3–6 years old, after which females may only breed every few years (Kagarise Sherman 1980, Kagarise Sherman and Morton 1984). Adults grow slowly, averaging only 2.5 mm per year at Tioga Pass, Tuolumne County, California (Kagarise Sherman and Morton 1984). The post-metamorphic diet consists of a variety of small arthropods including ants, bees, flies, wasps, beetles, millipedes, and spiders (Grinnell and Storer 1924, Mullally 1953, Kagarise Sherman and Morton 1984). The slow growth rate and lack of breeding every year is likely attributable to low metabolic rates associated with low caloric intake and relatively cold temperatures (Kagarise Sherman and Morton 1984). In the wild, adults appear to be able to tolerate a relatively wide range of temperatures (from 2°–30°C) (Karlstrom 1962), although they prefer temperatures higher in this range (Cunningham 1963). The estimated critical thermal maximum is 37–40°C for adults and 36–38°C for larvae (Karlstrom 1962).

Bufo canorus is known to occur sympatrically with *B. boreas* in two areas (see the "Distribution" section) and may occasionally hybridize. At the Frog Lakes locality, individuals that are morphologically intermediate in paratoid gland width and the extent of webbing on the hind feet occur and may represent natural hybrids (Morton and Sokolski 1978). No putative hybrids have been described from the Blue Lakes locality (Karlstrom 1962), although some authors suggest that hybridization may also occur there (Stebbins 2003). Artificial crosses in the laboratory readily produce hybrids (Karlstrom 1962).

Habitat Requirements

Bufo canorus prefers relatively open high-elevation meadows vegetated with grasses, sedges, rushes, and/or willow stands (Karlstrom 1962).

This species can be found in the margins of water bodies that form from snowmelt runoff, as well as in moist meadows. During the early part of the active season, individuals are often localized along meadow margins within approximately 30 m of the forest edge. This behavior may allow them to easily retreat to forest cover at night to avoid freezing temperatures (Karlstrom 1962). As the active season progresses and nights become warmer, the toads tend to move toward the center of meadows and become less restricted to the margins (Karlstrom 1962). This species prefers shallow (probably <7.5 cm) snowmelt pools on the margins of meadows or very slow moving runoff streams in which to breed, although they have also been found in deeper (>3 m) permanent pools (G. Fellers, pers. comm.). These need to be deep enough to avoid premature desiccation—a significant cause of mortality for larvae—but shallow enough to achieve the temperatures needed for rapid development (Karlstrom 1962). This species may prefer to oviposit in dark-bottomed pools, particularly at high elevations, as these may provide warmer water temperatures and more rapid larval development (Karlstrom 1962). The presence of pocket gopher, mouse, and vole burrows may provide additional beneficial cover and protection from predation (Grinnell and Storer 1924, Karlstrom 1962).

Distribution (Past and Present)

Bufo canorus is restricted to a relatively small area approximately 240 km (north–south) by 60 km (east–west) in higher elevation areas of the Sierra Nevada (Karlstrom 1962, Kagarise Sherman and Morton 1993). It ranges from the vicinity of Blue Lakes, Alpine County, California, south past Kaiser Pass to the Evolution Lakes area, Fresno County, California (Grinnell and Storer 1924, Livezey 1955, Karlstrom 1962, Jennings and Hayes 1994a, Stebbins 2003, Davidson and Fellers 2005). The known elevational range extends from 1950 to 3599 m, with most localities between 2390 and 3048 m (Karlstrom 1962).

Between 1915 and 1992, this species exhibited declines throughout some areas of its

range. Drost and Fellers (1996) resurveyed localities from Grinnell and Storer (1924) and found that this species had disappeared from 6 of 13 sites in the Yosemite area. Jennings and Hayes (1994a) also estimated that the species has disappeared from low-elevation areas on the western edge of the range, as well as at the northern edge of the range.

Trends in Abundance

In areas where *Bufo canorus* persists, marked declines in abundance have also been documented. In the Drost and Fellers (1996) resurveys, *B. canorus* was present in lower densities than in 1915 at three sites where it was still present. Between 1976 and 1982, the number of male toads entering breeding pools at Tioga Pass meadow declined from a maximum of 342 individuals to a low of 28, a ninefold decrease from the 1974–1978 mean (Kagarise Sherman and Morton 1993). However, the number of females entering breeding pools showed no obvious changes during this time period (Kagarise Sherman and Morton 1993). The average number of toads encountered in daily surveys also declined in the vicinity of Tioga Pass meadow between the early 1970s and 1990. In addition, these surveys documented declines in female toads, although they were not as severe as those documented in males (Kagarise Sherman and Morton 1993). Similar declines in abundance have also been documented at six additional localities in this region (Kagarise Sherman and Morton 1993).

Nature and Degree of Threat

The causes of decline in *Bufo canorus* require additional study. The declines have occurred in seemingly undisturbed areas and do not appear to be localized, suggesting that they are being driven by general changes to the environment, rather than localized causes such as habitat destruction. Several possible causes have been advanced, and more than one factor may be playing a role. These causes include environmental contamination, disease, drought and/or climate change, habitat modification due to

grazing or other activities, human disturbance of breeding choruses, increased predation pressure from birds and fish, and pesticides. Based on current data it is not possible to understand in detail which, if any, of these factors are most important in *B. canorus* declines.

Snowmelt pools have extremely low acid neutralizing capacity, leading to the hypothesis that acidification of aquatic breeding habitat due to atmospheric deposition may be contributing to declines. Bradford et al. (1992) examined the effect of increasing acidification and the associated increase in dissolved aluminum on embryos and hatchlings of *B. canorus*. Embryos and hatchlings exposed to decreasing pH (and increasing aluminum solute) showed no increase in mortality at levels found in nature. However, these factors did cause earlier hatching and smaller body size at metamorphosis. Bradford et al. (1994) attempted to correlate the distribution of declining Sierran amphibians with these environmental factors and found no relationship, concluding that acid deposition was an unlikely source of amphibian declines in the Sierra Nevada.

Disease has also been considered as a factor in declines, though there is little evidence to date. Green and Kagarise Sherman (2001) examined the cause of death in 12 adult *B. canorus* that were found during a die-off that immediately preceded the population declines documented at Tioga Pass meadow by Kagarise Sherman and Morton (1993). They found that a variety of diseases and parasites were present in the population, and chytridiomycosis and septiemia, alone or in combination, caused the death of at least four individuals. However, no single infectious disease was present in more than 25% of the samples, which is far below the proportion typically observed in other die-offs caused by these diseases (Worthylake and Hovingh 1989, Berger et al. 1998, Vredenburg et al. 2010).

California experienced a relatively severe drought between 1987 and 1992, a time when *B. canorus* population declines were occurring (Roos 1992, Drost and Fellers 1996). Although

it may have played an exacerbating role, drought alone seems unlikely to be responsible for declines. California experiences drought with some regularity, including during the time period of the Grinnell and Storer (1924) survey, which occurred before any major declines in *B. canorus* were observed (Drost and Fellers 1996). Drought does affect year-to-year reproductive success for this species, and prolonged drought may have a cumulative effect on populations (Kagarise Sherman and Morton 1993). Because climate change is expected to impact the amount of snow present in the Sierra Nevada and the speed and timing of snowmelt (Cayan et al. 2008b), drought might play an increasing role in declines of this species in the future.

Habitat modification is a leading cause of decline in many species throughout California and has been suggested as a factor for *B. canorus*. However, *B. canorus* is found largely within the boundaries of Yosemite National Park and other public (mostly National Forest) lands that have experienced varying impacts over the last 100 years. Drost and Fellers (1996) compared photos of habitat from the Grinnell and Storer (1924) surveys with current habitat and saw no apparent differences. Over the course of their 20-year study, Kagarise Sherman and Morton (1993) were also unable to detect significant habitat changes. That said, local impacts from changing habitat remain a potential driver of declines. All-terrain vehicle and snowmobile use in some localized areas may degrade habitat quality (D. Emery, pers. comm.). Some workers have postulated that livestock grazing in alpine meadows of National Forest land causes changes to hydrology, which may affect the suitability of breeding habitat and increase sedimentation in pools. Two recent, relatively short-term studies (5 years) have addressed this hypothesis: one that used experimental fencing treatments to exclude livestock from *B. canorus* breeding meadows and a second that included occupancy surveys across gradients of meadow moisture and livestock use levels (K. Tate and A. Lind, pers. comm.). Both of these studies demonstrated that meadow wetness was more influen-

tial in determining the current distribution and abundance of *B. canorus* than the level of livestock use. Sean Barry (pers. comm.) documented that toads seem to persist and even concentrate in areas that had been disturbed by cattle in the Kaiser Meadow population. It is also possible that the presence of cattle feces increases insect food supply for adult toads, although this remains untested. Martin (2008) suggests that the practice of fencing individual breeding pools to prevent grazing might actually lead to stronger habitat disturbance from cattle grazing in the terrestrial foraging habitats, potentially increasing the overall impact from grazing. These local-scale influences of livestock grazing along with more detailed and longer-term investigations of livestock use in the context of *B. canorus* metapopulation dynamics require further study.

Some researchers have suggested that increasing predation pressure could be causing declines. A variety of avian predators are known to feed on adult and larval toads, and increasing densities of common raven (*Corvus corax*) have been postulated as a possible cause of decline (Kagarise Sherman and Morton 1993). Ravens are known to prey upon other toad species in the *B. boreas* complex and likely also take *B. canorus*. Evidence suggests that declines in other amphibian species have occurred in areas where fish have been introduced (Drost and Fellers 1996). However, fish alone are unlikely to explain the declines in *B. canorus*. Most *B. canorus* reproduction takes place in ephemeral water bodies that do not contain fish (Drost and Fellers 1996). Knapp (2005) found no evidence for an effect of introduced trout on *B. canorus* presence and absence. Further, Grasso (2005) and Grasso et al. (2010) examined the palatability of early life stages of *B. canorus* to introduced brook trout and found that all life stages were highly unpalatable, suggesting that introduced trout may have little direct impact on populations.

Some authors have noted that breeding choruses of *B. canorus* are sensitive to human disturbance. Grinnell and Storer (1924) docu-

mented that choruses would abruptly stop calling when humans entered a meadow. They specifically noted that *B. canorus* seemed to be more sensitive to this disturbance than the sympatric Pacific treefrog (*Pseudacris regilla*). Karlstrom (1962) as well as several biologists presently working on this species disagree that this species' calling behavior is impacted more strongly by human disturbance than other toad species. Karlstrom (1962) did notice wariness at night and that cars moving through the area even at 0.8 km distance would cause choruses to cease calling and that "the almost continual daytime traffic in [Yosemite National Park] might help to explain the paucity of roadside populations" of *B. canorus*. It has also been suggested that the relatively frequent handling and study experienced by some populations could induce stress and immunosuppression, which may also be playing a role in declines (Green and Kagarise Sherman 2001). To our knowledge, this possibility has not been investigated.

Davidson et al. (2002) found that areas where toads had disappeared were downwind from disproportionately large areas of agricultural land (primarily the low-elevation populations on the western side of the Sierra Nevada), suggesting that wind-borne agrochemicals may be a factor in declines. However, this relationship was not statistically significant.

When this evidence is taken together, it is clear that the causes of decline for *B. canorus* are still poorly understood. It is possible that several factors act in combination, perhaps interacting with variation in life history or metapopulation dynamics. Individual populations may be susceptible to localized extirpation due to small population sizes and the species' slow maturation rate. Increasing frequency of localized extirpations could cause a breakdown of broader-scale metapopulation dynamics, leading to additional declines as recolonization ceases to counteract local population extirpations. Landscape genetic data suggest that migration rates between local populations are already low in several areas and this situation would likely be exacerbated by additional

localized population declines and extirpations (Wang 2012). These inferences are still speculative, however, and further research is needed on many aspects of *B. canorus* population biology to better understand ongoing declines.

Status Determination

Declines in both distribution and abundance, coupled with a poor understanding of the factors leading to decline, are the major factors justifying a Priority 1 Species of Special Concern status.

Management Recommendations

An effective management program for this species will depend on identifying and prioritizing the factors leading to observed, ongoing declines. Until this is accomplished, protecting breeding meadows from disturbance of natural hydrologic regimes and water table dynamics and limiting human disturbance to meadows during the breeding season may be helpful in safeguarding populations. In addition, upland wintering habitats adjacent to breeding areas should also be protected from grazing and other disturbances.

Monitoring, Research, and Survey Needs

Ongoing monitoring and study of this species is required with a particular aim of identifying the major factors leading to decline. It is possible that some populations are relatively stable, and comparisons with declining sites could lead to important insights into reasons for declines and potential management solutions. Experimental work, going beyond the primarily correlational studies that have been carried out thus far, could also be helpful in identifying the most important factors. In particular, experimental studies of human disturbance, susceptibility to disease, and the potential role of reduced snowpack on hibernation and breeding biology would all be useful. Populations should also be monitored for disease outbreaks.

Further genetic work also needs to be completed to characterize genetic diversity within the species. Several studies have already been

carried out, although they rely primarily on mitochondrial data alone, which is unable to distinguish true population substructure (or multiple lineages) from introgression from nearby *B. boreas* populations. Wang (2012) adds important information from the nuclear genome, but focuses on Yosemite National Park rather than the species' range as a whole. Future studies should utilize multiple unlinked nuclear markers to clarify the diversity present

in the species, gene flow among meadows, and effective population sizes.

Finally, the majority of survey efforts to date have focused on populations within the boundaries of Yosemite National Park. A committed survey effort is needed to better understand the location of populations, their trends in distribution and abundance, and their disease status and level of infection (or lack of) in areas outside of the park itself.



NORTHERN RED-LEGGED FROG

Rana aurora Baird and Girard 1852

Status Summary

Rana aurora is a Priority 2 Species of Special Concern, receiving a score of 55% (61/110). Previously this species was included as a Species of Special Concern by Jennings and Hayes (1994a).

Identification

Rana aurora is a medium-sized (70–100 mm SVL) brown, red, gray, or tan frog with dorsolateral folds (Dumas 1966, Nussbaum et al. 1983). The dorsum varies from having indistinct, irregular black spots 2–3 mm in diameter with many tiny flecks to an all-over network pattern of black lines (Dunlap 1955, Dumas 1966, Nussbaum et al. 1983). The dorsum can also be largely unmarked, though this is less common. A light lip line from eye to shoulder is usually present, often with a dark mask above (Nussbaum et al. 1983). Ventrally, the chest and abdomen are often marbled gray, with the groin area heavily and darkly mottled (Dunlap 1955). Red coloration on the venter and underneath the

hind legs is typical but varies in intensity and extent (Dunlap 1955). Yellow coloration is common in the groin, as well as red and sometimes green coloration (Dunlap 1955). Larvae are dark brown from above, with scattered small clumps

Northern Red-Legged Frog: Risk Factors

Metric (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	10
iii. Population concentration/migration (10)	10
iv. Endemism (10)	0
v. Ecological tolerance (10)	7
vi. Population trend (25)	10
vii. Vulnerability to climate change (10)	7
viii. Projected impacts (10)	7
Total Score	61
Total Possible	110
Total Score/Total Possible	0.55

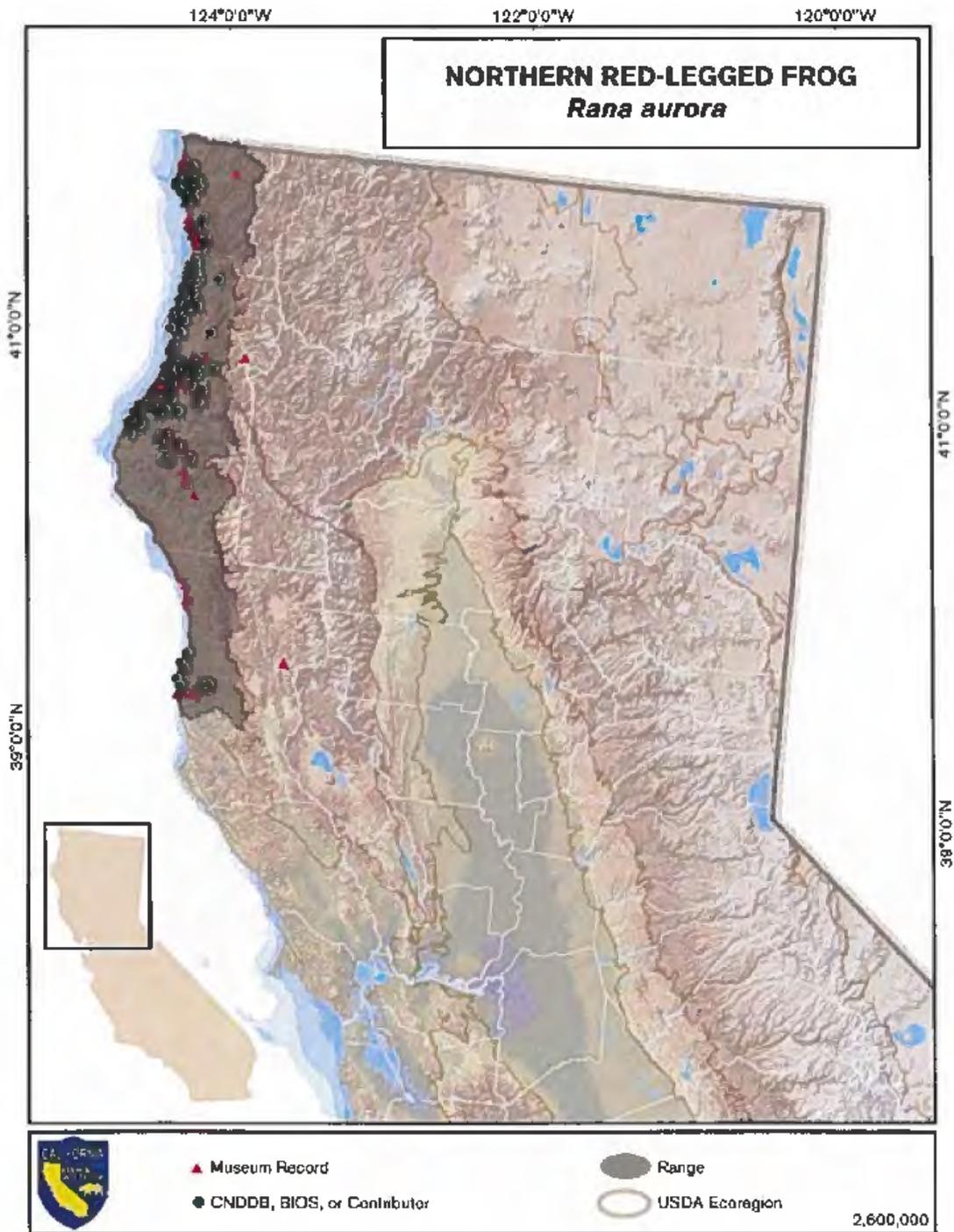


PHOTO ON PREVIOUS PAGE: Northern red-legged frog, Humboldt County, California. Courtesy of William Flaxington.

of metallic flecks and are 50–75 mm in TL (Nussbaum et al. 1983). In southern Mendocino County, this species could be confused with *R. draytonii* (Shaffer et al. 2004). *Rana draytonii* is a larger frog (up to 138 mm SVL; Stebbins 2003), and typically its dark dorsal markings have light centers (Stebbins 2003).

Taxonomic Relationships

Although initially described as a distinct species (Baird and Girard 1852), for much of the twentieth century northern red-legged frogs were regarded as the subspecies *Rana aurora aurora* (Camp 1917). Studies over the last few decades have supported the current taxonomic arrangement, with *R. aurora* and *R. draytonii* both recognized as distinct species. While they look superficially similar, these two species differ in morphology (vocal sacs, body size) and breeding behavior, and are genetically distinct (Hayes and Miyamoto 1984, Green 1985, Green 1986a, Green 1986b, Hayes and Kremples 1986, Shaffer et al. 2004). A narrow contact zone occurs between *R. aurora* and *R. draytonii* in southern Mendocino County (Shaffer et al. 2004).

Life History

Limited information is available on *Rana aurora* life history, with most studies occurring outside of its California range. Adults migrate to wetlands to breed for a few weeks between December and April when temperatures range from 4°C to 18°C (Storm and Pimentel 1954, Storm 1960, Dumas 1966, Licht 1969, Calef 1973). Males call beneath the water (Licht 1969, Brown 1975b). During one breeding season in Humboldt Bay National Wildlife Refuge, two breeding events more than a month apart produced over half of the egg masses (J. Betasso et al., unpublished data). Egg masses are 15–25 cm in diameter and contain approximately 500–600 eggs on average (Calef 1973, Licht 1974, Brown 1975b). Eggs are attached to emergent and floating vegetation, branches, or logs up to 150 cm below the water surface (Brown 1975b, Storm 1960, Calef 1973, Cary 2010). Surveys in Humboldt Bay National Wildlife Refuge found that

most egg masses occurred between 30 and 60 cm elevation in the stream channel, at an average height of 37 cm above the bottom and 8 cm below the water surface (J. Betasso et al., unpublished data). In southwestern British Columbia, eggs were found at least a meter away from the pond edge or river bank (Licht 1969). Water temperatures near developing eggs in a Washington pond were 6.2°C on average (Brown 1975b), and embryos tolerate temperatures from 4°C to 21°C (Licht 1971). Dumas (1966) reared embryos at 11°C, 15°C, and 20°C, and observed the greatest embryo mortality at 20°C.

Embryonic development (from laying to hatching) takes 34–49 days (Storm 1960, Licht 1971, Brown 1975b). In Humboldt Bay Wildlife Refuge, most egg masses (103/232) persisted for 4 weeks before completely hatching out (J. Betasso et al., unpublished data). Larvae hatch at 8–12 mm long (Storer 1925, Storm 1960, Brown 1975b) and grow to up to 80 mm TL (Brown 1975b). Metamorphosis occurs after 3–7 months (Brown 1975b, Storer 1925) and metamorphs are 18–29 mm (Brown 1975b, Storm 1960, Calef 1973). Larger metamorphs are more likely to survive and to emigrate farther (Chelgren et al. 2006). In a Washington population, eggs were laid in February and March, the first larvae hatched in April, and metamorphosis was completed in late July (Brown 1975b).

Rana aurora juveniles disperse from breeding sites within days or weeks after transformation (Licht 1974, Licht 1986a). While daily movements of adults may be on average only a few meters per day, movements of several hundred meters to 4.8 kilometers have been documented over longer periods (Haggard 2000, Hayes et al. 2001, Chan-McLeod and Wheeldon 2004, Hayes et al. 2007).

Larvae are algal grazers (Dickman 1968). Metamorphs and adults are generalist predators of insects, spiders, and mollusks (Licht 1986b).

Habitat Requirements

Rana aurora occurs in mesic forests and riparian areas, which in its northern California range are primarily steep coniferous forests,

coastal terraces, and floodplains (Nussbaum et al. 1983, Stebbins 2003). *Rana aurora* is relatively terrestrial for a ranid frog. Adults can occur hundreds of meters from water, and are often found in dense vegetated or downed log cover (Dunlap 1955, Dumas 1966). Adult frogs radio-tracked from March to July in Humboldt County were detected on land 90% of the time and usually within 5 m of water, though animals were found up to 80 m away from water (Haggard 2000). In habitat choice experiments, juvenile frogs spent most of their time out of the water (Pearl et al. 2004).

Both permanent and temporary breeding habitats are used, such as ponds, freshwater lagoons, lakes, and slow-moving streams (Licht 1969, Cary 2010, Sun 2012). Artificial habitats such as drainage ditches are also used (T. Fuller, J. Garwood, and M. van Hatterm, pers. comm.). Coastal streams may be important dispersal corridors to inland populations. For example, *R. aurora* have been found outside of the breeding season in coastal streams in Humboldt and Del Norte Counties, and egg masses have been found in backwaters and alcoves of the Smith River where surrounding areas have been diked, drained, and converted (J. Garwood, pers. comm.). Both aquatic and terrestrial vegetation are important determinants of breeding habitat quality. In Humboldt County, egg mass presence was positively correlated with low canopy cover (ponds with less than ~40% canopy cover are more likely to have egg masses present; Cary 2010). Egg mass density was higher in smaller ponds (< 2000 m²) and in ponds where the percentage of floating and emergent vegetation cover was at least ~40% (Cary 2010). Surveys in Oregon also found support for the importance of emergent vegetation, as wetlands used for breeding had 27% open water on average compared to 50% open water in unused wetlands (Pearl et al. 2005a). Occupancy models fit to 5 years of survey data in Oregon predicted that local extinction probability decreased as the percentage of trees along the shoreline increased and surface area of emergent vegetation increased (Adams et al. 2011).

Distribution (Past and Present)

Rana aurora occurs from Mendocino County, California, north along the west side of the Cascade Crest up through Vancouver Island and the adjacent mainland coast of British Columbia (Stebbins 2003). Populations also occur on Graham Island, British Columbia (Ovaska et al. 2002), and on Chichagof Island, Alaska (Hodge 2004). The elevational range extends from near sea level to 1160 m in Lane County, Oregon (Dunlap 1955), with populations in California occurring up to approximately 300 m (Jennings and Hayes 1994a). Two localities included on our map possibly extend the eastern edge and elevation range in California, and are in need of further investigation. A specimen collected by Camp in 1913 from eastern Mendocino County is in the UC Berkeley collection (MVZ 5068), photographs of which were reviewed by several experts. It is possible that the specimen is a misidentified *R. draytonii*, or it may be that *R. aurora* was historically more widespread. Despite the presence of potentially suitable habitat, contemporary CDFW biologists working in this region have not observed any *R. aurora* east of Highway 101 or in Mendocino National Forest (T. Fuller, pers. comm.). At another site, two individuals were found recently in eastern Humboldt County at around 800 m elevation (M. van Hatterm, pers. comm.).

In California, surveys have found *R. aurora* to be mostly absent from the river bottom lands of the Eel, Mad, and Smith Rivers. These areas have undergone extensive habitat conversion to beef, dairy, and bulb farming, though populations may persist on inaccessible private lands (M. van Hatterm, unpublished data). Surveys in Oregon's Willamette valley found *R. aurora* at 50% of sites, with highest occupancy probability observed in seasonal sites without fish (Rowe and Garcia 2013).

Trends in Abundance

Population declines have been suspected for *Rana aurora*, particularly in Oregon's Willamette Valley (e.g., Nussbaum et al. 1983; Hayes and

Jennings 1986). However, systematic surveys are lacking. Data on *R. aurora* abundance in California are limited, particularly with regard to documenting trends over time. Mean density of egg masses in breeding ponds in Humboldt County during one breeding season was 0.2/m², with densities up to 0.7/m² observed (Cary 2010). In Del Norte County, 382 egg masses were found in a 40 × 40 m area of a pond near the confluence of East Fork Mill Creek and West Branch Mill Creek (J. Garwood, unpublished data). Surveys in California have found more egg masses in areas where natural vegetation buffers the breeding habitat compared to developed areas (M. van Hattem, unpublished data).

Nature and Degree of Threat

The major threat to *Rana aurora* is development and forest conversion leading to habitat loss and degradation. Other threats include introduced predators, disease, and climate change, though more data are needed on each of these stressors.

Due to issues such as low capture rates, it is unclear whether *R. aurora* abundance varies consistently with stand age in harvested forests (reviewed in Pearl 2005). For example, terrestrial (Welsh et al. 2007) and aquatic (Ashton et al. 2006) amphibian surveys in northwestern California forests have documented only a handful of *R. aurora*. In Washington, breeding sites with high primary forest cover within 2 km had higher egg mass counts, as did breeding sites greater than 0.25 km away from roads (Holcomb 2012). On Vancouver Island, radio-tracked frogs tended to move toward old-growth stands and away from clear-cuts <12 years old, suggesting that recolonization of impacted sites may require several years (Chan-McLeod 2003). In an Oregon study, the highest capture rates of *R. aurora* were in mature, mixed large sawtimber forest (Martin and McComh 2003).

Agricultural and residential development has likely contributed to habitat loss and degradation for *R. aurora*, and is projected to continue to increase in the future. For example, much of the Smith River coastal plain in Del Norte

County has been converted to lily bulb production (J. Garwood, pers. comm.). In addition to habitat loss, such agricultural conversion can further degrade habitat through use of chemicals such as pesticides, herbicides, and fungicides. Similarly, the emerging issue of largely unregulated marijuana cultivation can degrade watersheds through grading and roadbuilding (which both destroy habitat and create runoff into aquatic habitats), application of pesticides and herbicides, and through dewatering of springs, streams, and wetlands used for irrigation (e.g., Thompson et al. 2014). Residential and commercial development is likely to increase in northern California, potentially leading to losses of breeding habitat or loss of access to remaining habitat. For example, the Humboldt County General Plan is currently being updated, with some proposals considering a doubling or tripling of rural development. However, *R. aurora* does use artificial habitat for breeding, and amount of urban cover was not a strong predictor of frog occurrence in surveys in Oregon (Rowe and Garcia 2013), suggesting some tolerance for certain kinds of habitat modification.

Introduced predatory fish and bullfrogs are widespread throughout *R. aurora* habitat in California, including sites near the coast (T. Fuller, J. Garwood, and M. van Hattem, pers. comm.). Negative impacts have been documented in mesocosm experiments, but field observations have yielded both negative and neutral effects of fish and bullfrogs on *R. aurora* distribution and abundance. Field-enclosure experiments in Oregon have shown reduced survivorship, shifts in microhabitat use, slower development, and smaller size at metamorphosis of *R. aurora* in the presence of fish and bullfrogs (Kiesecker and Blaustein 1998). Surveys in Oregon and Washington have found evidence for negative associations between *R. aurora* presence or abundance and the presence of nonnative fish but weak or no evidence for an effect of bullfrogs (Adams 1999, Pearl et al. 2005a, Rowe and Garcia 2013). Other studies in Oregon and Washington have not detected any effects of fish or bullfrogs on *R. aurora*

presence (Richter and Azous 1995, Adams et al. 1998, Adams et al. 2011). Little data are available from California. Freshwater Lagoon and Big Lagoon in Humboldt County both have a long history of fish stocking, and surveys of suitable habitat during the 2010 and 2011 breeding seasons never found more than 1 egg mass in either lagoon (M. van Hattem, unpublished data). While introduced fish and bullfrogs can prey upon *R. aurora*, the population-level impacts of such predation are unknown. Gut content analysis of 5075 bullfrogs collected over 5 years on Vancouver Island found *R. aurora* in only 0.2% of stomachs (Jancowski and Orchard 2013).

Expected climate changes within the California range of *R. aurora* over the next 100 years include increased temperatures, sea-level rise, changes in hydrology, changes in fire regime, and vegetation shifts (reviewed in PRBO 2011). The frequency of extremely hot days is projected to increase, with roughly nine additional days over 32.2°C (Bell et al. 2004), though the effects of increased temperature are difficult to predict. A mesocosm experiment on larval *R. aurora* found that the combined effects of warming and drying can offset each other: warmer conditions result in more algal resources, allowing larvae to develop faster and escape costs of drying (O'Regan et al. 2014). Sea-level rises as high as 72 cm above 1990 levels are predicted under some models for California (reviewed in PRBO 2011), which may cause saltwater intrusion into estuarine habitat used for breeding. Upwelling is expected to intensify, which may increase fog development and contribute to cooler, moister conditions (Snyder et al. 2003, Lebassi et al. 2009), possibly facilitating terrestrial habitat use by this species along the coast. Potential changes in precipitation are less clear, some models predict either modest increases or decreases in rainfall, while others predict sharp reductions of up to 28%. (reviewed in PRBO 2011). Reductions in water availability due to reduced snowpack and possibly reduced precipitation will affect the timing and magnitude of stream flows, which may negatively affect

habitat (Snyder et al. 2004, Stewart et al. 2005, Cayan et al. 2008b). How fire regime will be affected by climate change in northwestern California is not well understood. Some models predict little change in fire regime or even decreases in area burned along the northern coast (Fried et al. 2004, Lenihan et al. 2008), while increases in area burned have been predicted for the southern coast of northwestern California (Lenihan et al. 2008). Westerling et al. (2011) projected a 100% increase in area burned in northwestern California under some scenarios. How *R. aurora* responds to wildfire is unknown. Vegetation communities are expected to shift from moist conifer to drier mixed evergreen forest, with reductions in Douglas fir and redwood forest in particular (Lenihan et al. 2008, PRBO 2011). Loss of moist forest habitat would likely be detrimental to *R. aurora*; however, most of the predicted vegetation changes occur farther inland from its range.

Disease has been repeatedly implicated in amphibian declines, but to date there is little evidence that disease has played a major role in determining *R. aurora* abundance. While *Bd* has been documented from a high proportion of sites examined in Humboldt County (11/13; Nieto 2004, Sun 2012), the prevalence of infected individuals is relatively low (15%; Nieto 2004, Sun 2012). Water mold infection of egg masses has been observed in the field (Cary 2010, M. van Hattem, unpublished data) but population consequences of infection are unknown. Terrestrial versus aquatic life stages may respond differently to fungal infection. Juvenile metamorphs infected with *Saproglenia* in the lab did not have significantly higher mortality than uninfected individuals (Romansic et al. 2007), while two weeks of exposure was lethal to *R. aurora* larvae (Romansic et al. 2009a).

Status Determination

Rana aurora has a small range in California in a region that is undergoing continuing development, agricultural use, and timber harvest, making it a Priority 2 Species of Special Concern.

Management Recommendations

Management of *Rana aurora* should focus on addressing habitat degradation and loss due to development, timber harvest, and agriculture (including marijuana cultivation), introduction and spread of nonnative predatory fish and bullfrogs, and on minimizing unintended negative impacts due to salmonid restoration. Observations of higher abundance in breeding habitat with intact terrestrial vegetation nearby (though not excessively shading ponds; Cary 2010, Adams et al. 2011, Holcomb 2012) coupled with the terrestrial habitat use and long distances traveled by adults (Hayes et al. 2007) support the idea of maintaining vegetation buffers around breeding habitat in forested areas and setbacks between wetlands and development. Current regulations for development setbacks under the California Coastal Act of 1976 give distances from breeding wetlands of up to 30 m depending on land use. However, these setbacks are reducible upon request and we recommend that consistent, biologically based setbacks be developed. *Rana aurora* may experience less impact from timber harvesting methods that leave residual tree patches, particularly if multiple trees are included in patches between 0.8 and 1.5 ha in size and are near streams (Cham- McLeod and Moy 2007). Marijuana cultivation appears to pose a growing threat to maintenance of high-quality habitat for this species. Enforcement and regulation of marijuana cultivation is an ongoing issue in California and we suggest that the environmental impact of such activities be considered. Populations of introduced fish and bullfrogs should be prevented from invading *R. aurora* breeding habitat. While bullfrogs may already be widespread, intentional fish stocking should be restricted to avoid *R. aurora* habitat. Restoration projects for native salmonids should also take into consideration potential impacts to *R. aurora* that may be caused by converting freshwater wetlands to estuarine habitats and salt marshes.

Monitoring, Research, and Survey Needs

Monitoring of *Rana aurora* egg mass counts should continue in order to provide baseline data on distribution and abundance and to detect declines. *Rana aurora* management would benefit from additional study of movement and habitat use, life history, effects of marijuana cultivation, and impacts of introduced species in the field. Particularly as habitat becomes increasingly fragmented, data on connectivity among habitat patches, effects of road density, and use of terrestrial habitat away from breeding ponds can help inform appropriate setback distances and buffer configurations. Genetic studies may also be helpful for understanding patterns of frog movement across the landscape. Basic life history information overall and from the California range in particular is also lacking. Understanding saltwater tolerance of different life stages would be useful for predicting the extent of sea-level-rise effects on coastal populations. Field research on impacts of marijuana cultivation on amphibian populations would contribute to developing environmental regulations for this growing industry. Much of the concern for bullfrog impacts on *R. aurora* is from experimental mesocosm studies. Additional research that addresses the effects of bullfrogs and fish on *R. aurora* in the field is necessary to understand the community context of impacts, as the effects of bullfrogs in combination with fish may be greater than either singly (Kiesecker and Blaustein 1998), and fish may be facilitating bullfrog survival (Adams et al. 2003). Under the assumption that eradication of well-established introduced species is unlikely to be feasible at a large scale, a main goal of this work should be identifying factors that can potentially be manipulated to promote coexistence between *R. aurora* and nonnative predators, such as managing terrestrial and aquatic vegetation cover and hydroperiod.



FOOTHILL YELLOW-LEGGED FROG

Rana boylei Baird 1854

Status Summary

Rana boylei is a Priority 1 Species of Special Concern, receiving a Total Score/Total Possible of 83% (91/110). During the previous evaluation, it was also considered a Species of Special Concern, with varying levels of threat in different parts of the range (Jennings and Hayes 1994a).

Identification

Rana boylei is a small to medium-sized frog (up to 81 mm SVL) (Stebbins 2003). The skin usually appears rough and granular, with many tiny tubercles on the surface, including on the tympanum (Nussbaum et al. 1983). The dorsal coloration is variable and can be gray, brown, reddish, or olive, sometimes with extensive brick-red coloration around the weak dorsolateral folds (Nussbaum et al. 1983). Individuals can also change their overall coloration from relatively light to dark (Wheeler et al. 2005). An inverted triangle-shaped patch of buff coloration is usually present on the snout, but its dis-

tinguiveness varies (Stebbins 2003). The ventral coloration is typically yellow on the hind legs and posterior abdomen, with the rest of the venter mostly white with dark mottling on the throat and chest (Nussbaum et al. 1983).

Foothill Yellow-Legged Frog: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	5
ii. Distribution trend (25)	20
iii. Population concentration/ migration (10)	10
iv. Endemism (10)	7
v. Ecological tolerance (10)	7
vi. Population trend (25)	25
vii. Vulnerability to climate change (10)	10
viii. Projected impacts (10)	7
Total Score	91
Total Possible	110
Total Score/Total Possible	0.83

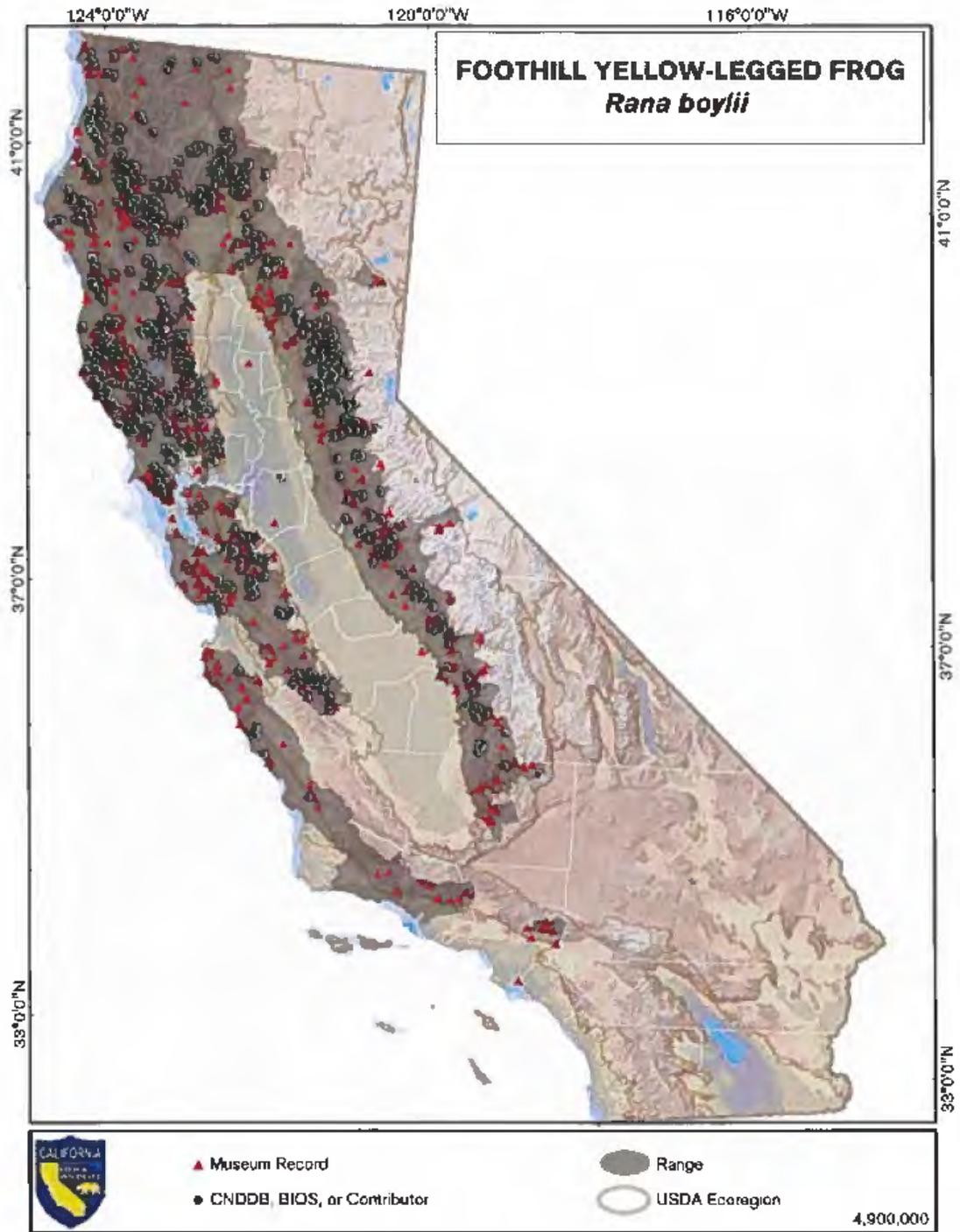


PHOTO ON PREVIOUS PAGE: Foothill yellow-legged frog, Del Norte County, California. Courtesy of Rob Schell Photography.

Jennings and Hayes (2005) documented orange or red coloration on the ventral surfaces of the hind limbs in post-metamorphic animals from Glenn, Tehama, and Stanislaus Counties. Tadpoles reach a maximum size of 55 mm and are usually olive dorsally with dark spots or mottling that matches the stream substrate and a silvery venter (Nussbaum et al. 1983). Males call primarily underwater but will also call above (MacTague and Northen 1993).

Other species that *R. boylei* could potentially be confused with in California include the California and northern red-legged frogs (*R. draytonii* and *R. aurora*), the mountain and Sierra Nevada yellow-legged frogs (*R. muscosa* and *R. sierrae*), and juvenile bullfrogs. *Rana draytonii* and *R. aurora* have smooth skin, a prominent jaw stripe, distinct dorsolateral folds, and usually have red coloration under the hind limbs (although *R. boylei* can also have red ventral coloration, and young *R. draytonii* and *R. aurora* often have yellowish thighs) (Stebbins 2003, Jennings and Hayes 2005). *Rana muscosa* and *R. sierrae* have smoother skin, smooth tympana, and tend to lack the light patch on the snout (Stebbins 2003). Bullfrogs occasionally co-occur with *R. boylei* but tend to be greenish in color, with smoother skin, and large, smooth tympana (Stebbins 2003).

Taxonomic Relationships

Rana boylei has been recognized as a distinct species for a long period of time, although its phylogenetic placement among other North American ranids has been revised repeatedly (Baird 1854, Macey et al. 2001, Hillis and Wilcox 2005). Zweifel (1955) documented variation in color and morphology among California *R. boylei* populations. Recent phylogeographic studies have found that genetic variation among *R. boylei* populations is structured along hydrologic boundaries (Dever 2007, Peek 2010, Lind et al. 2011). In a range-wide phylogeographic study, Lind et al. (2011) identified some peripheral populations that are deeply divergent from populations within the core of the range. In California, populations in southern-

most Monterey County west and south of the Salinas River Valley and populations from the southern Sierra Nevada were found to be phylogenetically distinct from the rest of *R. boylei*, suggesting a long history of isolation. While extreme southern populations from Los Angeles County are now extirpated, Lind et al. (2011) hypothesized that animals from those localities may also have been genetically distinct.

Life History

As a stream-dwelling frog, the life history of *Rana boylei* coincides with seasonal patterns in river flows associated with California's Mediterranean climate. The most sensitive life stages (eggs and larvae) develop during relatively stable conditions when streams are at their lower stages (Kupferberg et al. 2009b). Breeding and oviposition occur in spring after flood waters recede, and tadpoles metamorphose in late summer through early autumn before winter rains (reviewed in Lind 2005, Haggarty 2006, Wheeler and Welsh 2008). Southern populations breed earlier than northern populations (Zweifel 1955), and the onset and duration of breeding can be influenced by water temperature, cessation of rainfall, water velocity and depth, and day length (Zweifel 1955, Kupferberg 1996a, Lind et al. 1996). Between 2002 and 2007 at a site in Del Norte County, breeding activity was initiated in early April and lasted for 19–52 days, with earlier breeding occurring in low-flow years (Wheeler and Welsh 2008). Breeding activity ceased briefly during rain events that increased flows (Wheeler and Welsh 2008).

Females lay a single cluster of up to 2000 eggs (Zweifel 1955) attached to pebble or cobble substrates (Fuller and Lind 1992) or to bedrock (M. van Hattem, pers. comm.). Eggs take 2–3 weeks to hatch, depending primarily on water temperature (Kupferberg 1996a). Major sources of natural egg mortality are desiccation through stranding in dry years, and scour from floods in wet years (Kupferberg et al. 2009b). Adults breed at 2 or 3 years of age depending on the geographic location, and this translates into

fluctuations in adult populations being determined by environmental conditions during recruitment 2–3 years prior (Kupferberg et al. 2009b). Metamorphosed animals captured in Tehama County were 1.2–7.2 years old based on skeletochronology (Bourque 2008), suggesting that they can be relatively long-lived.

Radiotelemetry studies are beginning to offer more insight into terrestrial movements. Adults aggregate at pools in the spring but become more difficult to find in the summer (Van Wagner 1996, Haggarty 2006, Wheeler and Welsh 2008). In one study in Tehama County, frogs used watercourses for movement and were rarely more than 12 m from the stream channel (Bourque 2008). Females tended to move upstream during spring and downstream during the fall and winter. Travel rates in this population were up to 1386 m/day, faster than previously thought. In other studies, the longest distances traveled have been closer to 500 m at rates of tens to a few hundred meters per day (Van Wagner 1996, Drennan et al. 2006, Wheeler et al. 2006). Females tend to move farther distances than males, with female movements up to 7 km documented in one study (Bourque 2008, Gonsolin 2010). At one locality in Del Norte County, 68% of males remained in one breeding site during the reproductive season, with average home range sizes of 0.58 m² (Wheeler and Welsh 2008). At a site where the availability of permanent water is a limiting factor in Santa Clara County, resident tributary frogs moved to the main stem to breed and moved greater distances than resident main stem frogs (Gonsolin 2010). Greater than 90% of movements were associated with movements to or from breeding sites, and all movements outside of the breeding season were made in response to the channel drying back or to rainfall (Gonsolin 2010).

Larvae appear to be herbivorous, while metamorphs and adults consume terrestrial and aquatic insects. Algae with epiphytic diatoms are a preferred food for larvae, and the abundance of floating algae indicates the quality of larval food resources (Kupferberg 1996b, Kup-

ferberg 1997). Metamorphosed animals primarily forage terrestrially (Zeiner et al. 1988, Van Wagner 1996, Haggarty 2006, Hothem et al. 2009). Spiders, beetles, and flies are common prey items (Haggarty 2006, Wiseman and Bettaso 2007, Hothem et al. 2009). Gut content analyses of adults collected from 22 sites in the Cache Creek watershed found that 98% of individuals contained terrestrial prey, 28% contained aquatic prey, and one animal contained mammal hair and bone fragments (Hothem et al. 2009). Two occurrences of adults cannibalizing juvenile conspecifics have been documented (Wiseman and Bettaso 2007).

Habitat Requirements

Rana boylei is primarily stream dwelling and requires shallow, flowing water in streams and rivers with at least some cobble-sized substrate (Hayes and Jennings 1988). Different life stages use different habitat types for development, foraging, and overwintering.

Breeding and oviposition occur at the margins of relatively wide and shallow channel sections, habitats that experience reduced flow variation (Storer 1925, Fitch 1936, Kupferberg 1996b, Lind et al. 1996). Breeding sites are often located near tributary confluences (Kupferberg 1996a, Bourque 2008). Egg masses are attached in low-flow locations behind and sometimes under rocks. The most commonly used substrates for breeding sites are cobble, boulders, and gravel (Fuller and Lind 1992, Kupferberg 1996a). Eggs have been found at water depths up to 87 cm (C. Bondi, S. Yarnell, and A. Lind, pers. comm.), in water velocities of 0–0.21 m/s, and up to 12.5 m from shore (Kupferberg 1996a, reviewed in Lind 2005). The critical thermal maximum for embryos is 26°C, and eggs have been found in water ranging from 9°C to 21.5°C (Zweifel 1955). Density of egg masses was highest in Eel River reaches when July mean temperatures were between 17.5°C and 19°C (Catenazzi and Kupferberg 2013). Egg mass surveys from 1991 to 2002 across 11 small and large streams in the Northern Coast Ranges and the Sierra Nevada found

that oviposition sites occurred in a very narrow range of microhabitat conditions that were different from randomly selected habitats, strongly suggesting active habitat selection by frogs (Lind 2005). High-quality breeding areas are often used over multiple years (Lind 2005). Larvae tend to stay in natal habitats until they metamorphose (Van Wagner 1996). Surveys in the Mattole Watershed in northern coastal California across different channel types found that tadpole presence was best predicted by relatively warmer water temperatures (Welsh and Hodgson 2011). Tadpoles were never found in water colder than 13°C, and tadpole abundance increased with water temperature (Welsh and Hodgson 2011). In choice experiments, tadpoles selected temperatures between 16.5°C and 22.2°C (Catenazzi and Kupferberg 2013).

Metamorphosed animals use a variety of aquatic habitats, including riffles, pools, and glides (reaches intermediate between riffles and pools) depending on the life stage and season (Van Wagner 1996, Yarnell 2000, Lind 2005, Yarnell 2005, Haggarty 2006). At Red Creek in Tehama County, post-breeding season adults and subadults preferred pool and riffle habitats, while young of the year metamorphs selected slower-moving glides and runs (Haggarty 2006). In Nevada County, all age classes used riffles after the breeding season (Van Wagner 1996). In the Sierra Nevada foothills, subadults chose fast-flowing sections of stream, while adults used slower-moving pool habitats (Yarnell 2000, Yarnell 2005). In the Mattole Watershed, the best predictor of adult presence in streams was canopy openness (Welsh and Hodgson 2011). Abundance of adults and larvae was positively associated with larger basin areas and finer substrates, conditions more typical of alluvial channels than other channel types (Welsh and Hodgson 2011).

Less is known about terrestrial habitat use. Adults typically occur along waterways with some degree of shading (Fitch 1938, Zweifel 1955, Moyle 1973, Hayes and Jennings 1988, Van Wagner 1996), although they also occur in open habitats (Welsh et al. 2005, Haggarty

2006, Welsh and Hodgson 2011). During the spring, radio-tracked males and females in Tehama County were often found on land near water (38% and 66% of the time, respectively; Bourque 2008). The average distance from water was less than 3 m in all seasons, although adults occasionally used habitat up to 40 m distant from streams (Bourque 2008). Adults move to tributaries or upland habitats to avoid floods following large rain events (Kupferberg 1996b, Van Wagner 1996, Yarnell 2000, Bourque 2008). Tributaries are also used for overwintering in early spring before adults are abundant on the principal channels (Kupferberg 1996b, Yarnell 2000). Juveniles will also move into tributaries, with maximum movements of 860 m from hatching site to upstream tributaries observed in Santa Clara County (Gonsolin 2010). Adults may aggregate above ground in terrestrial microhabitats on tributaries post-breeding (Leidy et al. 2009).

Distribution (Past and Present)

Historically, *Rana boylei* occurred in foothill and mountain streams from the San Gabriel River in Los Angeles County to southern Oregon west of the Sierra-Cascade crest (Nussbaum et al. 1983, Stebbins 2003), from sea level to 1940 m (Hemphill 1952). There is an isolated, unverified record from northern Baja California, Mexico, at ~2000 m (Loomis 1965).

Jennings and Hayes (1994a) considered *R. boylei* endangered in central and southern California south of the Salinas River, threatened in the west slope drainages of the Sierra Nevada and Cascades, and of special concern in the Coast Ranges north of the Salinas River. They estimated that *R. boylei* were extirpated from 45% of their historical localities in California, and 66% of historical localities from the Sierra Nevada. Building on that mapping effort, Lind (2005) looked at 394 historic localities in California and Oregon, and found that 201 localities (51%) were no longer occupied, with extirpations largely in southern California and northern Oregon. Kupferberg et al. (2012)

determined current occupancy of 310 randomly selected sites that were occupied prior to 1975. They found that half of the sites still had *R. boylei* populations, with frogs more likely to be present in sites without large dams.

Extirpations likely began in the second half of the twentieth century. Grinnell and Storer (1924) noted several sites in the Sierra Nevada foothills around Yosemite where *R. boylei* were common. In resurveys of those sites and surveys of additional sites in the early 1990s, Drost and Fellers (1996) did not find any *R. boylei*. Surveys by Moyle (1973) in the 1970s found *R. boylei* at only 30/95 sites in the southern and central Sierra Nevada foothills. Field surveys since 1993 have found at least one frog at only 213/804 sites in 28/40 California counties (Fellers 2005a). Fellers (2005a) estimated that extant populations occur in 40% of streams in the Pacific Northwest, 30% of streams in the Cascade Mountains, 30% of streams in the south Coast Range (south of San Francisco), and 12% of streams in the Sierra Nevada.

Trends in Abundance

Kupferberg et al. (2012) compiled egg mass density data from multiple sources on 27 Sierran and coastal populations in northern California between 1991 and 2010. The range of densities reported was between 1.9 and 105.7 clutches/km of reach sampled. Average density was higher in free-flowing rivers (31.1 clutches/km) than in rivers with dams (5.5 clutches/km), but no differences were detected between abundances in coastal versus montane watersheds (Kupferberg et al. 2012). Fellers (2005a) reported that only 30 of 213 occupied California sites had population sizes greater than 20 adults. In the Coast Ranges, population sizes of greater than 100 adult frogs occurred at six sites, and populations greater than 50 adult frogs occurred at nine sites (Fellers 2005a). Small population sizes are presumably due to population declines, leading to predictions that populations in the southern Sierra Nevada will not be viable for more than another decade (Fellers 2005a). Minimum viable population sizes

are unknown, however, and may vary across the range.

Nature and Degree of Threat

The main threats to and likely causes of *Rana boylei* decline are human activities that alter natural hydrologic regimes of streams and rivers, such as dams for hydroelectric power generation, water storage, and water delivery. Other potential stressors include land use changes that degrade or destroy riparian habitat (particularly urban and agricultural development), pesticides, disease, and invasive species.

Alterations to the natural flow regime, for example, through dam releases, can have direct mortality effects and indirect negative effects on *R. boylei* by altering habitat availability and quality. Kupferberg et al. (2009b) reviewed published literature and Federal Energy Regulatory Commission hydroelectric dam relicensing reports to assess the effects of pulsed flow releases on *R. boylei*. The data spanned 1997–2007 and included seven major river basins in California. Pulsed flows from dam releases after oviposition resulted in scouring of egg masses, while flow changes during oviposition led to stranding when water levels subsequently dropped and exposed egg masses. Similarly, tadpoles can be scoured and stranded due to pulsed-flow releases. The effect of releases on post-metamorphic animals is less clear, and the impact of flow changes on habitat availability is highly site specific. Reservoirs and dams may also disrupt patterns of connectivity among *R. boylei* populations. Comparisons of genetic structure within and among *R. boylei* populations in three pairs of regulated versus unregulated Sierran rivers found that regulated rivers exhibited lower genetic diversity and greater genetic drift compared to unregulated river populations (Peek 2010).

Kupferberg et al. (2009c) modeled *R. boylei* population growth under different flow scenarios. A major result was that populations in regulated rivers had 4–13-fold greater extinction risk than populations in unregulated rivers due to smaller population sizes. Kupferberg

et al. (2009c) simulated how an unregulated population would be affected by flows more typical of regulated rivers. When subjected to aseasonal flow conditions, modeled populations showed a doubling of extinction risk. Many different kinds of hydrologic changes can contribute to these negative effects, and when different stressors are combined, the impact on frog populations is greater than expected from simply adding up the effects of individual stressors.

Field and laboratory experiments conducted by Kupferberg et al. (2011) showed that tadpoles suffered negative effects including death at or below water velocities experienced during aseasonal pulsed flows. For example, most tadpoles could no longer swim or seek refuge at velocities of ≥ 20 cm/s or greater, and in the absence of refugia tadpoles reached exhaustion in ~ 7 min in a 5 cm/s current. Rates of flow in regulated reaches can be much higher than this. For example, in the North Fork Feather River, surface velocity measured in larval rearing habitat near channel edges can reach over 30 cm/s after releases for recreational purposes (Garcia and Associates 2005).

Smaller-scale hydrologic modification and loss or degradation of riparian habitat due to urban and agricultural use is also a threat to *R. boylei*. Analyses correlating *R. boylei* distribution with landscape characteristics demonstrated negative effects of urban and agricultural land use change and pesticides on *R. boylei* presence (Davidson et al. 2002, Davidson 2004, Lind 2005). Vineyard conversion can have impacts on small creeks, and the establishment of permanent ponds used for irrigation and frost protection can create habitat for bullfrogs (S. Kupferberg, pers. comm.). Marijuana cultivation practices that divert water from small creeks can lead to premature drying. Growers have been observed to construct plastic-lined impoundments in creeks and add fertilizers directly to creek water, as well as use pesticides and herbicides in and around frog habitat (Gonsolin 2010). These practices are suspected to have contributed to declines in

some populations near Gilroy (Gonsolin 2010). Similar impacts are likely in Humboldt, Mendocino, and Trinity Counties (CDFG 2013). The large-scale effects of such illegal operations are unknown, and potentially dangerous to study. While in-stream gravel and suction dredge gold mining may have been more of a concern in the past, current regulations protecting salmonids have likely largely reduced the direct impact of such activities on *R. boylei*. For example, in Humboldt County in-stream gravel mining occurs above (in elevation) and outside the wetted channel, and relatively high egg mass density has been documented in reaches where gravel mining occurs in the Mad River (M. van Hattem, pers. comm.).

The current distribution of *R. boylei* is strongly correlated with climate variables, which suggests that this species may be sensitive to future climate changes, particularly those that affect stream hydrology (reviewed in PRBO 2011). Comparisons of occupied and extirpated historic localities found that sites where *R. boylei* persists have higher mean annual precipitation, less variability in precipitation, and fewer dry years than extirpated sites (Davidson et al. 2002, Lind 2005). Within the range of *R. boylei*, warming temperatures are predicted to result in more precipitation falling as rain instead of snow, and consequently less storage of water as snowpack. Reductions of 30–80% in snowpack accumulation are predicted within the northwestern range of *R. boylei*, and up to 90% reduction in snowpack is predicted for the south coast hydrologic region (Snyder et al. 2004, Cayan et al. 2008b). In the Sierra Nevada, snowpack losses of 50–90% are predicted by the end of the twenty-first century, with greatest losses at low to mid-elevations (Knowles and Cayan 2002, Hayhoe et al. 2004, Knowles and Cayan 2004, Maurer 2007, Cayan et al. 2008b). Loss of snowpack is likely to result in earlier runoff and reduced spring and summer streamflows. Timing of spring snowmelt is predicted to shift earlier in the spring in the Sierra Nevada (Snyder and Sloan 2005), while in northwestern California the opposite

has occurred over the last 50 years (Stewart et al. 2005). How frogs will respond to these changes in hydrology is unknown, but negative effects due to anthropogenic changes in hydrology are well documented. Reduction in water availability may also lead to more conflict with human use of water and affect how regulated reaches are managed (reviewed in Franco et al. 2011). It is important to note, however, that predictions of changes in precipitation are much less certain than predictions for temperature (Franco et al. 2011, PRBO 2011). In addition, climate change may also affect disease dynamics. Outbreaks of nonnative parasitic copepods occurred during two recent warm years at a long-term study site, resulting in morphological abnormalities and smaller sizes at metamorphosis (Kupferberg et al. 2009a). The outbreak was likely caused by increased summer water temperature, decreased daily discharge, or a combination of these factors. These conditions may increase under a changing climate, but could also occur as a result of marijuana cultivation.

No declines to date have been associated with *Bd*, but the disease does infect *R. boylei* in the field. Padgett-Flohr and Hopkins (2009) examined museum specimens from 1890 to 2000, and found that *Bd* first appeared in *R. boylei* samples from the 1960s, with 10% of specimens infected. In all, 0–40% of specimens were infected with *Bd* in the following decades. In laboratory trials, *R. boylei* appeared to be protected by skin peptides against *Bd* and therefore may not be very susceptible to chytridiomycosis (Davidson et al. 2007). Chytrid infection did not affect survival, even in the presence of a co-applied pesticide, but did suppress growth of recently metamorphosed individuals by approximately 40% (Davidson et al. 2007).

Observational data and surveys have found that *R. boylei* is rare or absent in habitats with introduced fishes and bullfrogs (Hayes and Jennings 1986, Hayes and Jennings 1988, Kupferberg 1997, Lind et al. 2003, Fuller 2008). Breeding populations of *R. boylei* can be an

order of magnitude smaller when bullfrogs are present compared to uninvaded reaches (Kupferberg 1997). In field experiments in outdoor enclosures, bullfrog tadpoles caused a 48% reduction in survivorship of *R. boylei* tadpoles, and a 24% decline in mass at metamorphosis. The mechanism behind the negative impacts of bullfrogs was competition for food (Kupferberg 1997). Metamorphosed bullfrogs prey on *R. boylei*, including post-metamorphic individuals (Crayon 1988, Hothem et al. 2009), but the population-level consequences of this predation are unclear. Another nonnative predator, the signal crayfish (*Pacifastacus leniusculus*), has been introduced into several Sierra Nevada drainages from farther north where the two species co-occur (Wiseman et al. 2005). Signal crayfish have been observed eating and dislodging egg masses and attacking larvae (Wiseman et al. 2005). Within *R. boylei*'s range, signal crayfish have been documented at 30–40 sites, with ~25 invaded sites occurring in the Sierran foothills (G. Fellers, pers. comm.).

Status Determination

Documented declines and extirpations of *Rana boylei* populations combined with continuing threats to remaining populations result in a Priority 1 designation for this species.

Management Recommendations

Several aspects of the biology of *Rana boylei* can help inform management efforts. *Rana boylei* use a variety of stream and streamside habitats during different life stages; therefore, protected habitat needs to provide adequate habitat diversity. The timing and pattern of releases of water from dams during April through June should be managed to minimize egg scouring and stranding. For example, dam releases can be staggered to better mimic the natural spring recession in snowmelt-fed streams. Further recommendations for hydrologic management can be found in Kupferberg et al. (2009b, 2009c). Dam removal should be explored where appropriate and is likely to benefit *R. boylei* and other native taxa. River management for other taxa

needs to take *R. boylei* into account. For example, in-stream structures to improve habitat for fish such as steelhead can negatively impact *R. boylei* (Fuller and Lind 1992). Habitat restoration and possibly repatriation of southern Sierra Nevada populations should be considered. Southern populations in general should be priorities for conservation because of the degree of losses and distinctive genetic diversity represented in this part of the range (Lind et al. 2011). Removal or management of nonnative predators such as fish and bullfrogs may help restore *R. boylei* habitat. For example, projects that remove artificial pools (e.g., relict mine tailing ponds) by restoring linkages to main river channels would result in more natural hydrologic conditions and reduce breeding habitat for bullfrogs (Fuller et al. 2010). Finally, Lind et al. (2011) suggested that an approach using genetic analyses of *R. boylei* and co-distributed riverine taxa would help in prioritizing drainages for protection based on levels of diversity.

Monitoring, Research, and Survey Needs

Modeling of population dynamics and hydrology are highly site specific and limited by available demographic data, and acquiring those additional data should be a high priority for *Rana boylei*. More research is needed on survivorship of tadpoles and juveniles, especially during overwintering. The mechanisms underlying hydrological effects are currently best understood for egg masses, and we need to develop a better functional understanding of how hydrology affects different life stages (Kup-

ferberg et al. 2009b). More research is also needed on post-metamorphic stages. Post-metamorphic stages may be less at risk from aseasonal pulses in river flow because they are more mobile, but in regulated rivers the timing of pulsed flow events can be decoupled from climatic cues (such as the first appreciable fall rains) that would normally trigger movement to safer refuges (Kupferberg et al. 2009b). Caution should be taken in using radio telemetry to study post-metamorphic animals, as 62% of frogs in one study suffered skin injuries from transmitters (Bourque 2008). Modeling efforts would also be improved by monitoring a Sierra Nevada population in an unregulated reach for comparison with more regulated sites (Kupferberg et al. 2009b). Egg mass counts are commonly used to monitor *R. boylei* populations. Females only lay one mass/year, so egg mass counts accurately reflect the number of reproductive females. However, operational sex ratios are female biased; therefore, accurate population size estimates cannot be made based on egg counts alone (Wheeler and Welsh 2008). Lind et al. (2011) provided important range-wide phylogeographic data, but their study was limited by very low nuclear genetic diversity and relied primarily on mitochondrial data. Additional work could provide valuable additional data on levels of variation and genetic isolation among local hydrologic basins, as might be predicted for this stream-restricted anuran. Finally, efforts to find remnant *R. boylei* populations in the San Gabriel Mountains and upper Piru Creek in southern California should continue.



CASCADES FROG

Rana cascadae Slater 1939

Status Summary

Rana cascadae is a Priority 2 Species of Special Concern, receiving a Total Score/Total Possible of 65% (72/110). During the previous evaluation, it was also considered a Species of Special Concern (Jennings and Hayes 1994a).

Identification

Rana cascadae is a medium-sized (2.0–8.0 cm SVL) frog with drab-green, tan, or brown dorsal coloration and well-defined black blotches scattered across the back (Slater 1939, Stebbins 2003). The number of blotches varies from very few to about 50 (Slater 1939), and unmarked individuals occur rarely (Jennings and Hayes 1994a). Blotches appear to be on the surface of the frog's skin and are reminiscent of spattered ink (Stebbins 2003). The species has a prominent light stripe above the jaw and strong dorsolateral folds. The venter is cream or buff, usually with yellowish (sometimes reddish) areas posteriorly and on the undersides of the legs. Laterally, the sides are mottled and

fade into the ventral coloration (Slater 1939). The male advertisement call is a series of low chucks given in rapid succession, usually ending with one slightly drawn out chuck (Elliott et al. 2009).

Cascades Frog: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	20
iii. Population concentration/ migration (10)	10
iv. Endemism (10)	0
v. Ecological tolerance (10)	3
vi. Population trend (25)	15
vii. Vulnerability to climate change (10)	7
viii. Projected impacts (10)	7
Total Score	72
Total Possible	110
Total Score/Total Possible	0.65

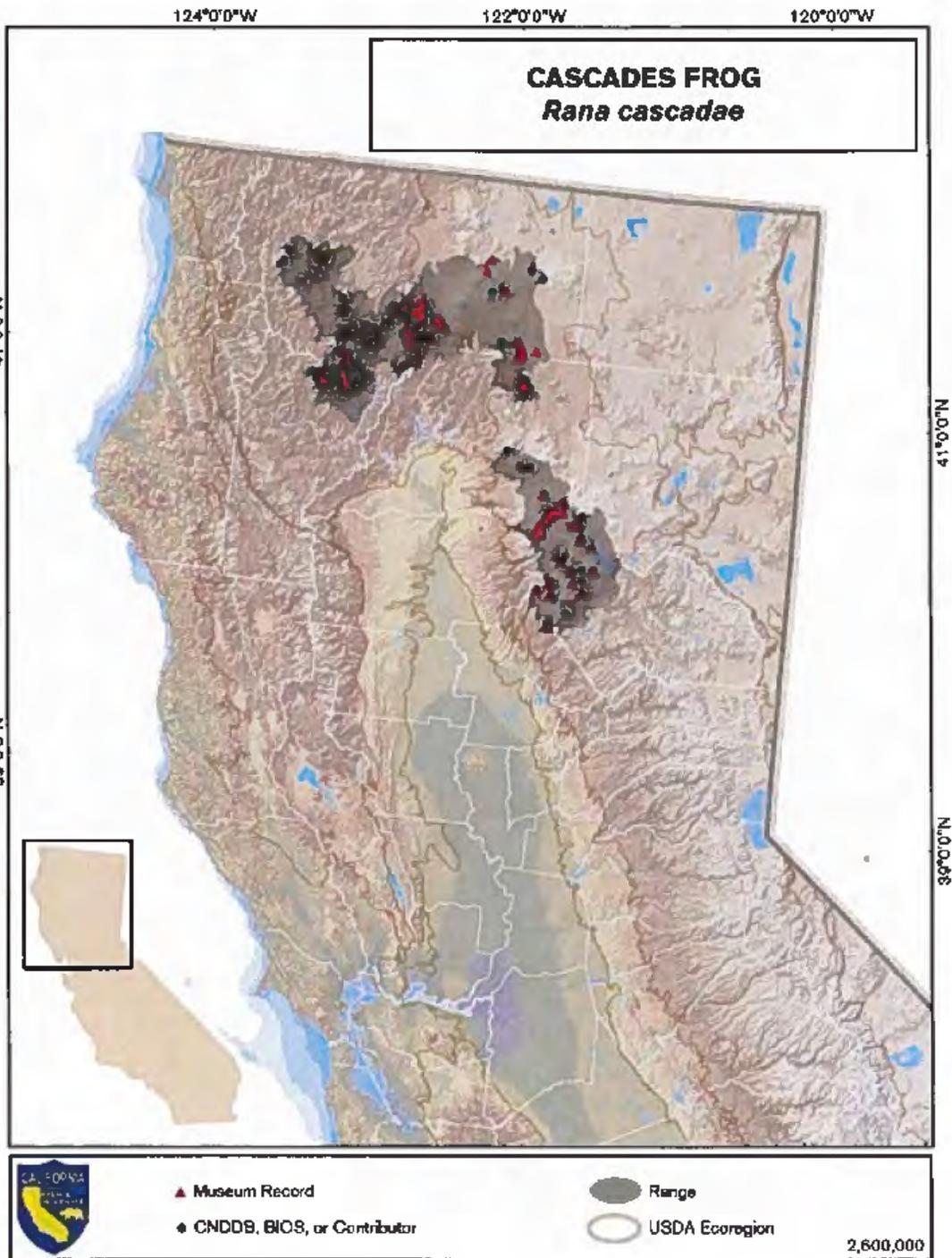


PHOTO ON PREVIOUS PAGE: Cascades frog, Trinity County, California. Courtesy of Adam Clause.

In California, this species could be confused with the California or northern red-legged frogs (*R. draytonii* and *R. aurora*), both of which it resembles in overall body shape. In adults, *R. aurora*/*R. draytonii* have extensive mottling on the venter with red pigmentation on the ventral thighs and groin, rather than the yellow that often characterizes *R. cascadae* (Dunlap 1955). However, the color of the thighs is variable in *R. cascadae* and may not be a reliable character to separate these taxa (S. Barry, pers. comm.).

Taxonomic Relationships

This species is closely related to *Rana aurora* and *R. draytonii* (Shaffer et al. 2004, Hillis and Wilcox 2005). It was proposed as a distinct species based on morphology (Slater 1939), and this interpretation has been repeatedly confirmed with additional morphological and genetic data (Dunlap 1955, Case 1978, Shaffer et al. 2004).

Based on genetic data, the species appears to show considerable differentiation among local populations that is consistent with an overall isolation-by-distance model of gene flow (Monsen and Blouin 2003, Monsen and Blouin 2004). In addition, the California populations appear to be strongly divergent in both mitochondrial and nuclear DNA from the remainder of the species' range in the Cascade and Olympic mountain ranges (Monsen and Blouin 2003). Populations of this species appear to have consistently small effective population sizes (<50; Phillipsen et al. 2011). The available data are primarily from outside of California, although the observed pattern is likely consistent throughout the range. Preliminary results based on mitochondrial DNA, nuclear DNA, and microsatellites suggested little divergence between Lassen and Klamath populations in California (Chang and Shaffer 2010). However, more extensive work with larger range-wide sampling is needed.

Life History

Rana cascadae breeds in the spring, soon after emerging from hibernation and the spring thaw that opens breeding pools (Nussbaum et al.

1983, Stebbins 2003). First-time breeders frequently disperse to new areas of suitable breeding habitat (51% of first-time breeders relative to only 7% of experienced breeders in Echo Lake Basin; Garwood 2009), which may help to connect local subpopulations into larger more stable metapopulations. Breeding occurs at the margins of waterbodies, with oviposition often occurring in large aggregations (Syte 1975, Nussbaum et al. 1983, Garwood 2009). Oviposition behavior appears to be variable throughout the species' range, with some authors reporting diurnal oviposition of largely unattached egg masses (Briggs 1987), and others noting that most egg masses are deposited at night and are attached to vegetation (Nussbaum et al. 1983; K. Pope, pers. comm.). Breeding at individual sites is relatively synchronous and occurs over a few days, although the timing of breeding across the range can vary widely with local weather conditions and elevation (Briggs 1987, Garwood 2009). Embryo development can occur at temperatures ranging from 6°C to 27°C (Syte 1975, Nussbaum et al. 1983). After hatching, larvae sometimes aggregate into dense clusters (generally fewer than 40 individuals) composed primarily of siblings (O'Hara and Blaustein 1981, O'Hara and Blaustein 1985, Blaustein and O'Hara 1987) and choose higher water temperature than those required during embryo development (up to ~28°C; Wollmuth et al. 1987, Bancroft et al. 2008). After metamorphosis, lower water temperatures are again preferred.

Rana cascadae appears to be largely diurnal. The diet of adult frogs is generalized and includes a wide variety of arthropods, as is the case for most other California ranids (Joseph et al. 2011). An analysis of stomach contents for 275 frogs documented the presence of 110 invertebrate taxa (Larson 2012). Frogs across all size classes generally avoided small prey items (<4 mm), and larger frogs more strongly preferred large prey items (Larson 2012).

Habitat Requirements

Rana cascadae utilizes a wide variety of aquatic habitats, including temporary and permanent

ponds, lakes, marshes, and streams, as well as adjacent vegetated terrestrial habitat (Nussbaum et al. 1983, Jennings and Hayes 1994a, Stebbins 2003, Pearl and Adams 2005, Garwood 2009). The species will also use wet meadows (often those that have formed from old sphagnum bogs) and can occasionally be found a large distance from water (Nussbaum et al. 1983). They require water year-round at all life stages and cannot tolerate habitats that freeze solid in the winter (K. Pope, pers. comm.). Montane lentic habitat is required for breeding and overwintering, with small, shallow, spring-fed ponds serving as the primary breeding habitat (Garwood 2009). Populations appear to be sustained by a matrix of varying habitat types that individual frogs disperse among throughout the year (Garwood and Welsh 2007, Garwood 2009), suggesting that habitat conservation needs to consider spatial scales larger than single lakes (or other patches of habitat). The presence of predaceous fish may limit their distribution (Welsh et al. 2006, Pope et al. 2008), although this alone cannot explain the broadscale pattern of population declines in this species (Fellers et al. 2008; also see the “Nature and Degree of Threat” section below).

Distribution (Past and Present)

In California, *Rana cascadae* occurs in two population segments. One is in the Lassen area and the extreme northern end of the Sierra Nevada (Lassen, Plumas, Shasta, and Tehama Counties) and is now nearly extirpated. The other occurs in the Trinity Alps and Siskiyou Mountains region. The species’ range in California extends from Siskiyou County south to the northern end of Butte County. Outside of California, the range of *R. cascadae* follows the Cascade Range nearly to the United States–Canadian border, with another disjunct population at high elevations on the Olympic Peninsula (Stebbins 2003).

Trends in Abundance

Populations of this frog have declined strongly in the Lassen area, where nearly all known

populations have disappeared in the last 30 years (Fellers and Drost 1993, Jennings and Hayes 1994a). More recent surveys in the Lassen region further confirm these declines. *Rana cascadae* was found at only 6 of 856 sites surveyed over 14 years, population sizes were small, and breeding was limited at these 6 sites (Fellers et al. 2008). Populations elsewhere, including the Klamath Mountains region in Siskiyou and Trinity Counties, are also fragmented, generally small, and at risk, although they are more intact overall than in the Lassen area (K. Pope, pers. comm.). Localized declines have also been detected elsewhere in the range (Pearl and Adams 2005, Fellers et al. 2008, Piovia-Scott et al. 2011). Welsh et al. (2006) found *R. cascadae* to be the most common anuran in the Klamath region. By contrast, more recent and ongoing surveys of eight populations in the Trinity Alps within the Klamath region find that only one of the populations is large and robust and that some of the threats present in the Lassen region are likely also operating there (K. Pope, pers. comm.). Pope and Larson (2013) report 11 remaining populations in the Lassen area and find that the number of young frogs was low at all sites that they surveyed.

Nature and Degree of Threat

Threats to this species appear to be complex and derived from multiple stressors. The largest factor contributing to declines in the Lassen region appears to be overall low recruitment due to changing hydrological conditions that lead to detrimentally high water temperatures and desiccation of egg masses and tadpoles, as well as impacts from *Bd* among subadult frogs (Pope et al. 2011). Extensive mark-recapture surveys in the Lassen region between 2008 and 2010 indicate widespread desiccation of egg masses and tadpoles and a lack of metamorphs relative to more stable populations in the Klamath area (Pope et al. 2011, Pope and Larson 2013). In comparisons between two of the remaining Lassen populations, the population with higher *Bd* prevalence and load in adult and

subadult frogs had lower survivorship for these two age classes. In both Lassen and the Klamath Ranges, subadult frogs had higher *Bd* prevalence and load than adult frogs, and the prevalence of *Bd* increased throughout the active season for subadult frogs but not for adult frogs. These results are consistent with previous studies of *Bd* in this species that suggest the pathogen has differential impacts depending on age class. Blaustein et al. (2005) examined the effect of *Bd* on larvae and found an increased incidence of mouthpart abnormalities but no effect on mortality or behavior. Garcia et al. (2006), however, found significant mortality in new metamorphs of *Rana cascadae* due to *Bd*.

Interestingly, *Bd* also appears to be widespread in the Klamath region where this species is currently much more stable than in the Lassen region (Piovia-Scott et al. 2011), suggesting more than one factor is playing a role in the declines. Ongoing characterization of *Bd* prevalence in these populations could help determine what factors are involved, although one hypothesis is that *Bd* achieves higher loads on frogs in declining populations than stable populations (J. Piovia-Scott, pers. comm.). Infection by the water mold *Saprolegnia* has also been implicated in *R. cascadae* declines. This pathogen is known to increase mortality in embryos, larvae, and metamorphs (Kiesecker and Blaustein 1999, Romansic et al. 2009a) and may have strong impacts on the outcome of competition between *R. cascadae* and sympatric *Pseudacris regilla* (Kiesecker and Blaustein 1999).

Habitat loss and modification is also a threat to continued persistence of populations in both the Klamath and Lassen regions. The species is highly associated with meadows, which have been impacted by cattle grazing, tree encroachment due to lack of wildfire, and changing hydrology associated with changes in the snowpack (K. Pope, pers. comm.; Pope et al. 2014).

Other possible contributors to *R. cascadae* declines that have been proposed include introduced fishes, environmental contaminants,

pathogens, and UV-B radiation. The presence of introduced trout appears to be inversely related to the distribution of *R. cascadae* (Welsh et al. 2006) and almost certainly impacts some populations. Aside from direct predation, introduced trout may affect *R. cascadae* indirectly by supporting higher populations of the aquatic garter snake (*T. atratus*), a predator on both trout and *R. cascadae* (Garwood and Welsh 2007, Pope et al. 2008), and by preemptive competition for aquatic prey (Joseph et al. 2011). However, trout have been present in the Lassen region for nearly a century and are also widely distributed in other areas where *R. cascadae* persists, making it unlikely that they alone can explain the declines over the last 30 years (Fellers et al. 2008). Nevertheless, populations appear to respond favorably to trout removal, showing marked increases in population size and recruitment following fish removal (Pope 2008).

Pesticide use is inversely correlated with the presence of *R. cascadae* (Davidson 2004). In particular, downwind transport of pesticides from intensively farmed areas in the Central Valley appears to be correlated with declines in several species of ranid frogs, including *R. cascadae* (Davidson et al. 2002, Davidson 2004). This hypothesis is attractive in that it explains the differential declines between the Trinity Alps region and the Lassen region because the Lassen region is directly downwind of areas that experience heavy agricultural use, whereas the Trinity Alps are not (Davidson et al. 2002). However, recent field measurements of contaminant residues in sediment and in *R. cascadae* and *P. regilla* tissue do not indicate higher levels in the Lassen compared to the Trinity Alps region, at least for the handful of different chemicals that have been analyzed to date, calling this hypothesis into question (Davidson et al. 2012). In addition, Sparling et al. (2001) measured the presence of cholinesterase levels in the non-declining *P. regilla* as a measure of the extent of pesticides that are locally deposited in an area and found strong effects in the Sierra Nevada but not in the Lassen area; these

results seem to indicate that pesticides may not be a major factor in the Lassen *R. cascadae* declines. Environmental contaminants at sub-lethal levels have also been shown to induce behavioral and morphological changes in *R. cascadae* (Marco and Blaustein 1999), suggesting that low-level agricultural residues may have important biological consequences. In summary, it appears that pesticides may be playing some role in *R. cascadae* declines in the Lassen region, but they are certainly not the entire story.

Finally, UV-B radiation may play a role, possibly in combination with other factors, in causing declines. Some studies have documented larval mortality and retinal damage due to UV-B, although the effect depends strongly on the intensity of UV-B, the duration of exposure, and possibly other factors including the presence of competitors, predators, or supplementary food (Fite et al. 1998, Hatch and Blaustein 2000, Belden et al. 2003, Garcia et al. 2006, Romansic et al. 2009b). The importance of these results has not yet been demonstrated in natural settings, however. Palen et al. (2002) found that dissolved organic matter in natural environments provided protection from UV-B at 89% of the sites examined for *R. cascadae*. Thus, it remains possible that UV-B is having an effect, although its importance in nature remains unclear.

Ultimately, it is likely that no one factor is solely responsible for the precipitous declines in Lassen region *R. cascadae* populations. Further, the causes of the initial range-wide declines may be distinct from the local factors that threaten the continued persistence of the few remaining populations. The most recent work suggests that the major factors playing a role in the range-wide declines are the presence of introduced fishes and *Bd*, while continued local persistence of the remaining populations is also threatened by low recruitment stemming from desiccation and detrimentally high water temperatures. Pope et al. (2014) present a recent and comprehensive review of both regional and local-scale threats to *R. cascadae*

throughout the range. The evidence that synergistic effects occur between several alternative mechanisms of decline is now widespread for a variety of amphibian species (Fellers et al. 2008). As declines have occurred, whatever the cause, it is likely that a breakdown of metapopulation dynamics will contribute to further declines as existing populations become more and more fragmented, decreasing the opportunity for population rescue via recolonization.

Status Determination

The catastrophic declines in the Lassen area are the primary reason for the SSC designation. *Rana cascadae* is nearly extirpated in the Lassen region, is undergoing local population declines elsewhere in its range, and appears to be susceptible to a wide range of threats. However, this frog is a moderate ecological specialist that appears to be relatively stable through much of its range, including a significant fraction of its range in California. The factors that caused declines in the Lassen area appear to not have operated in the Klamath area to date, leading us to project moderate future impacts on extant populations and a Priority 2 status. If strong declines begin to occur in the Klamath area, then a higher priority status will rapidly become justifiable.

Management Recommendations

Fellers et al. (2008), Pope et al. (2011, 2014), and Pope and Larson (2013) provide thorough reviews of threats to, and management recommendations for, *Rana cascadae*, and our recommendations largely follow those of these authors.

Habitat that supports this species in the Lassen area should be protected from modification that negatively impacts hydrology while further research is carried out. Pope et al. (2011) began some habitat restoration measures, and these efforts should be continued (coupled with ongoing monitoring to determine their effects). Fish removal in key populations has also been documented to increase recruitment and should be considered as a management strat-

egy, particularly in the Klamath where a larger number of existing populations might be stabilized before declines can occur. Pope et al. (2011) also proposed experimental treatment for *Bd* in newly metamorphosed frogs. Effective treatments for *Bd* may be essential for the long-term survival of many amphibian species, so these efforts should be further explored and potentially implemented if they are successful. At the same time, a captive colony of Lassen-area *R. cascadae* should be established, as the prospects for long-term survival in the wild appears to be low. If additional research can determine the causes of the declines and effective mitigation measures can be enacted, this captive population could eventually form the basis of a reintroduction program.

Monitoring, Research, and Survey Needs

Monitoring efforts should focus on the few remaining Lassen populations, with additional monitoring of stable populations elsewhere in the range as reference populations. Areas that have undergone habitat restoration or experimental treatments for *Bd* infection will require ongoing monitoring to quantify the long-term

effects of these efforts and to inform further work aimed at controlling the impact of these threats. If additional declines occur, this monitoring will facilitate early detection and, hopefully, provide the background data needed to understand the causes of declines.

As a reintroduction effort may eventually become necessary, it is important to further characterize the extent of intraspecific variation within this taxon now, before additional declines occur. Preliminary genetic work has been initiated, and it should form the basis of additional work that examines fine-scale population differentiation and structure. The obvious initial focus of such genetic work should be to assess the validity of the Lassen and Klamath regions as separate evolutionary units requiring their own management strategies. This work will also help to identify any potential population segments within either region that may qualify for independent management. Finally, additional studies that quantify the interactive effects among different causes of declines would be useful in providing a more complete picture of conservation threats in this taxon.



CALIFORNIA RED-LEGGED FROG

Rana draytonii Baird and Girard 1852

Status Summary

Rana draytonii is a Priority 1 Species of Special Concern, receiving a Total Score/Total Possible of 76% (84/110). During the previous evaluation, it was also considered a Species of Special Concern (Jennings and Hayes 1994a), and it has been listed as federally Threatened since 1996.

Identification

Rana draytonii is a relatively large (2.5–13.8 cm SVL) brown, gray, olive, or reddish-brown frog (Jennings and Hayes 1994a, USFWS 2002, Stebbins 2003). Prominent dorsolateral folds are usually present. Many small black flecks and larger irregular blotches are present on the back, and these occasionally form a network (Baird and Girard 1852). The larger black spots on the back often have a whitish or light center. The ventral surface is whitish or cream with extensive gray or black mottling, often overlain with red or reddish-orange coloration, particularly in the groin (Baird and Girard 1852, Steb-

bins 2003). In general, the red coloration in this species is individually and ontogenetically variable, with the undersides of the feet almost always red in adult animals, although the extent of red elsewhere on the legs and belly varies

California Red-Legged Frog: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	5
ii. Distribution trend (25)	20
iii. Population concentration/ migration (10)	10
iv. Endemism (10)	7
v. Ecological tolerance (10)	3
vi. Population trend (25)	25
vii. Vulnerability to climate change (10)	7
viii. Projected impacts (10)	7
Total Score	84
Total Possible	110
Total Score/Total Possible	0.76

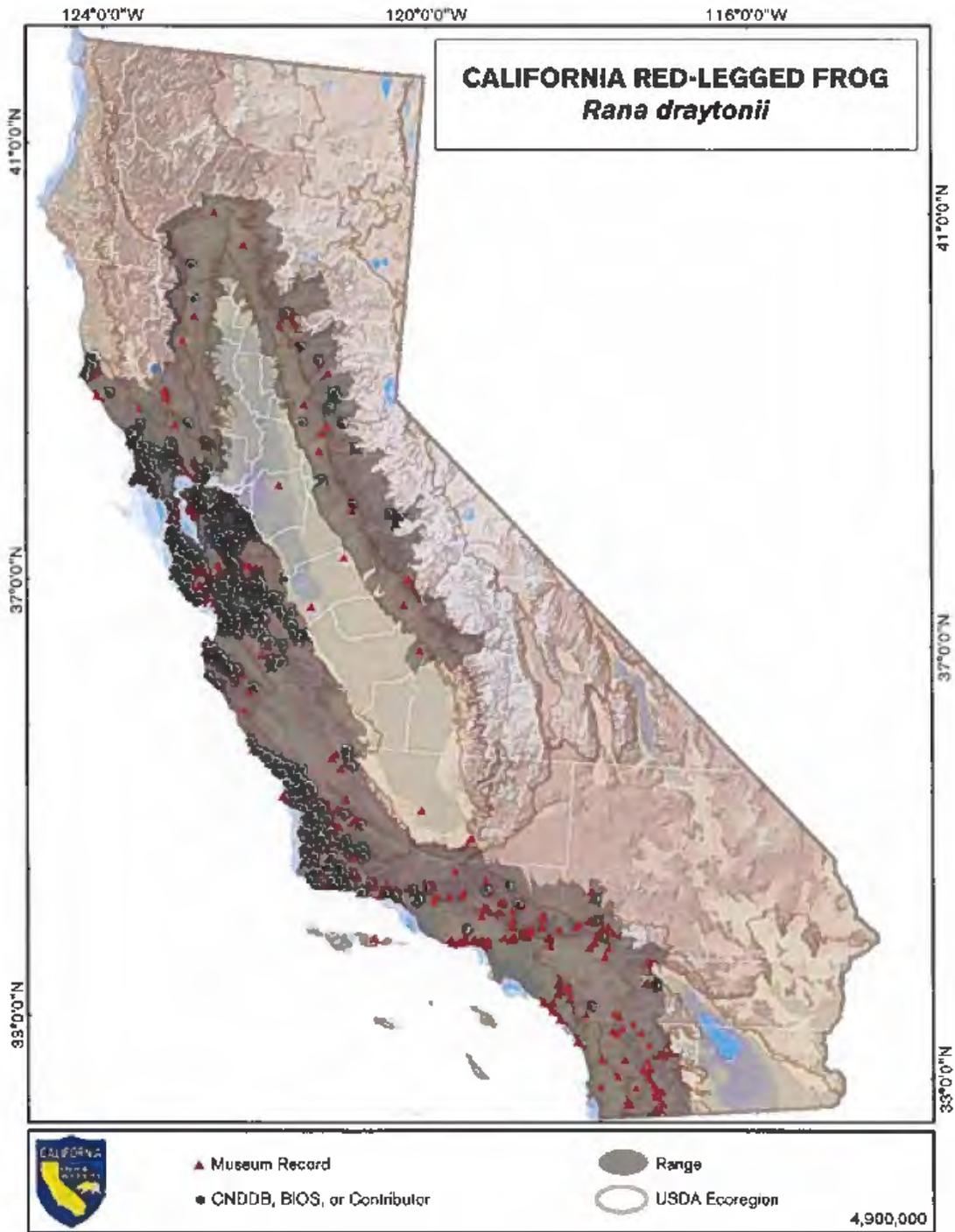


PHOTO ON PREVIOUS PAGE: California red-legged frog, Alameda County, California. Courtesy of Adam Clause.

from extensive to absent (S. Barry, pers. comm.). The advertisement call is a series of low guttural chucks sometimes followed by a low groan (Elliott et al. 2009).

This species could be confused with the northern red-legged frog (*R. aurora*) where their ranges meet in southern Mendocino County (Shaffer et al. 2004). *Rana aurora* is about 3.5–4.0 cm (SVL) smaller than *R. draytonii*, generally lacks light areas in the centers of dorsal blotches, has proportionally smaller eyes, and lacks vocal sacs (Baird and Girard 1852, Hayes and Krempels 1986, Stebbins 2003).

Taxonomic Relationships

Rana draytonii was initially described as a distinct species, although the original description notes that it is similar in appearance to *R. aurora* (Baird and Girard 1852). Subsequent to the original description, Camp (1917) reclassified the two red-legged frogs as subspecies of a polytypic *R. aurora*. This arrangement persisted, occasionally also including the Cascades frog (*R. cascadae*) as a third subspecies, until the mid-1980s. At this time, a series of studies emerged suggesting that a substantial amount of differentiation between the two forms was present in allozymes, morphology, calling behavior, and oviposition behavior, leading several authors to suggest that they may be distinct lineages with a broad zone of contact (Hayes and Miyamoto 1984, Green 1986a, Green 1986b, Hayes and Krempels 1986). Subsequent analyses of mitochondrial DNA variation supported this view but characterized a narrow zone of contact in southern Mendocino County (Shaffer et al. 2004). Based on both DNA and morphological differentiation, Shaffer et al. (2004) suggested that the two be recognized as distinct species, and since then *R. draytonii* has increasingly been recognized as a species distinct from both *R. aurora* and *R. cascadae*.

Life History

Few data are available on seasonal activity patterns, but coastal populations are probably

active throughout much of the year due to the moderating effect that the Pacific Ocean has on temperature. The timing of reproduction varies from year to year and according to site but occurs from late November to late April (Storer 1925, Fellers 2005b). Breeding occurs in the water, and eggs are attached to emergent vegetation (in clusters of 300 to >4000; Storer 1925, Hayes and Miyamoto 1984). Hatching occurs in 6–14 days depending on water temperature, after which larvae metamorphose in 3.5–7 months (Storer 1925, Wright and Wright 1949). Larvae are known to overwinter at several sites, metamorphosing the following spring (Fellers et al. 2001). *Rana draytonii* is a generalist predator that feeds predominantly on invertebrates but has also been documented to take vertebrate prey including Pacific treefrogs (*Pseudacris regilla*), western toads (*Bufo boreas*), and California mice (*Peromyscus californicus*) (Hayes and Tennant 1985, Arnold and Halliday 1986, USFWS 2002, Davidson 2010). The prey types taken appear to be determined by the size of the frogs, with individual frogs taking most prey types that they can successfully swallow (Jennings and Hayes 1994a) and large frogs taking proportionally more vertebrate prey than small ones. Baldwin and Stanford (1987) reported a large adult preying upon California tiger salamander (*Ambystoma californiense*) larvae. *Rana draytonii* feed both in the water and by foraging in dense riparian vegetation. *Rana draytonii* is active both diurnally and nocturnally, although adults are generally more active at night (Hayes and Tennant 1985; G. Fellers, pers. comm.).

Wading birds, raccoons, and garter snakes (*Thamnophis sirtalis* and *T. hammondi*) are important native predators on this species (Cunningham 1959b, Jennings and Hayes 1994a). Nonnative fishes are also important predators on larvae and recent metamorphs (Schmieder and Nauman 1994, USFWS 1999).

Habitat Requirements

Rana draytonii chiefly inhabits ponds, although it also uses marshes, streams, lagoons, and other waterways throughout most of its range.

In southern California (from Ventura County southward) it seems to favor slow-flowing streams rather than ponds or pools. Breeding takes place primarily in ponds (at least in central and northern California) and less frequently in quiet pools in streams (Stebbins 2003, Fellers 2005b). This species will also utilize ephemeral water bodies for breeding, although nearby permanent water is probably required to maintain populations over the long term (Jennings 1988a). After breeding, adults often disperse along nearby shaded streams. Similar to *R. boylei*, whose vulnerable early life stages (embryos and tadpoles) are susceptible to ill-timed flow fluctuations controlled by upstream dams and diversions, *R. draytonii* populations breeding in stream habitats suffer from decreased recruitment after anthropogenic perturbation of natural flow regimes (S. Kupferberg, pers. comm.).

Optimal aquatic habitat has traditionally been thought to include dense riparian vegetation overhanging deep (>0.7 m) slow-moving pools (Hayes and Jennings 1988). More recent work has documented an additional, more complex relationship between aquatic vegetation and introduced bullfrogs. D'Amore et al. (2009) documented that *R. draytonii* spend more time in vegetative cover when bullfrogs are present and more time in the open when bullfrogs are removed from ponds, suggesting that the optimal amount of vegetation is somewhat context-dependent for *R. draytonii*. In addition, surveys of 85 ponds occupied by *R. draytonii* in the East Bay Regional Park District showed that there were no significant differences in adult frog density among ponds with 0%, ≤15%, or >15% emergent vegetation, but tadpoles and metamorphs were more abundant in the most open ponds (Bobzien and DiDonato 2007). Outside of the breeding season when conditions are wet, and especially during rainfall, adult frogs will disperse from the breeding habitat and will move to upland sites, where they are often found under logs, rocks, and other debris (USFWS 2002, Bulger et al. 2003, Fellers and Kleeman 2007). At some

sites, populations appear to consist of both migratory (11–22% of the adult population) frogs that move 200–2800 m and resident frogs that remain at the breeding site (Bulger et al. 2003). Fellers and Kleeman (2007) found that adult female frogs were more frequently migratory than males, although migration behavior did not differ between the sexes among those individuals that did migrate.

Distribution (Past and Present)

Historically, *Rana draytonii* ranged throughout the Sierra Nevada foothills and the Coast Range mountains south of Elk Creek in southern Mendocino County, California, southward to the Arroyo Santo Domingo, Baja California Norte, Mexico (Hayes and Krempels 1986, Jennings and Hayes 1994a, Grismer 2002, Shaffer et al. 2004). In California, this taxon historically ranged through at least 46 counties, but it is now apparently extirpated from 24 of these (USFWS 1996). It is unclear whether reproductive populations of *R. draytonii* were present in most of the Central Valley, and it is possible that the few valley records represent waifs washed downstream from Sierran populations (G. Fellers, pers. comm.; S. Barry, pers. comm.). If they were present in the Central Valley, they were extirpated before 1960. Populations in the Sierra Nevada may have been connected to the largest remaining populations of the species in the Coast Ranges through the lower Cascade and Tehachapi Ranges (S. Barry, pers. comm.), but today they are isolated (USFWS 2002). A recent comprehensive survey of museum specimens and historical records identified 21 historical localities for this species in the Sierra Nevada. Follow-up surveys at 20 of these 21 sites found that the species persists in large numbers in at least 1 site, there are populations at 6 additional sites, and at least a single individual documented at 3 more sites (Barry and Fellers 2013).

Strong overall declines have clearly occurred across most of the large range of this species, particularly in the southern portion of the range. In the Bay Area and Coast Ranges,

populations are more robust, although severe localized declines have been documented (reviewed in USFWS 2002). In southern California, *R. draytonii* has declined drastically through the Transverse and Peninsular Ranges, and very few populations now persist in Los Angeles, Riverside, and Ventura Counties (USFWS 2002, and references therein). One population is known from Santa Cruz Island, although this apparently is an introduction (Sweet and Leviton 1983, Jennings 1988b). The known elevational range of *R. draytonii* occurs from near sea level to 1500 m, although most populations occur below 1050 m (USFWS 2002, Barry and Fellers 2013). Some higher-elevation populations may be introductions (unpublished data reported in Jennings and Hayes 1994a).

Trends in Abundance

Drastic and ongoing declines have been documented throughout parts of this species' range. Many of these declines have resulted in extirpation of populations, and in many areas where this taxon persists, declines in abundance have occurred. Food market collection in the late 1800s apparently drove much of the initial declines (Jennings and Hayes 1985). By 1879, the species had already become rare around San Francisco due to the market trade (Lockington 1879). Population trends of the species in the Sierra Nevada foothills are somewhat unclear, since several new, large (>100 breeding adults) populations have recently been discovered (e.g., in Placer County). However, in southern California, population densities are uniformly low (<25 adults frogs) and generally declining (USFWS 2002). The sole remaining population known in Riverside County at the Santa Rosa Plateau, which was at least somewhat genetically distinctive (Shaffer et al. 2004), is now extirpated.

Nature and Degree of Threat

The largest threat facing *Rana draytonii* is probably habitat loss and alteration, resulting from urbanization and agriculture. The large-scale conversion of habitat to agricultural uses has

also resulted in an increase in pesticide exposure, which may have strong negative impacts on this species (Davidson et al. 2002). This effect is particularly strong for cholinesterase-inhibiting pesticides (Davidson 2004), although the species still persists in some heavily agricultural settings in Monterey and Santa Cruz Counties. Additional and ongoing fragmentation of habitats, conversion of wetlands to other uses, and modifications to the hydrology of wetlands also likely have detrimental impacts.

The effect of introduced species, in particular bullfrogs, has been studied both empirically (Moyle 1973) and from a modeling perspective (Doubledee et al. 2003). There is a strong overall negative impact of bullfrogs on native *R. draytonii*, although coexistence of the two species can occur in nature. Human-modified aquatic and terrestrial habitats in central California (Elkhorn Slough, Monterey County) favor introduced bullfrogs compared to native *R. draytonii* (D'Amore et al. 2010). The bullfrog is also a strong competitor with, and predator on, multiple life stages of *R. draytonii*. In addition, crayfish, mosquitofish (Lawler et al. 1999), and other introduced predaceous fishes likely have negative impacts on this species, although this also needs further study (Hayes and Jennings 1986, Fisher and Shaffer 1996, Fellers 2005b).

Chytrid fungus (*Bd*) is known to have caused serious declines in many amphibian species and has been detected in *R. draytonii* in nature. However, the direct impact *Bd* has on *R. draytonii* appears to be relatively slight. In a laboratory setting, *R. draytonii* is susceptible to chytrid infection, but frogs can clear their infections, do not die from the infection, and suffer no growth consequences when they have access to unlimited food (Padgett-Flohr 2008). In nature, across a landscape of ponds where *Bd* presence and absence fluctuated between wet and dry years, *R. draytonii* were generally uninfected and found to be significantly associated with uninfected ponds (Padgett-Flohr 2010).

Predicted climate change over much of California will affect *R. draytonii*, as well as most

other pond- and stream-breeding amphibians. In particular, warmer average temperatures, generally reduced levels of precipitation, and increased variability in the timing of rainfall are all predicted to occur (PRBO 2011). While the precise effects of these shifts will vary regionally and at the watershed level, the permanence and reliability of breeding sites are generally predicted to decrease under climate change predictions.

Status Determination

Rana draytonii automatically qualifies as a Species of Special Concern because it is listed under the federal but not state Endangered Species Act. However, sharp declines in both range and abundance, coupled with a variety of ongoing threats to long-term survival, also combine to warrant a Priority 1 Species of Special Concern status.

Management Recommendations

Management of *Rana draytonii* should mirror the guidelines in the USFWS recovery plan for this taxon (USFWS 2002). As further management needs are defined and existing management strategies are refined (through 5-year reviews or other avenues), state-level management should be adjusted accordingly.

The most important management needs for this taxon currently are the protection of habitat that supports the species, reduced pesticide exposure, and elimination of nonnative predators. Land conversion and additional fragmentation should be avoided wherever possible, and adequate, complex upland habitat should be available in order to allow migration to occur naturally. Fellers and Kleeman (2007) found that the median distance of movement away from breeding ponds was 150 m and that there were some long-distance movements up to 1,400 m. Unpublished radiotelemetry observations from the East Bay Regional Park District (S. Kupferberg, pers. comm.) demonstrated that ground squirrel burrow density, sometimes more than 100 m from the aquatic habitat, was also a key component of habitat quality.

Taken together, these studies indicate that large tracts of terrestrial habitat are important (to accommodate both short- and long-distance dispersal) and that a healthy population of ground squirrels (and possibly other burrowing rodents) may be essential for long-term population viability.

Finally, pesticide use should be curtailed in areas where this species occurs, including areas upwind where pesticides are likely to be blown into areas that support this species. Unpublished data from the East Bay Regional Park District (S. Kupferberg, pers. comm.) indicate that cattle-grazing does not appear to negatively impact this species.

Monitoring, Research, and Survey Needs

Further research is needed to determine what the precise impacts many of these threats identified above are having on *Rana draytonii*. Surveys of private land in the Sierra Nevada are slowly revealing the presence of extant populations that were previously missed (S. Barry, pers. comm.), suggesting that this may be a fruitful strategy elsewhere in the range as well. Managers should partner with private landowners to gain access and survey for remaining populations of this species in areas where it has previously been thought to be extirpated, and these populations, which may be very small in size, should be monitored regularly.

Finally, the only range-wide genetic analysis of the species thus far conducted was based purely on mitochondrial DNA (Shaffer et al. 2004), and supporting data from a large set of nuclear DNA markers is badly needed. In particular, the potential genetic break between populations north and south of Santa Barbara County, and the genetic affinities of remnant populations from southern California and Baja California, Mexico, will form an important part of future management.

Additional monitoring, research, and survey needs are covered in depth in the USFWS recovery plan for this taxon. We refer the reader to this document for more information (USFWS 2002).



NORTHERN LEOPARD FROG

Rana pipiens Schreber 1782

Status Summary

Rana pipiens is a Priority 1 Species of Special Concern, receiving a Total Score/Total Possible of 73% (80/110). During the previous evaluation, it was also designated as a Species of Special Concern (Jennings and Hayes 1994a).

Identification

Rana pipiens is a medium-sized ranid frog with strong, continuous dorsolateral folds that do not angle inward posteriorly. Its dorsal coloration is green to brown with large well-defined black or dark-brown oval or round spots. Each spot is ringed with a narrow band of white or cream. The ventral coloration is white or cream with no mottling or other dark markings (Stebbins 2003). The call is a low, snore-like trill, often followed by low chuckling and/or grunts (Stebbins 2003, Elliott et al. 2009).

Within its range in California, this species can potentially be confused with the Oregon spotted frog (*R. pretiosa*). However, *R. pretiosa* has much smaller, more irregular spots, which

often have diffuse borders and are not ringed in white. It also has conspicuous red or salmon markings on the underside, which *R. pipiens* lacks. Other members of the leopard frog complex in California, the lowland leopard frog

Northern Leopard Frog: Risk Factors

Ranking Criteria (Maximum Score)	Score
i. Range size (10)	10
ii. Distribution trend (25)	20
iii. Population concentration/migration (10)	10
iv. Endemism (10)	0
v. Ecological tolerance (10)	0
vi. Population trend (25)	20
vii. Vulnerability to climate change (10)	10
viii. Projected impacts (10)	10
Total Score	80
Total Possible	110
Total Score/Total Possible	0.73

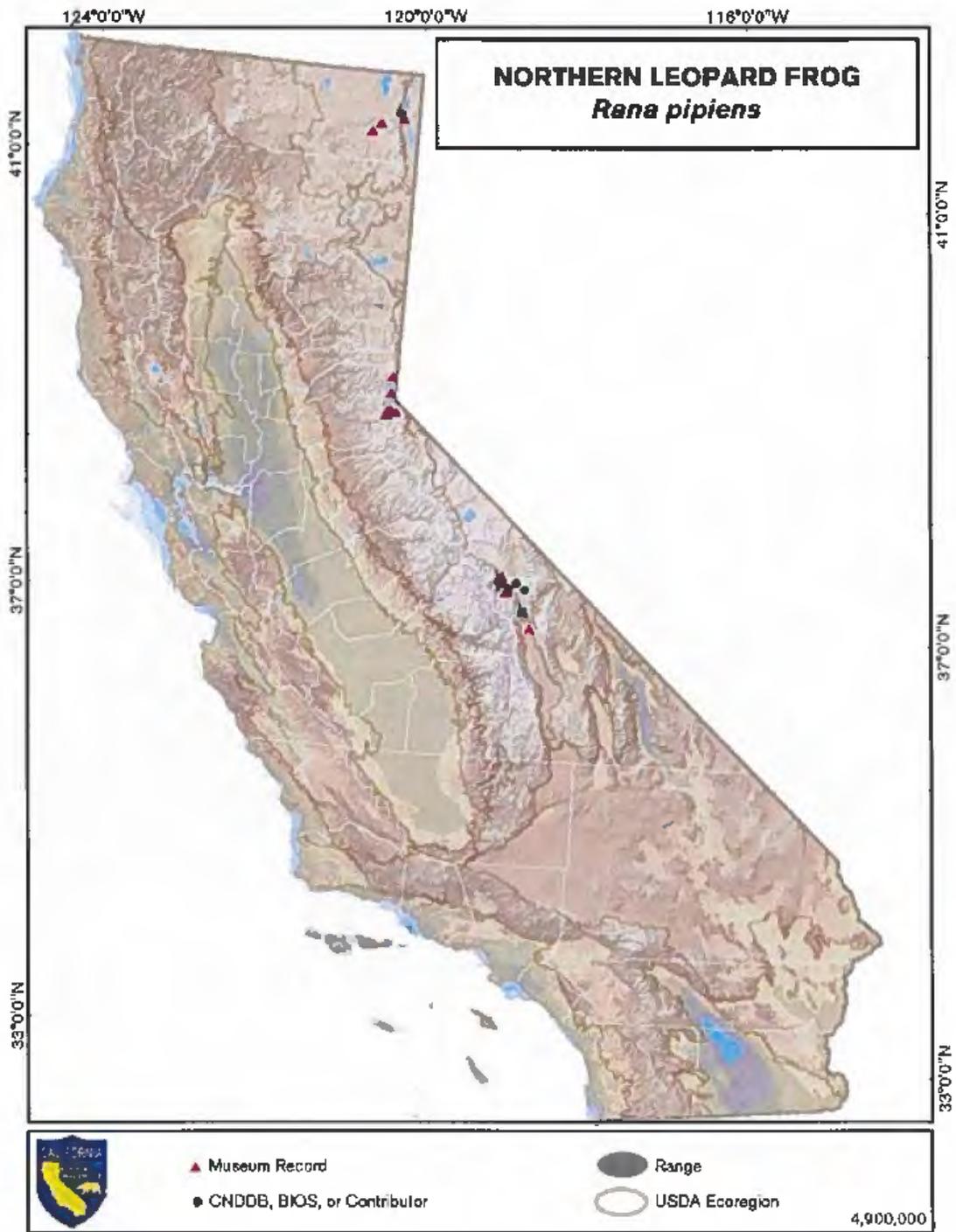


PHOTO ON PREVIOUS PAGE: Northern leopard frog, Washington County, Utah. Courtesy of William Flaxington.

(*R. yavapaiensis*) and the Rio Grande leopard frog (*R. berlandieri*), have dorsolateral folds that are discontinuous and angle inward posteriorly. In addition, both are yellow ventrally. The Cascades frog (*R. cascadae*) has more numerous, small, irregular black dots that are not ringed in white.

Taxonomic Relationships

The taxonomic history of the leopard frog species complex, and *Rana pipiens* in particular, is complicated (Hillis 1988) and remains incompletely understood. The name *R. pipiens* previously included all members of the leopard frog complex from Canada south to Panama, including *R. yavapaiensis*, also native in California, and the introduced *R. berlandieri*. However, this concept of a single wide-ranging leopard frog species changed in the last several decades, and over a dozen species are recognized at present. The current taxonomy of the *R. pipiens* complex was initially based on variation in morphology and vocalizations (Pace 1974). Subsequent work including molecular analyses recognized several additional taxa and clarified relationships among the contained species (Platz and Meham 1979, Hillis et al. 1983, Platz and Frost 1984, reviewed by Hillis 1988).

Frost et al. (2006a) recommended placing this species and many other North American ranids in the genus *Lithobates*, although this proposal and the analyses that support it are controversial (Crother 2009, Frost et al. 2009a, Pauly et al. 2009). We retain the traditional taxonomy here to maintain stability pending further analyses.

Life History

No life history data for California populations have been published. Because *Rana pipiens* in California are a mixture of introduced and presumably native populations (see the "Distribution" section) and live on the extreme western edge of the species' range, we are reluctant to use information from more easterly populations as a proxy for those that occur in California. In Colorado, breeding occurs during the

first spring nights that have relatively "mild" temperatures near or above freezing (Corn and Livo 1989), and this presumably is also the case in California. Tadpoles are present through the summer months and are not known to overwinter, suggesting a late summer or fall metamorphosis. Further east, adults and juveniles are known to range far from water and breeding sites (Dole 1971), although it is unknown if this also characterizes California populations. Range-wide, *R. pipiens* is a generalist predator, feeding on a wide variety of arthropods and small vertebrates (Knowlton 1944, Linzey 1967, Harding 1997), and this presumably also characterizes the species in California.

Habitat Requirements

Despite the paucity of records from California, this species is known from a variety of habitats, including small streams, rivers, and lakes (Storer 1925, Stebbins 1951, Jennings and Hayes 1994a). *Rana pipiens* occupies a wide variety of habitat types throughout its range, so we are hesitant to speculate on microhabitat requirements in California. Generally, the species hibernates underwater and requires aquatic habitats that do not freeze solid during winter (Emery et al. 1972, Licht 1991), and this presumably is also the case for California populations. Nearby damp upland habitat is utilized for foraging during the active season (Dole 1967). The species has been found in a variety of open grassy areas and meadows, although heavily grazed areas and cultivated fields do not appear to be suitable (Pope et al. 2000). In the Midwestern United States, the presence of quality upland foraging habitat seems to affect the abundance of this species. When grasslands were restored around suitable pond-breeding habitat, the density of frogs increased markedly (K. Mierzwa, pers. comm., in Pope et al. 2000).

Distribution (Past and Present)

Outside of California, *Rana pipiens* ranges widely across North America, from Nova Scotia and Newfoundland, Canada, west to Washing-

ton and Nevada. In California, *R. pipiens* populations that may be native are known from Modoc and Siskiyou Counties, the Lake Tahoe basin, and the upper Owens Valley (Jennings and Fuller 2004), although some workers question whether the latter two regions constitute natural, as opposed to purely introduced, populations (S. Barry, pers. comm.). Numerous introductions have occurred throughout the state, including some within the putative native range. The vicinity of Fallen Leaf Lake in the Lake Tahoe Basin is one such example (Bryant 1917). It is also possible that putatively native populations of this frog are all the result of human introductions, and determining their status is an important research priority. The upper Owens Valley supports tiger salamander populations that were recently shown to be introduced (Johnson et al. 2010), demonstrating that similarly distributed nonnative species have been established in this region. The tiger salamander introductions occurred as a consequence of the fishbait industry (Riley et al. 2003), which also sometimes sells leopard frog tadpoles and adults.

We are not aware of any additional recent records in California beyond those reported by Jennings and Hayes (1994a), though an unverified sight record of a "spotted frog" in Surprise Valley, Modoc County, California, could have been *R. pipiens*. However, the circumstances and description of this frog make it more likely that it was *R. pretiosa*, another California Species of Special Concern (see that species account for additional information).

Trends in Abundance

Trends in abundance for California populations of *Rana pipiens* are difficult to interpret because of the uncertainty regarding which populations are native or introduced. However, assuming that historical California populations are native, severe declines have clearly occurred. We are aware of only scattered sight records for the species over the last two decades. Jennings and Hayes (1994a) reported two relatively recent sight records in the early 1990s from Siskiyou

and Inyo Counties. Macey and Papenfuss (1991a) reported that leopard frogs occurred on the east side of the White Mountains below Boundary Peak, though they failed to detect the species in follow-up surveys (T. Papenfuss, pers. comm.). More recent surveys of historical localities in the Owens River also did not detect this species and found that much of the habitat currently appears to be unsuitable (Becker and Henderson 2010). We are not aware of any presumed-native populations of this species occurring in the state since these records. Elsewhere in its range, *R. pipiens* has undergone severe declines and localized extirpations, particularly in the western parts of the United States (reviewed by Rorabaugh 2005).

Nature and Degree of Threat

Habitat modification is probably the most important threat for *Rana pipiens* in California. *Rana pipiens* forages in upland habitat having moderately tall vegetation with a moist substrate. Livestock grazing in these habitats tends to reduce vegetation height, which leads to drying of the substrate, apparently rendering this habitat unsuitable for the frog. It is likely that this process contributed to the declines observed in both the Owens Valley and the Modoc Plateau areas where most California records for *R. pipiens* are concentrated. Changing hydrology elsewhere in the range has led to the extirpation of some local populations (Corn and Fogleman 1984). Given that California populations are at the western range limit of the species, projected climate changes may have a strong effect in the state. Current models project warmer summer and winter temperatures, decreases of 8–21% of annual precipitation, and a 34% decrease in snowpack (PRBO 2011). Taken together, these climate projections indicate that the moist soil and wetland complexes favored by this species will probably decrease in the Great Basin of California, further reducing the already sparse habitat for this species.

Some studies have detected significant negative impacts from pesticides on *R. pipiens*,

although the importance of this threat in nature is not well understood. In other parts of their range, *R. pipiens* are known to be sensitive to herbicides and pesticides used in agriculture (Relyea 2008, Relyea and Jones 2009), and mixtures of these chemicals can result in 99% mortality rates (Relyea 2008). However, the evidence on this topic is complex and dependent on the specific chemicals tested. A popular herbicide consisting of a mixture of glyphosate and POEA (commonly marketed under the commercial name Roundup®) is one such example. Some studies have found limited impacts from these chemicals and concluded that direct mortality in wild populations from this herbicide is unlikely (e.g., Wojtaszek et al. 2004), while other studies have found very strong direct lethal effects (e.g., Relyea 2005b). When direct lethal effects were not found, several studies demonstrated that chemical contaminants can have lethal impacts when combined with other stressors (e.g., predator cues; Relyea 2005a) or sublethal detrimental effects such as decreased immune system functionality (Christin et al. 2003, Gilbertson et al. 2003, Rohr et al. 2008). These seemingly unpredictable effects of agrochemicals may depend on specific populations and conditions in a local area (Relyea 2005b). Although these results are both complex and sometimes contradictory, substantial evidence exists that environmental contaminants are likely to have significant impacts on *R. pipiens* and other amphibians in California (e.g., Davidson et al. 2002, Davidson 2004).

Other potential threats to *R. pipiens* include introduced exotic bullfrogs and predatory fishes, and extensive habitat modification associated with agriculture (Hayes and Jennings 1986).

Status Determination

Rana pipiens' small range in California coupled with severe declines drives the high score for this species. None of these threats are currently being reversed, so it is reasonable to expect additional declines in the future, assuming that native populations still exist in California.

Rana pipiens is sensitive to localized extirpation due to drought (Corn and Folgeman 1984), and the expected increase in temperature and decrease in precipitation due to climate change are likely to have additional negative impacts. The combination of these factors justifies a Priority 1 status.

Management Recommendations

The development of an effective management strategy will largely depend on finding remnant populations in the state, carrying out research on the life history of those specific populations to determine their habitat needs, and then taking a proactive management and habitat restoration approach to recover it in its native range. A key first step with any remnant population is to determine whether it is native or introduced. Researchers can most easily accomplish this using DNA markers, and we recommend that larval tail tips be collected for any population that is discovered. A considerable amount of phylogenetic work, particularly using mitochondrial DNA markers, has been published for this species, and straightforward DNA sequencing of California animals should allow them to be placed into a phylogenetic context with other *Rana pipiens* from across the species' range. This approach was used by Johnson et al. (2010) and demonstrated that potentially native populations of tiger salamanders (*Ambystoma tigrinum*) were in fact nonnative introductions. If native populations of *R. pipiens* are found, the habitat supporting them should be protected in order to reduce potential threats such as nonnative predators, agricultural disturbance, grazing, off-highway vehicle use, pesticide applications, and changes to local hydrology. If nonnative populations are found, managers should evaluate their potential to spread and pose a threat to other native taxa. In certain cases, removal programs could be effective at mitigating threats posed by nonnative *R. pipiens*.

Monitoring, Research, and Survey Needs

Comprehensive surveys of historical localities as well as the Modoc Plateau area, including the

Goose Lake Basin and the Warner Mountains, should be conducted to determine whether any viable populations persist in California and to identify areas of potential habitat for ongoing surveys. The most recent records for this species come from the vicinity of Owens Valley, and all drainages flowing into the valley should be carefully surveyed. It is critically important that tissue samples be collected from any extant populations that are found so that frogs can be genetically characterized with respect to their introduced or native status.

Given our current lack of information about the life history of this species in California, basic ecological research is a key priority for any native populations that remain in the state.

Information about habitat preferences and requirements, demography, and timing of key life history events would all improve our ability to conserve remnant populations of *Rana pipiens*.

Finally, if remnant populations are found, multi-locus microsatellite or single nucleotide polymorphism DNA data should be analyzed to estimate the effective population size and potential connectivity with other remaining populations. If populations are determined to be native, small, and genetically isolated, *R. pipiens* could be a prime candidate for human-mediated translocations to establish new populations in currently unoccupied habitat patches.