DOCKET
07-AFC-5
DATE MAR 15 2010
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STATE OF CALIFORNIA

Energy Resources Conservation and Development Commission

In the Matter of:

APPLICATION FOR CERTIFICATION
FOR THE IVANPAH SOLAR
ELECTRIC
GENERATING SYSTEM

DOCKET NO. 07-AFC-5

INTERVENOR CENTER FOR BIOLOGICAL DIVERSITY

ADDITIONAL TESTIMONY FOR TOPICS TO BE HEARD IN MARCH 22, 2010, UPDATED EXHIBIT LIST, ADDITIONAL EXHIBITS, AND PROOF OF SERVICE

March 15, 2010

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Pursuant to the Notice of Additional Evidentiary Hearing issued March 11, 2010, Intervenor Center for Biological Diversity (the "Center") provides this Additional Testimony for Topics to be Heard on March 22, 2010.

All of the testimony submitted concurrently was prepared by the testifying expert. All experts sponsored by the Center, Mark C. Jorgensen, Ileene Anderson, and Bill Powers, will be available to testify telephonically on March 22, 2010.

A List of the *Additional* Exhibits and copies of the additional exhibits are also being submitted with this testimony.

ADDITIONAL EXHIBIT LIST

(Exhibits Numbers 900-940 were provided along with CBD's Opening and Rebuttal Testimony and were entered into the record during the earlier hearings in this matter; below is a list of the Additional Exhibits submitted with Additional Testimony for the March 22, 2010 hearing)

Doc. No.	Author and title
941	Additional Testimony of Mark C. Jorgensen
942	Additional Testimony of Ileene Anderson
943	Kochert, M. N., K. Steenhof, C. L. Mcintyre and E. H. Craig. 2002. Golden Eagle (*Aquila chrysaetos*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.oca.ucsc.edu/bna/species/684(this document was referenced by Energy Commission staff in rebuttal testimony ISEGS (07-AFC-5), Exhibit 305 at pg. 20, but not submitted to the record)
944	Marzluff et al. 1997 (this document is referenced in Kochert)
945	Gowan and Berry 2010. In DTC Symposium 2010 Abstracts at pg. 14-15.
946	Wessells, S.M., and Schwarzbach, S.E., 2010, The Heat Is On: Desert Tortoises and Survival: U.S. Geological Survey General Information Product 98, DVD movie, 30 minutes. Available at http://pubs.usgs.gov/gip/98/ and submitted as a transcript (USGS 2010).
947	SupplementalTestimony of Bill Powers

Dated: March 15, 2010

Respectfully submitted,

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STATE OF CALIFORNIA

Energy Resources Conservation and Development Commission

In the Matter of: APPLICATION FOR CERTIFICATION FOR THE IVANPAH SOLAR ELECTRIC GENERATING SYSTEM	DOCKET NO. 07-AFC-5

INTERVENOR CENTER FOR BIOLOGICAL DIVERSITY

Additional Testimony of Mark C. Jorgensen for Additional Evidentiary Hearing Scheduled for March 22, 2010

Re: Impacts to Bighorn Sheep from the Proposed Ivanpah Solar Electric Generating System from

Docket 07-AFC-5

Statement

I have reviewed the Applicant's Exhibit 88 which discusses a reduced project alternative proposal called the "Mitigated Ivanpah 3" project proposal.

This new proposal fails to address any issues regarding the lack of identification and analysis of potential impacts to bighorn sheep which I discussed in my early testimony regarding the FSA. Without that information it is impossible to assess the extent of the impacts to the bighorn population in this area from the proposed Project or this new proposal including the potential loss of foraging habitat on the alluvial fan and the loss of connectivity between the ranges.

The changes to the proposed project in this somewhat smaller project design do not make up for the failure to obtain and consider basic information about the use of the area by bighorn and the likely impacts to bighorn from the project.

Through this additional testimony, I also re-adopt my previous testimony.

Declaration of Mark C. Jorgensen

Re: Impacts to Bighorn Sheep from the Proposed Ivanpah Solar Electric Generating System

Docket 07-AFC-5

I, Mark C. Jorgensen, declare as follows:

1) I am currently retired. I recently retired from my position as State Park Superintendent at Anza-Borrego Desert State Park, a position I held for 8 years.

2) My relevant professional qualifications and experience are set forth in the resume provided to the Commission with my opening testimony. The attached additional testimony and my resume and earlier testimony are incorporated herein by reference.

3) I prepared the additional testimony attached hereto and incorporated herein by reference, relating to the impacts of the Project on bighorn sheep.

4) I prepared the additional testimony attached hereto and incorporated herein by reference relating to the proposed Project in the Ivanpah Valley in San Bernardino County.

5) It is my professional opinion that the attached testimony are true and accurate with respect to the issues that they address.

6) I am personally familiar with the facts and conclusions described within the attached testimony and if called as a witness, I could testify competently thereto.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Dated: March 12, 2010

At: Borrego Springs, CA

Signed: Mark C. Jorgensen

STATE OF CALIFORNIA

Energy Resources Conservation and Development Commission

In the Matter of: APPLICATION FOR CERTIFICATION FOR THE IVANPAH SOLAR ELECTRIC GENERATING SYSTEM	DOCKET NO. 07-AFC-5

INTERVENOR CENTER FOR BIOLOGICAL DIVERSITY

Additional Testimony of Ileene Anderson for Additional Evidentiary Hearing Scheduled for March 22, 2010

Re: Impacts to Sensitive Wildlife from the Proposed Ivanpah Solar Electric Generating System

Docket 07-AFC-5

Additional Testimony

I have reviewed the Applicant's Exhibit 88 which discusses a new "reduced project" alternative proposal—the so-called "Mitigated Ivanpah 3" project proposal. This proposal fails to address many of the issues regarding biological impacts raised in my earlier testimony. It is my professional opinion that the newly proposed project design would still have major impacts to the biological resources of the Ivanpah Valley, affecting many sensitive plant and wildlife species by eliminating a broad expanse of relatively undisturbed Mojave Desert habitat (FSA at 6.2-95) and significantly fragmenting the remaining habitat. Through this additional testimony, I re-adopt my previous testimony on the biological impacts of the project and the inadequacy of the analysis provided in the FSA and other documents and I provide additional recent data that regarding the impacts of the proposed project was not available at the time of my previous testimony or rebuttal.

Wildlife

Golden Eagle

In my opinion there is still insufficient evidence before the Commission regarding the number of golden eagles that could be impacted by the proposed project. The impact to the foraging area for the golden eagle still remains problematic, because the golden eagle is a fully-protected species under state law. Even for the two known pairs of nesting golden eagles in the Clark Mountains, there is insufficient evidence to show that the proposed project will not "take" golden eagles by destroying and disturbing foraging areas and other important eagle-use areas.[1] For example, the project as proposed will impact foraging areas. Despite staff's assertion that golden eagle's "breeding season home range of 20-33 km^2 (Kochert et al. 2002)"[2] that citation relies on an earlier study, Marzluff et al. (1997)[3] which identifies the breeding season home range between 190 to 8,330 ha (0.7 to 32.2 square miles) with core usage during the breeding season of 30 to 1,535 ha (0.12 to 6 square miles) in Idaho which, seasonally, is a more productive habitat than the Mojave desert. Staff's analysis identifies two pairs of golden eagles nesting within 8 miles of the proposed project site. Therefore, the proposed project area, for both the initial proposal and the new so-called "mitigated" proposal, currently likely includes breeding season home ranges for both golden eagle pairs, and likely breeding season core area for at least one pair of golden eagles. Absent necessary surveys on the breeding season home range and core usage habitat for golden eagles on the site, I believe there will likely be an impact on the foraging of the adjacent golden eagles and therefore an impact on breeding success.

Moreover, the literature shows that golden eagles generally avoid "disturbed areas"[4]. Because the proposed project site is likely within breeding season core areas and/or home ranges of the two eagle pairs, at minimum the proposed project will likely cause a reduction in use of important forage areas and other important eagle-use areas and may cause "take" of the golden eagle pairs already documented in the area. None of the impacts to the know golden eagle pairs have been adequately identified or analyzed in the FSA or other documents in this proceeding.

Additionally, shrubland fragmentation of eagle foraging habitat is a documented impact[5] because it affects their prey base. The cumulative impacts section fails to include an analysis of the cumulative fragmentation of the golden eagles' breeding season home ranges and core areas.

Migratory Birds and other Birds

I re-adopt my earlier testimony and remain concerned that no studies of the use of this area by migratory birds were undertaken and the record is inadequate to identify and analyze the potential impacts to migratory bird species and other species. The revised proposed project proposal does not change the fact that these and other impacts have not yet been fully identified or analyzed.

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[1] The Bald and Golden Eagle Protection Act, 16 USCS § 668, prohibits take of golden eagles without a permit. The new revisions to the regulations provide definitions many useful definitions. 50 C.F.R. § 22.3,

[2] Energy Commission staff's rebuttal testimony ISEGS (07-AFC-5) Exhibit 305 at pg. 20.

[3] Exh. 943, Marzluff et al. 1997.

[4] Ibid

[5] Ibid

Moreover, since the hearings were closed in January, I have continued to research the potential impacts of the proposed project on migratory birds and other birds as described by McCrary (Exh. 912). Unfortunately, there has been a lack of follow up on this issue in the published literature which is surprising. Generally when a significant impact has been identified at a project site, follow-up studies are done at that site or other similar sites. However, it appears that no follow-up studies were done at the SEGS plant nor have such studies been undertaken at the existing plants in Spain or Israel or if studies have been done they have not been published or made available to the public.

It is clear from the McCrary study that the proposed project may lead to the "take"[6] of migratory birds when they are found in the project area by burning, singeing and direct collision with heliostats. As I noted in my earlier testimony, the information from the partial list provided in the FSA (at pg. 6.2-15) and references that "Mojave creosote bush scrub at the power plant site provides foraging, cover, and/or breeding habitat for migratory birds, including a number of special-status bird species confirmed to be present at the site (golden eagle, burrowing owl, loggerhead shrike, Crissal thrasher and Brewer's sparrow)." FSA at pg. 6.2-45. Therefore, if the Commission decides to approve the proposed project at any site and in any configuration (which I do not believe would be prudent), at minimum, I believe that the conditions of certification must include monitoring for impacts to all bird species, monitoring for migratory birds during the migration seasons, and a requirement that operations be shut down when migratory birds are found to be in the project area.

Desert Tortoise

Since my previous testimony, additional data on the success of translocation of desert tortoise has become available. Gowan and Berry[7] reported at the Desert Tortoise Council Symposium on February 27, 2010, results of monitored desert tortoises on the the Fort Irwin translocation site. An overall 45% mortality of translocated desert tortoise has been documented since the translocation occurred 2008 and the last surveys in 2009.

In addition, the presence of mycoplasmosis which causes the usually fatal Upper Respiratory Tract Disease (URTD) has increased in the translocated animals, all of which were disease-free when moved yet by 2009, 9.2% of the remaining translocated tortoises were positive or suspect positive for the disease. These data indicate that translocation is not an effective strategy for mitigating impacts to desert tortoise. In fact translocation may cause additional harm to existing populations by introducing disease through translocated tortoises as vectors or by exposing translocated tortoises to diseased tortoises in the host area.

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[6] The Migratory Bird Treaty Act, 16 USCS § 703. prohibits take of migratory birds without a permit.
[7] Exh. 944, Gowan and Berry 2010. In DTC Symposium 2010 Abstracts at pg. 14-15.

The U.S. Geological Survey has recently released an informative video on desert tortoises entitled “The Heat Is On: Desert Tortoises and Survival”[8]. In that video a BLM wildlife biologist comments on the siting of renewable energy projects stating "So, siting of the energy projects is crucial, the *first priority being to put them on lands already disturbed or where there is no tortoise habitat*, and the *second being to not fragment large areas that are a uniform block of habitat*." (Emphasis added. USGS transcript at pg. 39). It is my opinion that the ISEGS project fails follow either of the priorities for siting as identified by the BLM wildlife biologist.

Conclusions

I would like to summarize my conclusions as follows:

- Impacts to golden eagles still need to be adequately identified and analyzed based on the best available science.
- Impacts to migratory birds and other birds still need to be adequately identified and analyzed based on the best available science.
- Translocation of desert tortoise is not an effective mitigation strategy and will likely cause additional harm to existing populations.
- The ISEGS project location is not appropriately sited as prioritized by BLM.

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[8] Exh. 945, Wessells, S.M., and Schwarzbach, S.E., 2010, The Heat Is On: Desert Tortoises and Survival: U.S. Geological Survey General Information Product 98, DVD movie, 30 minutes. Available at http://pubs.usgs.gov/gip/98/ and submitted as a transcript (USGS 2010).

Declaration of Ileene E. Anderson

Re: Impacts to Wildlife and Plants from the Proposed Ivanpah Solar Electric Generating System

Docket 07-AFC-5

I, Ileene Anderson, declare as follows:

1) I am currently a biologist for the Center for Biological Diversity. I have worked with the organization for five years.

2) My relevant professional qualifications and experience are set forth in the resume and testimony submitted for my original testimony on 12-17-09 and are incorporated herein by reference.

3) I prepared this additional testimony attached hereto and incorporated herein by reference, relating to the impacts of the new "reduced project" alternative on wildlife and plants.

4) I prepared the testimony attached hereto and incorporated herein by reference relating to the proposed new "reduced project" alternative in the Ivanpah Valley in San Bernardino County.

5) It is my professional opinion that the attached testimony is true and accurate with respect to the issues that is addressed.

6) I am personally familiar with the facts and conclusions described within the attached testimony and if called as a witness, I could testify competently thereto.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Dated: 3/15/10 Signed:

At: Los Angeles, California

Golden Eagle Aquila chrysaetos
Order FALCONIFORMES
Family ACCIPITRIDAE
Issue No. 684
Authors: Kochert, M. N., K. Steenhof, C. L. Mcintyre, and E. H. Craig

Recommended Citation

Kochert, M. N., K. Steenhof, C. L. Mcintyre and E. H. Craig. 2002. Golden Eagle (Aquila chrysaetos), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.oca.ucsc.edu/bna/species/684

doi:10.2173/bna.684

Introduction

Adult Golden Eagle, Goshute Mountains, Nevada, October 1999.

Figure 1. Distribution of the Golden Eagle in North America.

The Golden Eagle inhabits a wide range of latitudes throughout the Northern Hemisphere and uses a variety of habitats ranging from arctic to desert. Rare in the eastern half of North America, it is most common in the West near open spaces that provide hunting habitat and often near cliffs that supply nesting sites. Northern breeders migrate thousands of kilometers to wintering grounds; southern pairs tend to be resident year-round. As one of North America's largest predatory birds, this eagle has been prominent in human lore and culture, inspiring awe, reverence, and sometimes fear and hatred. Humans kill Golden Eagles both intentionally and accidentally by trapping, shooting, poisoning, and electrocution; at the same time, urbanization, agricultural development, and wildfires encroach on this eagle's traditional shrub-steppe foraging habitat. The species persists, but some U.S. nesting populations may be declining. In the twenty-first century, humans will determine the fate of this species and its habitat.

The Golden Eagle has astonishing speed and maneuverability for its size and uses a wide variety of hunting techniques to capture prey, including soaring, still-hunting from a perch, and low contouring flight. Although capable of killing large prey such as cranes, wild ungulates, and domestic livestock, this species subsists primarily on rabbits, hares, ground squirrels, and prairie dogs. Most do not acquire a nesting territory until they are at least 4 years old, after they have molted into Definitive plumage. Once an individual establishes a territory, it tends to stay there, defending an area of approximately 20–30 square kilometers from conspecifics. A territory may contain up to 14 nests, which a pair maintains and repairs as part of their courtship. The nesting season is prolonged, extending more than 6 months from the time eggs are laid until young reach independence. A typical Golden Eagle raises an average of only 1 young per year and up to 15 young over its lifetime. Pairs commonly refrain from laying eggs in some years, particularly when prey is scarce. The number of young that Golden Eagles produce each year depends on a combination of weather and prey conditions. The black-tailed jackrabbit (*Lepus californicus*) is a key prey species throughout much of the range, and eagle reproductive rates fluctuate with jackrabbit population cycles.

Although much information on Golden Eagle life history comes from studies in Europe (Watson 1997), important North American research has provided insights about developmental behavior (Ellis 1979), survival rates (Hunt 2001, Harmata 2002), and migration (Brodeur et al. 1996, Craig and Craig 1998, CLM). Much information about Golden Eagle ecology comes from southwestern Idaho, where research on this species has been conducted in and near the Snake River Birds of Prey National Conservation Area (NCA) for more than 35 consecutive years, beginning with Hickman (1968). NCA studies have focused on diet (Beecham 1970, Kochert 1972, Steenhof and Kochert 1988), food consumption/energetics (Collopy 1980, 1983a, 1983b), parental care and feeding ecology (Collopy 1984), long-term reproduction (Steenhof et al. 1983, 1997), dispersal (Steenhof et al. 1984), home-range characteristics (Dunstan et al. 1978, Marzluff et al. 1997), and effects of habitat alterations on nesting populations (Steenhof et al. 1997, Kochert et al. 1999). Despite the wealth of information from this one study area, much remains unknown about populations in other parts of this eagle's range, particularly Alaska and western Canada. New work in these areas is shedding light on Golden Eagle ecology and may suggest differences between northern migratory populations and southern resident ones.

Distinguishing Characteristics

Juvenile Golden Eagle, Wasatch Mountains, Utah, October 2003.

Golden Eagle Sub-adult II, Goshute Mountains, Nevada, October 1998.

Golden Eagle Sub-adult I, Goshute Mountains, Nevada, September 1999.

Adult Golden Eagle, Wasatch Mountains, Utah, July 2003.

From Clark and Wheeler 1987, Watson 1997, and others as noted. Large, dark-brown raptor with long, broad wings. Length ranges from 70 to 84 cm; wingspan 185–220 cm. Mass of males 3,000–4,475 g; females 3,940–6,125 g (see Measurements, below). Adults (Definitive Basic plumage) entirely dark brown except for golden rear crown, nape, and sides of neck; gray bars on tail; and rear underparts and upper wing-coverts often paler than rest of feathers, the latter forming a tawny diagonal bar on upper wing; visible both on flying and perched birds. Some individuals also have small white "epaulet" at upper end of scapulars (Spofford 1961). Additionally, feathered tarsi vary from almost white to dark brown (Jollie 1947). Bill and talons black-tipped, fading to slate gray near the base. Cere, orbital ring, and feet yellow. Sexes similar in appearance, although females average larger than males. Suspected sexual differences in pattern and number of bands on tails of adults (Wheeler and Clark 1995) not verified in subsequent studies; not a reliable method for distinguish-ing sexes (W. Clark pers. comm.). Plumages the same throughout the year, but feathers dark, shiny, and smooth on edges when plumage fresh, while old feathers appear faded, more brownish, and frayed on edges.

Adult plumage differs from Juvenal and subsequent subadult plumages. Juvenal plumage (0–1 yr) distinguished from adults by much darker (unfaded) color, and by white at base of secondaries and inner primaries (Brown and Amadon 1968). These white areas form a white “window” at carpal joint of wing, visible in flight from above and below. Occasionally some upper wing-coverts also white (Johnsgard 1990). Amount of white varies individually, and a few juveniles lack white on wing entirely (Jollie 1947). Rectrices have wide, black band at tip with narrow, white terminal band. White terminal band wears away quickly as feathers age. Basal two-thirds of tail is usually white, although some dark flecks, particularly near the dark band, may occur (Jollie 1947). Amount of white in tail and wing gradually diminishes with each progressive molt. Adult plumage usually acquired in fifth summer, but older individuals may retain white in tail. Physiological condition of individual can influence rate of molt (Jollie 1947, T. and E. Craig unpubl.). See Appearance, below, for more detail.

Golden Eagles most often seen soaring or gliding with wings held in slight dihedral. Flapping flight consists of 6–8 deep wing-beats interspersed by short glides lasting several seconds.

Distinguished from most other North American raptors by combination of large size and all or mostly dark-brown coloration. However, confusion possible with immature Bald Eagle (*Haliaeetus leucocephalus*), which has similar size and coloration. Most striking differences involve distribution of white in plumage. Immature Bald Eagle has irregular white/tawny areas on much of body (especially underparts) as well as on under wing (coverts, flight feathers, axillaries) and undertail surfaces, while Golden Eagle lacks extensive white on body and has white on undersurface of wing restricted to base of flight feathers and white on undersurface of tail cleaner and more sharply divided from wide, dark, terminal band. Immature Bald Eagle also has darker (blackish) bill and cere. With experience, structural and behavioral differences also useful in distinguishing these species. In flight, Golden Eagle’s head does not project more than half the length of the tail (head projects more than half the length of tail in Bald), and Golden Eagle has longish outer secondaries, which produce a noticeable round bulge on the trailing edge of the wing (trailing edge straighter in Bald Eagle). At close range, Bald Eagle has naked tarsi (feathered in Golden Eagle; Clark and Wheeler 1987). Golden Eagle wing-beats also somewhat shallower than those of Bald Eagle, and wings held flatter on soaring Bald Eagle than on soaring Golden Eagle (Dunne et al. 1988).

Soaring Golden Eagle could be confused with the California Condor (*Gymnogyps californianus*) or Turkey Vulture (*Cathartes aura*). Condor larger with white or mottled under wing-coverts. Vulture smaller, with small head, underwing black in front and silver on trailing edge; holds wings in a dihedral and soars with rocking motion. For more information on Golden Eagle identification, see Wheeler and Clark 1995, Clark and Wheeler 1987, and Dunne et al. 1988 .

Distribution

Figure 1. Distribution of the Golden Eagle in North America.

The Americas

Breeding Range

Mainly w. North America (west of 100th meridian) from Alaska south to central Mexico (Fig. 1) with small numbers in e. Canada and a few isolated pairs in e. U.S.

Alaska. From north slopes of Brooks Range (north to 69°30'N in the east and to the Lisborne Peninsula in the west) south throughout most of Alaska (including e. Aleutians west to Unalaska), except rare on Kodiak I. and in s.-coastal and se. Alaska (Armstrong 1995, Young et al. 1995, Am. Ornithol. Union 1998, B. Ritchie unpubl.).

Canada. From southern coast of Beaufort Sea (east to Coronation Gulf; Poole and Bromley 1988) south throughout w. Canada to U.S. border. Absent from coastal portions of British Columbia (except se. Vancouver I. and Fraser Lowlands; Campbell et al. 1990), and much of Saskatchewan (except Lake Athabasca, Foster Lakes, Lower Churchill River, and S. Saskatchewan River regions; Smith 1996). Breeding records scattered for Northwest Territories, Nunavut, se. Yukon, ne. British Columbia, n. and all but southern portions of e. Alberta, and much of Saskatchewan. Also discontinuous nesting in e. Canada in nw. Ontario south of Hudson Bay (De Smet and James 1987), n. Quebec, n. Labrador, and se. Quebec especially on Gaspé Peninsula (Kirk 1996, Robert 1996, Brodeur and Morneau 1999). May breed in Manitoba, s. Ontario, s. Quebec (Godfrey 1986), New Brunswick, and Nova Scotia (Erskine 1992), but breeding records unknown or very few in these areas (De Smet 1987, K. D. De Smet pers. comm.).

United States. In West, from Canadian border south through Washington, Idaho, and Montana to Mexican border and east to sw. North Dakota (Stewart 1975, Ward et al. 1983), w. South Dakota (Peterson 1995), panhandle of w. Nebraska (Wingfield 1991, Sharpe et al. 2001), n.-central and se. Colorado (Barrett 1998), western panhandle of Oklahoma (Baumgartner and Baumgartner 1992), panhandle of Texas (Swepston et al. 1984, Texas Breeding Bird Atlas [BBA] 1987–1992 unpubl.), e. New Mexico (Hubbard 1978), and the Trans-pecos of Texas. Within this area, rare or absent west of Cascades in Washington (except Olympic Mtns.) and Oregon (except some southern valleys and some higher portions of Cascades), the immediate coast and flat portions of Central Valley of California, the Salton Sea, the lower Colorado River, desert regions of se. California and sw. Arizona, agricultural portions of e. Washington, and mountains of the panhandle of Idaho (Bruce et al. 1982, Gilligan et al. 1994, Small 1994, Smith et al. 1997, Stephens and Sturts 1997, Arizona BBA 1993–2000 unpubl.). Patchy nesting in w. Kansas (Weigel 1993), and suspected nesting in central S. Dakota west of the Missouri River (Peterson 1995). Breeds irregularly in w. Nebraska (Sharpe et al. 2001).

In East, 2 nesting pairs in Maine (Todd 1989, Maine Dept. Inland Fisheries and Wildlife [DIFW] unpubl.) and 1 each in Tennessee and nw. Georgia (B. Anderson and T. Touchstone pers. comm.); both the result of re-introductions (see Conservation and management: management, below).

Mexico. N. Baja California and highlands of central Mexico, including ne. Sonora (Russell and Monson 1998), and from Chihuahua and Coahuila south to San Luis Potosí, Guanajuato, and

Queretaro (Howell and Webb 1995, Instituto Nacional de Ecologia 1999). Suspected nesting in s. Baja California (Rodríguez-Estrella et al. 2002). May be extirpated as breeding in Guanajuato and Queretaro (E. Inigo-Elias pers. comm.).

Winter Range

Winters in sw., s.-coastal, and se. Alaska (rare; Armstrong 1995), and from southernmost British Columbia, s. Alberta, and s. Saskatchewan, south throughout breeding range in w. U.S. and Mexico, and in areas of lower elevations not occupied during breeding season west to Pacific Coast (rarely), south to s. Baja California and nw. Sonora and Hildago, Mexico (Howell and Webb 1995, Am. Ornithol. Union 1998, Russell and Monson 1998), and (regularly) east to central Dakotas, central Kansas, w. Oklahoma, and w. Texas (Sauer et al. 1996). Also winters very locally east throughout e. U.S. north to Great Lakes and mid-Atlantic states (e.g., n. Wisconsin, n. Pennsylvania, se. New York, central Massachusetts, and se. Maine) and south to Gulf Coast and Florida Panhandle (Millsap and Vana 1984, Mitchell and Millsap 1990, Robbins 1991, Robertson and Woolfenden 1992, Veit and Petersen 1993, Am. Ornithol. Union 1998, Levine 1998, McWilliams and Brauning 2000, Turcotte and Watts 1999, Maine DIFW unpubl.), with rare reports south to Florida Keys (Robertson and Woolfenden 1992, Am. Ornithol. Union 1998). Emigrates from northern latitudes and higher elevations in winter, but can winter at >66°N latitude whenever sufficient prey is available (Kessel 1989). Rare in Kuskokwim River drainage and Alaska and Brooks Ranges, AK, and Mackenzie Mtns., Northwest Territories (Fleck et al. 1987, Petersen et al. 1991, T. and E. Craig unpubl., CLM).

Outside The Americas

Holarctic distribution spanning latitudes from approximately 20 to 70°N, with scattered populations farther south (Orta 1994, Watson 1997, Snow and Perrins 1998). Occurs throughout Europe, Asia, and n. Africa. Northern extent of range stretches from n. Europe (n. British Isles and Scandinavia) to Kola Pen-insula and on to e. Siberia and Kamchatka Peninsula. Breeds in s. Europe from Iberian Peninsula to Turkey and much of Asia south to Israel, Saudi Arabia, Yemen, Oman, Afghanistan, the Himalayas, s. China, Korea, and Japan. Nests in n. Africa and large Mediterranean islands from Mauritania and Niger to Egypt; isolated sub-Saharan population in Bale Mtns. in s. Ethiopia. Accidental in Belgium, Netherlands, Cyprus, Kuwait, Canary Is., and Hawaiian Is.; 1 individual seen in Hawaiian Is. for 17 yr (Pyle 1984).

Historical Changes

Historically nested throughout most of North America (Bent 1937), but breeding records lacking for Iowa, Minnesota, and Indiana (Wingfield 1991). Formerly nested in e. Nebraska, se. South Dakota, Wisconsin, and Central Valley of California (Harlow and Bloom 1989, Wingfield 1991). Historical nesting confirmed in Maine, New Hampshire, New York, and Vermont (Todd 1989). Last reported nesting in New Hampshire in 1961 and New York in 1972 (Todd 1989). In Maine, 2 pairs nested in 1983, only 1 pair between 1984 and 1998, and 2 in 1999 (Todd 1989, C. Todd pers. comm.). Historical nesting suspected in Pennsylvania, Massachusetts, N. Carolina, Tennessee, Kentucky, W. Virginia, Virginia, S. Carolina, and Georgia (Smith 1982, Palmer 1988, Todd 1989, C. Todd pers. comm.). Nesting not confirmed in s. Appalachians (Lee and

Spofford 1990) until late 1990s after successful reintroduction efforts (see Conservation and management: management, below). Nested historically in s.-central Mexico (Guanajuato and Querétaro de Arteaga; Instituto Nacional de Ecologia 1999).

Most breeding records for Maritime Provinces of Canada unsubstantiated (De Smet 1987). Believed to have nested in Nova Scotia in late 1800s, and evidence exists for nesting in New Brunswick. Casual visitor to Maritime Provinces in late 1980s, with a large increase in sightings between late 1960s and 1980s. More common historically in Ontario and Quebec; currently rare, particularly in southern portions (De Smet 1987).

Fossil History

Pleistocene records of Golden Eagle in North America for Oregon, California, Nevada, New Mexico, Texas, Utah, and Mexico (Emslie and Heaton 1987, Palmer 1988). Remains also found at archaeological sites inhabited by prehistoric Native Americans in Utah (Parmalee 1980) and New Mexico (Emslie 1981). *Aquila* remains reported in fossils from the Upper Miocene in Nebraska (Wetmore 1923), and *Aquila* -like remains reported in fossils from the Upper Eocene or Lower Oligocene in Europe (Brodkorb 1964). Considerable overlap and gradation between contemporary Golden Eagle and Pleistocene specimens (Howard 1947).

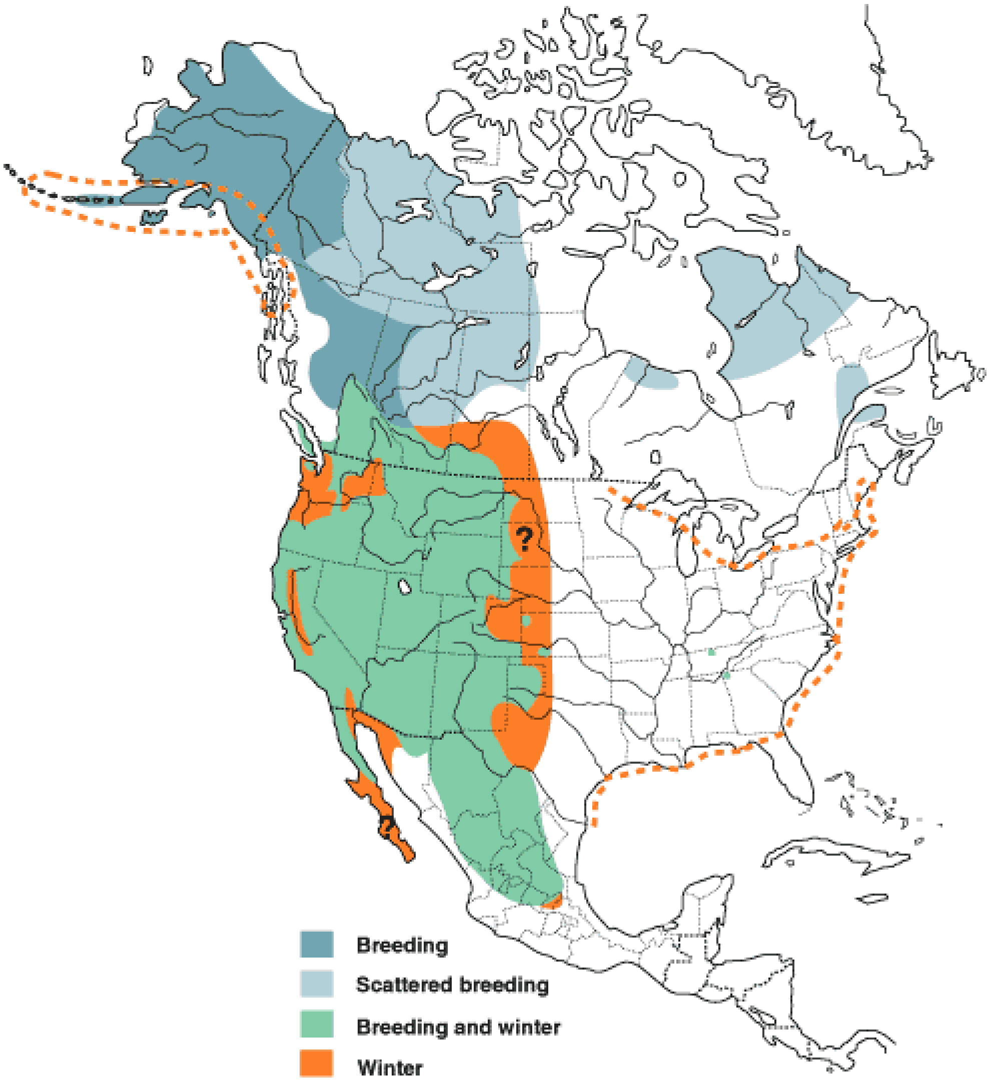

Figure 1. Distribution of the Golden Eagle in North America.

This species winters locally within the areas enclosed by the dashed lines. Blue dots in n.-central Tennessee and nw. Georgia depict isolated recent breeding locations. Question marks denote areas of suspected nesting. This species also breeds in Europe and Asia. See text for details.

Systematics

Geographic Variation; Subspecies

Of 5 or 6 subspecies worldwide, only one occurs in North America: *A. c. canadensis* . No information on geographic or genetic variation within the North American subspecies. Individuals from ne. Asia may be the same subspecies (Brown and Amadon 1968), but are larger (female wing 690 vs. 650 mm for North America) and may represent a distinct subspecies, *A. c. kamtschatica* (Watson 1997). Range of *A. c. kamtschatica* extends across ne. Asia from w.

Siberia and the Altai, where it intergrades with *A. c. chrysaetos,* to Kamchatka Peninsula and the Anadyr District of ne. Russia. Four other subspecies recognized; descriptions and female wing lengths from Watson 1997 . The palest, *A. c. chrysaetos* (medium size; wing 670 mm), occurs in n. Europe and w. Asia. *A. c. homeyeri* (small; wing 640 mm) found in Spain and n. Africa east to Iran, and the largest race, *A. c. daphanea* (wing 700 mm), is in e. Asia (Iran to central China). The smallest and darkest race, *A. c. japonica* (wing 630 mm), breeds in Korea and Japan.

Related Species

Member of the genus *Aquila*, one of several allied genera known as "booted" eagles that are medium to large eagles with feathering down to toes (Amadon 1982); regarded as the most highly evolved group within family Accipitridae, even perhaps within order Falconiformes (Brown and Amadon 1968). Closely related to Lesser Spotted (*A. pomarina*), Greater Spotted (*A. clanga*), Steppe (*A. nipalensis*), Tawny (*A. rapax*), Imperial (*A. heliaca*), Verreaux's (*A. verreauxii*), Gurney's (*A. gurneyi*), and Wedge-tailed (*A. audax*) eagles (Watson 1997). These species have feathered tarsi, no crests, moderately long wings, medium to long tails, and large bills, legs, and talons (Brown and Amadon 1968, Brown 1976).

Migration

Nature Of Migration In The Species

Short- to medium-distance partial migrant. Individuals from northern breeding areas (>55°N) usually migratory (Brown and Amadon 1968, Kerlinger 1989); migrate longer distances than individuals nesting farther south (McGahan 1966, Mead 1973). Former can migrate >5,000 km from breeding to wintering areas (Kuyt 1967, CLM). Migratory adults and juveniles usually fly directly to wintering areas (Brodeur et al. 1996, CLM). Overwintering in interior and n. Alaska coincides with high abundance of snowshoe hare (*Lepus americanus*; Kessel 1989). Many individuals breeding south of 55°N are not migratory; winter ranges of individuals from Canada and U.S. probably overlap extensively. Juveniles from sw. Idaho moved in almost all directions from natal areas after breeding season (Steenhof et al. 1984).

Timing And Routes Of Migration

Autumn

Individuals leave northern areas from Sep to early Oct; main exodus from Alaska occurs before end of Sep (Kessel 1989). Juveniles from Denali National Park, AK, tracked by satellite telemetry, initiated migration between mid-Sep and early Oct (mean 24 Sep ± 5 d SD [*n* = 43]; CLM). A radio-tagged adult remained in its northern (>55°N) breeding area in ne. Quebec until 30 Oct (Brodeur et al. 1996) before migrating south. Autumn flights occur from early Sep through Dec at raptor migration count sites in n. U.S. and s. Canada, with most peak flights in Oct. Long-term median passage dates with 95% C.I. at sites with ≥8 yr of observations between 1983 and 1999: 1 Oct ± 1.7 d at Wellsville Mtns., UT (Tidhar and Peacock 1999); 7 Oct ± 2 d at Goshutes Mtns., NV (Lanzone 1999); 10 Oct ± 3.3 d at Bridger Mtn., MT (Neal 1999); 13 Oct ± 2 d for Manzano Mtns., NM (Rossman 1999); 14 Oct for w. Alberta (Sherrington 2000).

Maximum passage rates early Oct in Glacier National Park, MT (Yates et al. 2001). Peak flights usually later at eastern raptor migration sites; median passage date 4 Nov for Hawk Mtn., PA (Hawk Mountain Sanctuary unpubl.).

Immatures migrate earlier in autumn than adults at most locations. Median passage dates ± 95% C.I. follow. Bridger Mtn., MT: immatures, 7 Oct ± 4 d; adults, 11 Oct ± 2.5 d (Neal 1999). Manzano Mtns., NM: immatures, 13 Oct ± 2.8 d; adults, 16 Oct ± 2.8 d (Rossman 1999). Hawk Mtn., PA: immatures, 31 Oct; adults, 6 Nov (Hawk Mountain Sanctuary unpubl.). However, median passage dates for adults (29 Sep ± 3.1 d) slightly earlier than for immatures (1 Oct ± 2.2 d) at Wellsville Mtns., UT (Tidhar and Peacock 1999).

Juveniles from Denali National Park, AK, reached their wintering areas in 28–58 d (mean 44 d ± 9 SD [*n* = 26]), arriving on winter ranges throughout w. North America from s. Alberta to se. New Mexico from 26 Oct to 19 Nov (mean 7 Nov ± 7 d SD [*n* = 16] CLM). Second-year eagles from Denali National Park arrived on winter ranges from 1 to 8 Oct in 2000 (mean 5 Oct ± 3.9 d SD [*n* = 3]; CLM). Radio-tagged adults from e. Hudson Bay took 26–40 d to reach their wintering areas in central Michigan, e. West Virginia, s. Pennsylvania, and ne. Alabama, arriving early Nov–early Dec (Brodeur et al. 1996). Individuals arrive on wintering areas in New Mexico and w. Texas in Oct, reaching peak numbers from Dec to Feb (Boeker and Ray 1971).

Spring

Adults from e. Hudson Bay departed winter ranges early to late Mar and arrive on breeding areas from late Mar to mid-May (Brodeur et al. 1996). Ju-veniles from Denali National Park, AK, departed wintering areas in s. Canada and w. U.S. 6 Apr–8 May (mean 21 Apr ± 12 d SD [*n* = 12; CLM]). Travel time be-tween wintering areas and summering areas in Alaska and nw. Canada, determined from satellite telemetry, ranged from 22 to 47 d (mean 35 d ± 6 SD [*n* = 12] CLM). Adults departed wintering areas in sw. Idaho 20 Mar–13 Apr in 1993 (mean 29 Mar ± 12 d SD [*n* = 3]) and 9–20 Mar in 1994 (mean 14 Mar ± 6 d SD [*n* = 3]; L. Schueck, J. Marzluff, M. Vekasy, M. Fuller, and T. Zarriello unpubl.); both age groups leave wintering areas in sw. U.S. in Mar (Boeker and Ray 1971). Travel time between sw. Idaho wintering areas and breeding areas in Alaska and nw. Canada, determined from satellite telemetry, ranged from 7 to 15 d (*n* = 3; L. Schueck et al. unpubl.). Median passage date ± 95% C.I. at Sandia Mtns., NM, is 20 Mar ± 4 d (Smith 1999). Maximum passage rates during second and third weeks of Mar at Glacier National Park, MT (Yates et al. 2001). Peak flights from 8 to 27 Mar at Rogers Pass, MT (Tilly and Tilly 1998), and 19 to 25 Mar in w. Alberta (Sherrington 1998). Spring migration in w. Alberta spans ≥92 d (Sherrington 1997): first migrants seen in mid-Feb, with large movements of immatures from mid-Apr to May (Sherrington 1997). Adults arrive on breeding areas in Alaska from late Feb to late Mar (Kessel 1989, Young et al. 1995, CLM).

Adults usually migrate earlier in spring than immatures. Median passage date for adults at Sandia Mtns., NM (9 Mar ± 1.7 d), significantly earlier than for immatures (3 Apr ± 3.4 d; Smith 1999). Proportion of immatures migrating at Glacier National Park increased from mid-Mar to mid-Apr (Yates et al. 2001). Adults move through s. Alberta earlier than immatures; adults common in Mar, immatures in Apr (Sherrington 1998).

Routes

Poorly known except for small numbers tagged with satellite-received radio transmitters. Large concentrations at raptor-migration count sites in U.S. and s. Canada suggest migration corridors exist along Rocky Mtns. and Appalachian Mtns. Largest autumn and spring passages in w. Alberta (Dekker 1970; Sherrington 1993, 1997) and w. Montana (Tilly and Tilly 1998, Neal 1999). In n. continental U.S. and w. Canada, most concentrated flights detected along north-south–oriented mountain ranges, (e.g., Rocky and Appalachian Mtns.); concentrated flights also noted in Great Lakes region. Smaller passages along Cascade Mtns. in Oregon and Washington (van der Geld 1998). Concentrations also observed in spring at Anaktuvuk Pass, AK (Irving 1960). Spring migration corridor near Marsh Lake and Whitehorse, Yukon, Canada; upper Tanana River Valley, AK; e. and central Alaska Range, AK (CLM); and the Matanuska Valley, AK (T. Swem and B. Dittrick pers. comm.). Migration corridors in sw. U.S. include Sandia Mtns. and Manzano Mtns., NM (Grindrod 1998, Rossman 1999). Spring migration corridors in e. U.S. include ridges on or near Appalachian and Allegheny Mtns. in New York, Pennsylvania, w. Maryland, Virginia, W. Virginia, N. Carolina, and Tennessee (Brodeur et al. 1996, Brandes 1998). Spring migration evident in Great Lakes region; increasing numbers observed at Whitefish Point, MI, since 1986 (Nicoletti 1998). Very rare at coastal raptor-migration sites (i.e., Sandy Hook, NJ; Cape Henlopen, DE; Plum I., MA); and at raptor-migration count sites in Massachusetts, Vermont, and Maine (Brandes 1998, Kellog 2000).

Satellite-telemetry studies provide detailed information on migration routes of adults and juveniles (Brodeur et al. 1996, CLM). Four adults radio-tagged at nesting areas in n. Quebec used different migration routes to reach their winter ranges. Three flew south through central Quebec, around Lake Ontario and south along Appalachian Mtns. to their winter ranges in Pennsylvania, W. Virginia, and Alabama, while another migrated along Hudson Bay, south through Ontario, crossing Great Lakes by Straits of Mackinac to its winter range in Michigan (Brodeur et al. 1996). In spring, 2 of the 4 adults generally retraced their southbound route to return to their breeding areas, and 1 wandered westward, remained west of Hudson Bay for a month, before heading back to e. Hudson Bay (Brodeur et al. 1996). Juveniles from Denali National Park, AK, used different migration routes in autumn and spring. In autumn, most flew eastward along Alaska Range, southeast through Yukon, and south along Rocky Mtns. through Alberta into the U.S. Others flew eastward along Alaska Range, southeast through Yukon, and south through Rocky Mtn. trench in British Columbia to winter range. Followed similar routes in spring until reaching central Alberta, where they veered east of Rocky Mtns., flying north through Alberta, across central Yukon, and to summer ranges throughout Alaska and n. Yukon (CLM).

Migration patterns of adults and immatures may differ; immatures move through New Mexico and w. Texas at beginning and end of wintering period (Nov and Mar), but winter in unknown areas (Boeker and Ray 1971). Immature:adult ratios recorded at autumn raptor-migration count sites vary geographically. Mean immature:adult ratio 0.27 in Alberta (P. Sherrington unpubl.) and 1.2 at Bridger Mtn., MT (Neal 1999). Ratios ± 95% C.I. are 1.74 ± 0.401 at Goshutes Mtns., NV (Lanzone 1999); 1.8 ± 1.15 at Wellsville Mtns., UT (Tidhar and Peacock 1999); 2.5 ± 0.86 in Manzano Mtns., NM (Rossman 1999); and 1.03 at Hawk Mtn., PA (Hawk Mountain

Sanctuary unpubl.). Most individuals observed at coastal raptor-migration counts in e. U.S. are immatures (Greenstone 1996).

Little information continent-wide on age ratios in spring. Mean immature:adult ratios 0.12 in Alberta (P. Sherrington unpubl.); 0.08 at Rodgers Pass, MT (Tilly and Tilly 1998); and 5.51 ± 1.85 C.I. in Sandia Mtns., NM (Smith 1999). Differences between immature:adult ratio in fall and spring at raptor-migration count sites might reflect age class differences in survival rates or migration routes.

Migratory Behavior

From Kerlinger 1989, Brodeur et al. 1996, and others as noted. Diurnal migrant; nonflocking (Omland and Hoffman 1996), but observed in small "kettles" near thermals (Sherrington 1993). Up to 137/h counted in nw. Montana in autumn (Yates et al. 2001). Mean number seen/h (± 95% C.I.) in autumn: 0.06 at Hawk Mtn., PA; 0.26 ± 0.05 in Manzano Mtns., NM; 0.44 ± 0.37 at Goshute Mtns., NV; 5.4 near Mt. Lorrette, Alberta; 5.6 ± 0.67 at Bridger Mtn., MT; and 0.66 ± 0.17 at Wellsville Mtns., UT (Lanzone 1999, Neal 1999, Rossman 1999, Tidhar and Peacock 1999, Hawk Mountain unpubl., P. Sherrington pers. comm.).

Uses orographic lift (uplifts of thermal convection: Kerlinger 1989: 79, 86) along ridges, but also migrates over large flat or featureless terrain. Might compensate for potential flight-path displacement caused by winds; radio-tagged eagles deviated little from a direct line during migration. Water crossings >50 km not recorded; large water bodies may divert migrating eagles.

Individuals from northern breeding areas migrate to wintering areas with little or no wandering, but some wander after reaching winter destinations (Applegate et al. 1987, Brodeur et al. 1996, CLM). Migrants commonly use continuous gliding flight (Yates et al. 2001). Speed during migratory flights up to 51 km/h (Broun and Goodwin 1943). Radio-tagged eagles from e. Hudson Bay migrated mean of 65 km/d (range 49–81) during fall migration and 68 km/d (range 32–91) during spring migration. No evidence that adults and juveniles in northern areas start migration together, as reported by Palmer (1988). Significant shifts in magnitude of hourly passage rates at Hawk Mtn., PA, related to cold fronts; passage rates peaked 1 d after a cold front and declined steadily for next 3 d (Allen et al. 1996). Four radio-tagged eagles from e. Hudson Bay usually stayed <2 d in any local area during migration (Brodeur et al. 1996). Immatures may abandon summer ranges earlier than adults because they have less experience in foraging (Omland and Hoffman 1996). Compared to adults, immatures in sw. Montana spent more time migrating each day and were less selective about time of day for migrating; at autumn migration lookouts in sw. Montana, immatures observed more frequently than adults from 08:00 to 12:00 and >17:00 (Omland and Hoffman 1996). Individuals often hunt during migration (Dekker 1985).

Control And Physiology

Few data on proximate cues for migration. Tendency to migrate is strongest at northern latitudes (Kerlinger 1989). Departure from northern breeding areas coincides with first lasting snowfall, freeze-up, or decreasing prey abundance; also north winds (Brodeur et al. 1996). Poor winter foraging conditions due to low jackrabbit abundance in w. U.S.'s Great Basin may stimulate migratory movements among otherwise sedentary eagles (Rossman 1999), but individuals from sw. Idaho did not exhibit "irruptive" movement patterns during prey shortages (Steenhof et al. 1984). Eagles respond opportunistically to varying weather factors in complex landscapes with high topographic relief. Numbers of migrating individuals increased with increasing air temperature, rising barometric pressure, and decreasing relative humidity at Glacier National Park, MT in autumn; numbers increased with increasing wind speed and rising barometric pressure in spring (Yates et al. 2001).

Habitat

Breeding Range

Breeds in open and semiopen habitats from near sea level to 3,630 m (Poole and Bromley 1988, G. R. Craig pers. comm.)—tundra, shrublands, grasslands, woodland-brushlands, and coniferous forests (Kochert 1986). Also in farmland and riparian habitats (Kochert 1972, Menkens and Anderson 1987). Avoids heavily forested areas.

Occurs primarily in mountainous canyon land, rimrock terrain of open desert and grassland areas of w. U.S. Also nests extensively in riparian habitats in e. Great Plains (Menkens and Anderson 1987) and occasionally in forested areas. Nesting territories in sw. Montana are at lower elevations and contain more sagebrush (*Artemisia* spp.)-grassland habitat than unused areas (Baglien 1975). Nesting density in s.-central Idaho was higher in areas bordered by sagebrush/grass seedings than in areas bordered by agriculture (Craig and Craig 1984b). In ne. Colorado, nests primarily in grasslands near cliffs and avoids cultivated areas (Olendorff 1973). In n. Utah, nests mainly in grass, shrub, and juniper (*Juniperus* spp.) habitats (Peterson 1988). In e. Utah, used valley, aspen (*Populus* spp.)-conifer, and piñon (*Pinus* spp.)-juniper habitats as expected based on availability and talus habitat less than expected (Bates and Moretti 1994). In Wyoming, nests primarily in grassland, shrubland, or riparian habitats; absent or rare in flat desert terrain, farmlands, and dense forests (Phillips et al. 1984). In central California, nests primarily in open grasslands and oak (*Quercus* spp.) savanna and to a lesser degree in oak woodland and open shrublands (Hunt et al. 1995, 1999). In Arizona, prefers desert grasslands and chaparral habitats (Millsap 1981).

Typically forages in open habitats: grasslands or steppelike vegetation. In sw. Idaho, prefers to forage in shrub habitat; avoids agriculture, grassland, and burned habitats (Marzluff et al. 1997, USGS unpubl.). In central California, forages in open grassland habitats (Hunt et al. 1999). In forests west of Cascade Mtns., associated with open habitats (Anderson and Bruce 1980, Bruce et al. 1982). In e. North America, nests near burns, open marshes, meadows, bogs, and lakes and forages in open and semiopen mountainous or hilly terrain (Spofford 1971, Singer 1974, Brodeur and Morneau 1999).

Farther north in interior and n. Alaska and interior w. Canada, breeds in habitat dominated by rugged topography or mountainous terrain, near or above timberline, and along riparian areas (Ritchie and Curatolo 1982, Petersen et al. 1991, Young et al. 1995). Also breeds on bluffs and cliffs along rivers below timberline in Alaska (Ritchie and Curatolo 1982) and on sea cliffs in nw. Alaska (K. Titus pers. comm.). Common in mountainous areas dominated by subalpine and alpine vegetation between 300 and 1,525 m in Denali National Park, AK (CLM). Associated with tundra areas, river outwash plains, and alpine-subalpine ecotypes in e.-central Yukon (Hayes and Mossop 1981). Occurs in areas with high topographic relief dominated by low-arctic tundra plant species in coastal central Canadian Arctic (Poole and Bromley 1988); in areas with cuesta relief (asymmetric hills or ridges with gentle slopes and steep escarpments) and rugged topography in e. Hudson Bay region (Morneau et al. 1994). Forages on alpine tundra slopes at edges of subalpine scrub in sw. Alaska; rarely in open areas below timberline (Petersen et al. 1991). Forages in wet marsh tundra, heath tundra, tussock-heath tundra, and hillside heath tundra valleys in Alaska along the Kolomak River and Yukon-Kuskokwim Delta and in the Atigun and Sagavanirktok River valleys (Holmes and Black 1973, Sage 1974).

Spring And Fall Migration

In w. U.S. and Canada, may hunt over wetlands, agricultural areas, and grassy foothills during migration (Dekker 1985). In w. Canada, may select areas with strong thermal activity and uplifts for energy-efficient migration (Sherrington 1993). Radio-tagged eagles followed topographical features in e. U.S., but where these features were lacking in central Quebec and Ontario, they migrated over largely flat or featureless terrain (Brodeur et al. 1996).

Winter Range

From Root 1988 and others as noted. Primarily Humid Temperate and Dry ecoregion domains (Bailey 1989) from s. Alaska and Canada to central Mexico. Frequents areas in w. North America >457 m in elevation and winters up to 2,500 m (e.g., San Luis Valley, CO). Generally absent from harsh, dry areas (<20 cm annual precipitation) of Sonoran Desert and central Nevada; does not winter in western temperate forests in and west of Rocky Mtns. Winter habitat east of Canadian Rockies skirts northern edge of grasslands and excludes mixed mesophytic and deciduous forest. Forages at edges of woodland-scrub habitat in valley floors, riparian areas, and over areas dominated by dwarf shrub mat at northern limit of wintering distribution in Alaska (Petersen et al. 1991). In s. Yukon, may frequent local dumps and roadways searching for road kills (Burles and Frey 1981).

Across w. U.S., prefers open habitats with native vegetation and avoids urban, agricultural, and forested areas (Millsap 1981, Fischer et al. 1984, Craig et al. 1986, Marzluff et al. 1997). Uses sagebrush communities, riparian areas, grasslands, and rolling oak savanna (Knight et al. 1979, Fischer et al. 1984, Hayden 1984, Estep and Sculley 1989). In sw. Idaho, forages primarily in shrubland and avoids grassland and agriculture, with foraging points concentrated in sagebrush/rabbitbrush (*Chrysothamnus* spp.) habitat and cliff areas (Marzluff et al. 1997). Common in grazed areas; much remaining habitat in central and s. California in patches of relatively inaccessible mountainous country, primarily livestock ranches (Thelander 1974).

Common near reservoirs and wildlife refuges that provide foraging opportunities at winter waterfowl concentrations in midwestern U.S. (Wingfield 1991). Associated with riverine or wetland systems east of Mississippi River (Millsap and Vana 1984). Most sightings in e. U.S. concentrated within or along southwestern border of the Appalachian Plateau (30% of records) and within the Coastal Plain physiographic region (33% of records). Associated with steep river valleys, reservoirs, and marshes in inland areas; estuarine marshlands, barrier islands, managed wetlands, sounds, and mouths of major river systems in coastal areas. These wetlands are attractive due to a dominance of open vegetation, large concentrations of prey, and absence of human disturbance. Winters on montane grass and heath balds in the Appalachian Plateau region (Millsap and Vana 1984). Immatures more common along coastal plain on lower river estuaries, adjacent marshlands, and barrier islands of e. U.S.; adults more common than immatures near inland waterways on Appalachian and New England plateau (Millsap and Vana 1984, Todd 1989).

Food Habits

Feeding

Main Foods Taken

Small to medium-sized mammals: hares (*Lepus* spp.) and rabbits (*Sylvilagus* spp.); also ground squirrels (*Spermophilus* spp.), prairie dogs (*Cynomys* spp.), marmots (*Marmota* spp.).

Microhabitat For Foraging

See Habitat, above. Takes most prey on or near ground.

Food Capture And Consumption

Three main strategies to search for prey: soaring, still-hunting from a perch, and low contouring flight (Edwards 1969, Dunstan et al. 1978, Dekker 1985, Palmer 1988). Strategy determined by weather conditions, topography, and prey's escape response (Dekker 1985, Watson 1997). Soars more often on sunny and windy days; hunts from perches on overcast, calm, or rainy days; uses contour flight in broken topography and high soar in open habitats. Uses contour hunting to surprise prey that might escape to burrows. Contour hunting is most common overall (Watson 1997), but perch hunting was most common in sw. Idaho where habitat was open and perches (power lines, canyon rims, and rock outcrops) were abundant (Dunstan et al. 1978).

Usually attacks prey from upwind (Palmer 1988). Uses 7 techniques to attack prey (Watson 1997: 48): (1) "high soar with glide attack" to attack solitary or widely dispersed prey (hare, grouse [Phasianidae]) from a thermal (>50 m) with a long (≥1 km), low angle glide; (2) "high soar with a vertical stoop" to attack slow-flying or flocking prey (geese [*Branta* spp.], cranes [*Grus* spp.], sage grouse [*Centrocercus urophasianus*]; EHC) from a high (>50 m) soar; (3) "contour flight with a short glide attack" to surprise colonial prey (ground squirrels and prairie dogs) from low-level flight quartering over the ground; (4) "glide attack with tail chase" to flush, chase, and capture agile mammals and birds in flight from a low angle stoop; (5) "low flight with slow descent attack" to capture slow-moving prey (tortoise [Testudinidae], snakes [Serpentes]) from a low-level quartering flight and slow "parachute" stoop; (6) "low flight with sustained grip attack" to kill ungulates by landing on victim's back or neck, and riding it until the animal dies

(Deblinger and Alldredge 1996); and (7) "walk and grab attack" to capture quarry protected by an obstruction (Dixon 1937, M. Collopy pers. comm.).

Frequently feeds on carrion, especially during winter and even when live prey is available (Kalmbach et al. 1964, Watson 1997); consumes fresh carrion during nesting season (Bogg 1977). Locates carrion from high-soaring flight; often cues in on activity of crows (*Corvus* spp.) and other scavengers (Watson 1997).

Also hunts cooperatively with conspecifics; most cooperative hunting involves large prey (e.g., ungulates, red fox [*Vulpes fulva*], Wild Turkeys [*Meleagris gallopavo*] in winter; Thomas et al. 1964, Hatch 1968, Deblinger and Alldredge 1996). Mated pairs also hunt jackrabbits cooperatively during breeding season; pairs pursue prey with one individual following the other at different elevations above the ground. Initial pursuer diverts prey's attention by stooping while the second makes the kill (Willard 1916, Hunsicker 1972, Collopy 1983b).

Tandem hunting less successful than solo hunting in sw. Idaho (Collopy 1983b). Overall prey-capture success 20% (*n* = 115 capture attempts); capture success 4.6% for tandem hunting (*n* = 42), 29% for solo hunting (*n* = 73). Males initiated significantly more prey-capture attempts when solo hunting; females used both foraging methods equally.

Less common feeding behaviors include klepto-parasitism, piracy, nest-robbing, cannibalism, and fishing. Takes prey from corvids (Ladygin 1994, Marzluff et al. 1994), foxes (Meinertzhagen 1959), Bald Eagles (T. and E. Craig unpubl.), Great Horned Owls (*Bubo virginianus*; Henderson 1920), Northern Harriers (*Circus cyaneus*; MNK), Red-tailed Hawks (*Buteo jamaicensis*; Dekker 1985), Prairie Falcons (*Falco mexicanus*; J. McKinley pers. comm.), and other Golden Eagles (Dekker 1985). Takes eggs and young from nests. Preys on Canada Goose (*Branta canadensis*) eggs (Valutis and Marzluff 1997) and nestling Gyrfalcons (*Falco rusticolus*; Dittrick and Moorehead 1983). Remains of Prairie Falcon, Ferruginous Hawk (*Buteo regalis*), Great Horned Owl, Barn Owl (*Tyto alba*), Common Raven (*Corvus corax*), Yellow-billed (*Pica nuttalli*) and Black-billed (*P. hudsonia*) magpie, and Rock Dove (*Columba livia*) nestlings in Golden Eagle nests suggest nest-robbing (Carnie 1954, Houston 1985, Hunt et al. 1995, USGS unpubl.). Cannibalism occurs rarely. Collopy (1983a) reported apparent cannibalism of a nestling by its sibling in a nest in sw. Idaho, and partially eaten remains of a Golden Eagle nestling in a Montana nest suggest cannibalism by a sibling or parent (Palmar 1954). Fishing rare, but ≥5 individuals frequently captured live trout from shallow streams and pools in Arizona during winter (Brown 1992).

Hunts from 1 h before sunrise to 1 h after sunset during the breeding season in sw. Idaho (Dunstan et al. 1978). Hunting pattern bimodal in n.-central Utah: 08:30–12:00 and 14:45–18:30 (Smith and Murphy 1973). In central Idaho in winter, hunting activity usually greatest from midmorning until late afternoon (T. and E. Craig unpubl.).

Diet

Major Food Items

Feeds mainly on mammals (80–90% of prey items), secondarily on birds, and less often on reptiles and fish during nesting season (Olendorff 1976). Preys principally on leporids (hares and rabbits) and sciurids (ground squirrels, prairie dogs, marmots); the 2 groups combined constituted 49–94% of individual prey items reported in 24 studies throughout w. North America during nesting season (Appendix 1). Relative importance of taxa varies by region. Arctic ground squirrels (*Spermophilus parryii*), snowshoe hares, and arctic hares (*Lepus arcticus*) are principal prey in Alaska and n. Canada (Poole and Bromley 1988, Appendix 1). White-tailed (*Lepus townsendii*) and black-tailed jackrabbits, cottontails (*Sylvilagus* spp.), and white-tailed (*Cynomys leucurus*) and black-tailed (*C. ludovicianus*) prairie dogs are primary prey species in the n. Great Plains, with yellow-bellied marmots (*Marmota flaviventris*) and Richardson's (*Spermophilus richardsonii*) or Wyoming ground squirrels (*S. elegans*) important secondary prey (McGahan 1968, Reynolds 1969, Lockhart et al. 1977, MacLaren et al. 1988). Black-tailed jackrabbits and cottontails are main prey in Great Basin, with yellow-bellied marmots and Piute ground squirrels (*S. mollis*) or rock squirrels (*S. variegatus*) chief secondary prey (Arnell 1971, Bloom and Hawks 1982, USGS unpubl.). Yellow-bellied marmots are primary prey in e. Washington (Marr and Knight 1983). California ground squirrels (*S. beecheyi*) and black-tailed jackrabbits constitute most remains in central California (Carnie 1954, Hunt et al. 1995). In sw. U.S., black-tailed jackrabbits and cottontails are main prey, and rock squirrels and prairie dogs are chief secondary prey (Mollhagen et al. 1972, Lockhart 1976, Eakle and Grubb 1986).

Gallinaceous birds (pheasants, grouse, and partridge) are main birds taken (Olendorff 1976). Ptarmigan (*Lagopus* spp.) are important secondary prey in central Alaska (McIntyre and Adams 1999), and waterfowl are secondary prey in arctic Canada (Poole and Bromley 1988). Ring-necked Pheasants (*Phasianus colchicus*) and Chukars (*Alectoris chukar*) are secondary prey in the Great Basin (Hickman 1968, Arnell 1971, Marr and Knight 1983, USGS unpubl.).

Occasionally kills large prey, including seals (Phocoidea), ungulates (mountain goat [*Oreamnos americanus*], bighorn sheep [*Ovis canadensis*], Dall sheep [*O. dalli*], caribou [*Rangifer* spp.], deer [*Odocoileus* spp.], and pronghorn [*Antilocapra americana*]), coyotes (*Canis latrans*), badger (*Taxidea taxus*), bobcat (*Lynx rufus*), turkeys, geese, Trumpeter (*Olor buccinator*) and Tundra (*O. columbianus*) swans, Sandhill (*Grus canadensis*) and Whooping (*G. americana*) cranes, Ospreys (*Pandion haliaetus*), and Great Blue Herons (*Ardea herodias*; Bent 1937, Brandborg 1955, LaFontaine and Fowler 1976, Olendorff 1976, Ellis et al. 1999, Mason 2000, R. Ritchie unpubl.). Mainly takes young ungulates, but also kills adults (Deblinger and Alldredge 1996). Also preys on domestic animals, inluding sheep (*Ovis aries*), goats (*Capra hircus*), calves (*Bos taurus*), pigs (*Sus scrofa*), poultry (*Gallus gallus*), dogs (*Canis familiarus*), and cats (*Felis catus*; Bent 1937, Olendorff 1976). May kill livestock even when preferred prey is available (Phillips et al. 1996). In studies where sheep and goat remains were found at nests, these species constituted 0.2 to 7% of remains and accounted for only 1.4% of 7,094 prey items identified in studies throughout the w. U.S (Reynolds 1969, Mollhagen et al. 1972, Olendorff 1976, Bloom and Hawks 1982). Livestock remains include both carrion and eagle kills (Olendorff 1976).

Diet data lacking for e. North America. Although snowshoe hare, cottontails, and marmots are common prey, e. North American nests have a high proportion of American Bitterns (*Botaurus lentiginosus*), Canada Geese, and Great Blue Herons (Spofford 1971, Weik 1987, Todd 1989, Brodeur and Morneau 1999).

Winter diet does not appear to differ appreciably from nesting-season diets in temperate areas, but few data exist. Of 65 individuals identified in stomachs of 50 eagles killed Mar 1948 in Colorado, 52% were hares and rabbits (Woodgerd 1952). Of items identified in 63 eagle stomachs collected between Nov and Mar from 15 states throughout the U.S., 59% were hares/rabbits and 27% were suspected ungulate and jackrabbit carrion (Kalmbach et al. 1964). Sheep and goats constituted 11% of items, but proportion taken as carrion was unknown. Winter diet in central Utah consisted almost entirely of black-tailed jackrabbits (Edwards 1969). Also preys on waterfowl during winter (Kalmbach et al. 1964, McWilliams et al. 1994); waterfowl important in winter diets on Chesapeake Bay and eastern coastal areas (D. Buehler pers. comm.).

Quantitative Analysis

Appendix 1 . Data available primarily for the nesting season. Usually based on analyses of pellets and prey remains collected at nests; some data derived from direct observation of prey deliveries. Intensity variable, ranging from systematic collections every 4 d during the nesting season for >10 yr to 1 collection/nest for only 1 season. Results may not be reliable for quantitative estimates of food intake, particularly with longer intervals between collections (McGahan 1967), but are reliable for interpreting relative importance of prey species. Earlier dietary estimates derived from analysis of stomach samples (Kalmbach et al. 1964), but quality of data collected from stomach samples from individual raptors is minimal compared to other available methods (Marti 1987).

Most extensive information about diet composition comes from Snake River Birds of Prey National Conservation Area in sw. Idaho where >2,200 individual prey items were identified from 1971 to 1981 (Steenhof and Kochert 1988). Proportion of main prey in diet varied annually, and proportion of jackrabbits in diet correlated with jackrabbit density in the environment. Diet breadth was smaller than that of Red-tailed Hawks but larger than that of Prairie Falcons from the same area. Golden Eagles had smallest variation in sizes of prey taken; sizes of prey varied from 10 to 5,800 g (geometric mean 609 g, $n = 2,203$). Diets vary within nesting season, reflecting opportunistic hunting. In sw. Idaho, proportions of Ring-necked Pheasants in nests highest in Apr, coinciding with the peak of pheasant breeding activity; subsequently decreased when pheasant incubation began (Kochert 1972).

Food Selection And Storage

Opportunistic predator; wide variety of prey species and sizes, but in North America focuses on leporids and sciurids 500–2,000 g (Watson 1997; see Diet, above). Generally eats large prey at kill site; fresh limbs of young ungulates in nests suggest eagles may disarticulate animals before bringing to nests (Kalmbach et al. 1964; MNK). Parents may bring more food to nests than young can eat. Sometimes excess food is carried away from the nest, but in most cases, it is left there (see Breeding: parental care, below). Caching of prey rare, but a pair in Scotland deposited prey on a cliff near the nest before feeding it to the young (Macpherson 1910).

Nutrition And Energetics

Pairs delivered 885 g of prey biomass/d to nests in w. Texas (Lockhart 1976) and 1,417 g/d during the 10-wk brood-rearing period in sw. Idaho (Collopy 1984). Pairs in Montana brought an estimated 1,470 g of prey/d to a nest during a 39-d portion of the brood-rearing period (McGahan 1967). See Breeding: paren-tal care, below, for additional information on prey-delivery rates.

Between 23.9 and 33.2 kg of food needed to raise a chick from hatching to fledging (10 wk), based on estimates from feeding trials (Collopy 1980). Prey biomass consumed by nestlings increased during brood-rearing with peak at 7–9 wk of age (Collopy 1984). Amount of food consumed/d by 2 male and 2 female captive nestlings increased steadily from 11 to 15 d of age, peaked at 28–44 d, and declined slightly until experiments ended at 53–57 d (Collopy 1986). Food consumption did not differ between male and female nestlings. During late brood-rearing (47–57 d old), captive eaglets consumed 12–15% of their body mass/d; much greater than consumption rates of adults and juveniles (5.7–6.6%/d; Fevold and Craighead 1958). Greater food consumption by nestlings reflects cost of producing body tissue and feathers. Captive nestlings were 74.4% efficient at assimilating food energy consumed; no difference between males and females. Assimilation efficiency is related to fat content of prey (Collopy 1986). Ground squirrels contain 4–17 times more fat and provide 1.7 times more energy than rabbits (U.S. Dept. of Interior 1979, M. Collopy unpubl.).

Metabolism And Temperature Regulation

Overall mean gross and net energy efficiency (proportion of total ingested and metabolized energy, respectively, converted to feathers, fat, and other body parts) of 4 captive nestlings was 31% and 42%, respectively, and did not differ between sexes (Collopy 1980). Growth efficiency (ratio of biomass produced to biomass consumed) of nestlings decreased linearly with age and did not differ between males and females (Collopy 1986). Growth efficiency averaged 27% at 2 wk of age and steadily decreased to <5% at fledging. As chicks aged, more of their energy budget was allocated to maintenance. Trends in metabolized energy (ME) paralleled food consumption and peaked at about 2,500 kJ/d, with no difference between sexes. ME of wild males peaked 7–8 wk of age at about 2,000 kJ/d, and females peaked at about 3,100 kJ/d during week 8 (Collopy 1986). Energy metabolism ranged from 4.33 to 4.01 W/kg for 2 captive Golden Eagles (Gessaman et al. 1991). Body temperature of a telemetered nestling ranged from 37.9 to 39.1°C over 18 d (Rudeen and Powers 1978).

Drinking, Pellet-Casting, And Defecation

Drinks occasionally, but most or all liquid requirements, particularly for nestlings, are met by ingesting prey (Brown and Amadon 1968). Adults and immatures in Nevada drank in mountain bogs and springs and ingested snow near or above timberline (Charlet and Rust 1991, Johnson 1994). Drinking was a frequent daily activity of a captive adult female (Kish 1970). Casts pellets, usually once early in the day (M. Collopy pers. comm.). To cast, eagle arches neck with face down and forward and gapes widely while rapidly shaking head laterally. Behavior repeated several times with brief pauses between head-shakes; soft squeaks or whistles often accompany casting. Often bobs head in a Neck Pump prior to casting, and conspicuous swallowing often follows casting attempt. Adults do not cast at nest; chicks cast 1–3 pellets/d from age 20 d to fledging, but some chicks did not cast every day (Ellis 1979). Two captive male and 2 captive female chicks produced an average of 7.7 g/d (dry mass) and 6.9 g/d (dry mass) of pellets (Collopy 1980). The same captive eaglets defecated an average of 57.0 g/d (dry mass) and 59.6 g/d (dry mass), respectively (Collopy 1980). Number of defecations/d increases linearly to about 20 d in wild nestlings and then levels off to 10–16/d until fledging (*n* = 4; Ellis 1979).

Sounds

Fig. 2. Flight calls of an adult male Golden Eagle.

Vocalizations

Mostly silent except during breeding season, but vocalizations not well studied or documented outside breeding season. Most known calls associated with food deliveries by adults and food-begging by nestlings. Food-begging call probably most commonly heard vocalization; calls from larger nestlings can be heard ≥1.6 km away from the nest (CLM).

Development

Newly hatched eaglet emits a clear chirp; developing voice proceeds through a series of chirps, cheeps, and high-pitched chitters (Jollie 1943). Per Ellis 1979, unless specified: Nestlings begin chirping 2 d before hatching and continue throughout nestling period. By 10 d of age, chirp largely replaced by rattle-chirp in stressful situations, and feeding chirp replaced by a disyllabic *tsik* . At 15 d, *tsik* evolved into a 2-syllable *seeir* call. At 25 d, *seeir* merges into louder and harsher *pssa* or *tsycuk tsycuk* (Brown and Amadon 1968) when eaglet is very hungry or highly stimulated to solicit feeding. Food-begging calls may become more frequent and harsher with age (Watson 1997). By 40 d old, many of nestling calls indistinguishable from those of adult.

Vocalizations of nestling and fledgling usually associated with food solicitation (chirp, *seeir, pssa*), temperature stress (chirp), aggression, stimulation of parental care, or appearance of a parent (Brown and Amadon 1968, Hickman 1968, Ellis 1979, Watson 1997, O'Toole et al. 1999). *Seeir* and *pssa* intergrade; *pssa* is louder (Ellis 1979). In w. Montana, *chirps* usually used only at feeding time or when tiny eaglets are exposed to hot or cold weather (Ellis 1979). Nestlings may hiss when an intruder enters the nest (Sumner 1929a, Ellis 1979) or may emit harsh high-pitched chattering when angry (Brown and Amadon 1968). Fledglings use *pssa* and *yarp/yelp* to solicit food (Watson 1997) or may call to facilitate location by parents (O'Toole et al. 1999). Other vocalizations of nestling and fledgling include *weeo-hyo-hyo-hyo* and *weeo* (Brown and Amadon 1968).

Array Of Sounds

Vocalizations used in communication not as song or territorial markers. Vocal array is limited. No information on geographic variation. Nine distinct calls (chirp, *seeir, pssa, skonk,* rattle-chirp or cluck, *wonk, wip,* honk, and hiss) described in w. Montana (Ellis 1979). Vocal array and calls of immature not described; assumed to be similar to those of adults. Common adult vocalizations are yelping and mewing-type calls (Snow and Perrins 1998), doglike barks (Watson 1997), *skonk* or *wonk* (Ellis 1979), or *yaps* (Jollie 1943). Adult vocalizations associated with copulation (*pssa*), nest-building, entering nest, threatening or alarming situations (*skonk*), food deliveries (*wip*), meeting or approaching each other (*wonk*), coming into an evening roost, or intruders approaching a nest (*cherop*; Sumner 1929a, Jollie 1943, Camenzind 1969, Ellis 1979, Bergo 1987). Incubating female may call from nest when she sees male approaching with prey (Bergo 1987); may emit *pssa* during copulation and when approached by adult male on nest (Ellis 1979), and may call or cluck in anticipation of a nest visit by the male (Dixon 1937). Adult male may emit a long series of brief calls, *wip*, interspersed with an occasional *wonk*, during food deliveries at nest (Ellis 1979); *wip* is distinctly shorter and of higher frequency than *wonk* (Ellis 1979). The *wonk* is a greeting call used in various contexts including deliveries of prey and nesting material and incubation changes (Ellis 1979). Adult male also may call before entering a nest during incubation (Dixon 1937). During courtship, both members of pair *yarp* rapidly (Snow 1973). Pitches of individual males and females may differ enough in tone to be distinguishable (Dixon 1937, Jollie 1943); male has a more high-pitched *yap*, female a more “barking” voice (Jollie 1943). Figure 2 shows flight calls of an adult male near a nest.

Phenology

In w. North Dakota, calling rate of juveniles did not change with time since fledging and did not differ between sexes (O’Toole et al. 1999). Call rate/h nearly doubled with a parent present (mean 21.8 calls/h ± 3.526 SE) versus a parent absent (mean 11.5 calls/h ± 1.739 SE; O’Toole et al. 1999).

Daily Pattern

No information.

Places Of Vocalizing

Nestlings and adults vocalize near nest during breeding season (biased to nests, as this is where most studies are conducted).

Social Context And Presumed Functions

See above.

Nonvocal Sounds

None known with a communicative function.

Behavior

Golden Eagle adult being harassed by Chihuahuan Ravens, San Rafael Grasslands, Santa Cruz Co., Arizona.

Locomotion

Walking, Hopping, Climbing, Etc

Walks with awkward gait. May land and walk when approaching carrion during winter; also walks uphill when crop is full to gain elevation for flight (T. and E. Craig unpubl.). Often runs along ground, flapping wings, prior to flight; flapping always accompanies running. Unsuccessful aerial attempts to capture prey often followed by flapping and running wildly in an attempt to catch prey on ground (Ellis 1979). Recently fledged young often walk uphill to gain elevation to become airborne again. See Breeding: young birds, below.

Flight

Soars with outstretched wings and tail held in one plane, although wings sometimes held in a slight dihedral; primary tips spread fingerlike (Ellis 1979, Watson 1997). Two types of soaring flight: slow gliding flight, which includes parachuting, and fast gliding flight (Bergo 1987). May glide in high winds on partially folded wings (Ellis 1979). Glides can be 190 km/h (Darling 1934). Parachutes with wings and tail elevated and spread; legs dangling. Suggested functions of soaring include gaining height for gliding to other areas, hunting, territorial advertisement, courtship, migration, and exploration (Bergo 1987, Collopy and Edwards 1989). Flapping flight appears labored and consists of 6–8 deep wing-beats, interspersed with 2- to 3-s glides; less common than soaring or gliding flights (Watson 1997). Stoops with wings tightly closed, legs raised against tail. Speeds of 240–320 km/h attained in these vertical dives (Brown and Amadon 1968); can exceed speed of diving Peregrine Falcons (*Falco peregrinus*; Darling 1934). Also uses Delta-Wing Stoop, with wing-tips nearly touching, wrist areas extended laterally, alulae flared; legs sometimes dangling (Ellis 1979). Often makes conspicuous, long dives to eyries; dives occasionally preceded by undulating flight (Bergo 1987). Undulating display flight (sky-dancing) involves series of steep dives and upward swoops with 3 or 4 strong wing-beats near each apex; repeated in rapid succession with up to 20 undulations in a single display (Ellis 1979, Bergo 1987, Collopy and Edwards 1989). Special form of undulating display is Pendulum flight; eagle dives, regains height, turns over, and repeatedly retraces same course (Bergo 1987). Undulating flights function most often as a territorial display (Harmata 1982, Bergo 1987, Collopy and Edwards 1989; see Spacing, below), but also may be associated with courtship behavior (Harmata 1982, Bergo 1987).

Swimming And Wading

Swims only when necessary; one waded in water toward duck decoy (Sperry 1957). Two nestlings forced into river by human intruders swam to shore by paddling with wings (Hickman 1971). Captive immatures paddled with both wings and feet when swimming (Ellis 1979).

Self-Maintenance

Preening, Head-Scratching, Stretching, Bathing, Etc

Variety of preening methods to oil feathers, rearrange barbs, etc.; scratches head, neck, upper throat with claw of middle toe; may shake, ruffle feathers during preening; see Ellis 1979 for details.

Bathing often associated with drinking; observed in wild eagles in Nevada (Charlet and Rust 1991, Johnson 1994) and a frequent activity of captive birds (Sumner 1934, Kish 1972). In Arizona, a pair bathed and drank in a pool every morning (Bailey 1917). Communal bathing of up to 12 individuals reported in Arizona and Texas (Brandt 1951, Spofford 1964).

Sleeping, Roosting, Sunbathing

Nestling often sleeps on belly, with head resting on nest. Adult sometimes sleeps with head drooped; may tuck head under back- and scapular-feathers. Eyes sometimes covered by feathers during sleep; lower lids may cover cornea. Adults and large nestlings often stand on one leg when perched (Ellis 1979). During nesting season, both males and females have preferred perches near nest (Bergo 1987); female often roosts at nest during nesting season (Collopy 1984). Uses several preferred perches and spends long periods of time during the day roosting on prominent perches with good views of the landscape; usually perches above nest site but below ridge during nesting season (Watson 1997). During nonnesting season, both members of resident pair may spend many hours together on prominent perches; prefer sunny aspect in winter and avoid windy, exposed locations (Watson 1997). Rarely perches communally, but see Social and interspecific behavior, below.

From Ellis 1979: spreads wings wide to shade young, dry plumage, or absorb radiant energy. Responds to overheating by moving into shade or next to cool object, panting, and/or wing-drooping. Maximum recorded panting: 50 cycles in 25 s. Maximum rate accompanied by salt secretion running from nostrils. Wing-droop often accompanies panting and probably facilitates heat loss from under-wing surface; performed with back to sun, and sometimes with scapulars erected.

Daily Time Budget

In Idaho, males perched average of 78% of daylight hours, females 85% (Collopy and Edwards 1989). Males in Idaho spent 1.9, 19.1, 0.4, and 1.4% of daylight hours during chick-rearing in direct flight, soaring, undulating flight, and self-maintenance, respectively. Females spent 0.9, 13.9, 0.1, and 0.8% of daylight hours performing same functions. Agonistic encounters constituted <1% of male’s or female’s time (Collopy and Edwards 1989). Average time spent flying or soaring during breeding season: 20% for males and 28% for females in 1 Idaho study (Dunstan et al. 1978), 22% for males and 15% for females in another (Collopy and Edwards 1989); time spent in flight fluctuated with chick-rearing. Aerial activity may be reduced in some areas during cold winter weather, which is less conducive to soaring (Bergo 1987). Average time spent flying during winter in Idaho: males, 21%; females, 16% (Dunstan et al. 1978). Time not flying is spent perched, often in shaded area during hot summer afternoons. Males incubated 13.8% and females 82.5% of day (Collopy 1980). Females brooded/shaded 10.9% of time; males 0.08%. Males attended the nest 0.6%, females 24.0%. Females fed young 3.1% and males fed 0.04% of day-light hours during 1,194.6 h of observation during brood-rearing from 1978 to 1979 (Collopy 1980).

Agonistic Behavior

Physical Interactions

Territorial defense usually accomplished adequately by undulating flight and occasionally chase behaviors (Collopy and Edwards 1989, Marzluff et al. 1997). In Europe, physical contact during territory defense uncommon; individuals sometimes killed or wounded by other Golden Eagles in a saturated population in the Alps (Haller 1996). Three resident adults and a floater apparently killed by other eagles in California and Scotland (Grant and McGrady 1999, Hunt et al. 1999). Aggressive behavior toward nonbreeders by territorial adults may involve a steep dive followed by a chase after the intruder (Haller 1982, Bergo 1987). Flights sometimes preceded or followed by intense bouts of undulating displays (Bergo 1987). Invader often responds by rolling over and presenting talons to the aggressor. Rarely, lock talons and tumble through the air; sometimes fall several revolutions and other times tumble to the ground before releasing grip (Ellis 1979). Talon-grappling probably most often an aggressive encounter, rather than courtship; 2 adult females in Montana locked talons in the air, fell to the ground, and fought for >2 h in what appeared to be a territorial conflict. An observer broke up fight before either eagle was killed (Harmata 1982). Conflicts with conspecifics at carcass feeding sites during winter/migration period often involve both display threats and physical contact (Halley and Gjershaug 1998, T. and E. Craig unpubl.). Five of 7 aggressive encounters at carcasses during winter in Norway were won by females; in 15 of 21 conflicts, the younger bird dominated an older conspecific, but the difference was not significant (Halley and Gjershaug 1998).

Reactions of territorial adults to immatures varies. Adults usually reacted passively to immatures near nests during the breeding season in Scotland and sw. Idaho (Brown and Watson 1964, Kochert 1972, M. Collopy pers. comm.). Parents were not aggressive toward their own offspring during the postfledging period in N. Dakota (O’Toole et al. 1999). However, 2 instances of talon-grappling in Montana both occurred near an eyrie after a “rushing attack” by an adult at an immature (Ellis 1979), and talon wounds on a fledgling and 2 nestlings close to fledging in central California suggest they were killed by another eagle (Hunt et al. 1997, G. Hunt pers. comm.). Residents chased 4 of 8 intruding subadults from territories in Norway and performed undulating displays in response to ≥2 of the other 4 intruders (Bergo 1987).

Communicative Interactions

From Ellis 1979, Bergo 1987, and others as noted. Threat displays include Undulating Flight and aggressive direct Flapping Flight with exaggerated downstroke; function as threats to intruders in territory and do not usually end in physical contact (Marzluff et al. 1997). Aggressive encounters occur most often before egg-laying, less often during nesting (Watson 1997). Fledged young sometimes make mock attacks on their parents; adults sometimes engage in mock attacks and displacement behavior against recently fledged offspring (Bahat 1992). Sometimes utter a shrill *cherop* call when disturbed at nest site by human or other intruder (Camenzind 1969). Aggressive perch posture: head and body upright, feathers on head and neck erect; wings may be slightly spread and beak open; often accompanied by intense gaze. Similar posture with wings spread wide and oriented toward the threat; may rock back on tail and even flop over on back with talons extended upward as defense. Behavior may be accompanied by wing slap against threatening intruder. When approached by an intruder, turns away, partially spreads tail, lowers head, and remains still; adult on nest may lower head and "freeze" when approached by a person or a helicopter. To protect prey from other eagles, mantles by spreading wings, head, and tail over prey, while perched (Ellis 1979).

Spacing

Territoriality

In Idaho, breeding home ranges overlapped slightly (mean 3.7% ± 1.7 SE), and pairs defended boundaries of the entire home range (Collopy and Edwards 1989, Marzluff et al. 1997). Undulating flight displays and high soaring flight usually sufficient to maintain territory boundaries (Marzluff et al. 1997, Watson 1997); aggressive attacks and chases among neighbors uncommon. Undulating display was main territorial behavior in Israel (Bahat 1989); mostly performed by adults, but sometimes by immatures or juveniles (Harmata 1982, Bahat 1989). Adults establishing themselves in nesting territories may display more often than established breeders (Bergo 1987). Females in Israel displayed more than males and mostly against interspecific intruders; males displayed primarily as part of courtship (Bahat 1989). Most (67% for males and 76% for females) Undulating Flights in Idaho occurred near the territory boundary or within view of a neighboring territorial eagle rather than near the nest site (n = 388; Collopy and Edwards 1989). Eagles from adjacent territories sometimes perform flights simultaneously (Collopy and Edwards 1989), usually directed toward intruders (Bergo 1987, Bahat 1989). Frequent territorial encounters may stress resident pairs and decrease the number of copulations (Haller 1996). Undulating flight by adults observed year-round (Ellis 1979, T. and E. Craig unpubl., M. Vekasy pers. comm.); 46% of undulating displays in Montana occurred during winter (Harmata 1982), suggesting that some residents defend and maintain territories year-round (Marzluff et al. 1997). Aggressive encounters in Israel and Scotland occurred more often in autumn/winter and before egg-laying than during breeding season (Bergo 1987, Watson 1997), but vagrant nonbreeders or winter residents often in territories of residents wintering in Idaho with no defensive behavior observed (Marzluff et al. 1997). Wintering migrants do not defend a wintering territory; no aggression observed among eagles wintering in sw. Idaho (L. Schueck et al. unpubl.).

Individual Distance

Up to 7 observed roosting on a single power pole in se. Idaho (Craig and Craig 1984a); individuals perched within 0.25 m of each other (T. and E. Craig unpubl.). Gather communally at carcasses; dominant individual tends to feed while subordinates wait their turn (Halley and Gjershaug 1998, T. and E. Craig unpubl.). Are aggressive and generally do not tolerate another bird within 2 m (Halley and Gjershaug 1998).

Mean distances between adjacent occupied nests ranged from 3.1 to 8.2 km (mean 5.3) in 12 areas of Wyoming (Phillips et al. 1984) and 9.8 to 44.7 km (mean 26.5) in Quebec (Morneau et al. 1994). Nearest-neighbor distances between pairs are rarely <1 km, even in optimal habitat. Nearest-neighbor distances range from 1.5 to 8 km ($n = 72$ pairs; mean 6) in Denali National Park, AK (CLM), and 0.8 to 16 km ($n = 56$ pairs; mean 4.3) in sw. Idaho (Kochert 1972). Distances between nearest nests along Salmon Falls Creek, ID, averaged 4.39 km ± 2.3 SD (Craig and Craig 1984b). Pairs on Kisaralik and Tuluksak Rivers of Alaska are regularly spaced, with 4.8 km between nearest adjacent territory centers (Weir 1982).

Sexual Behavior

Mating System And Sex Ratio

Usually monogamous, but 2 males copulated with 1 female in central California, and the trio successfully raised young (G. Hunt pers. comm.). Several reports of trios in Norway (Bergo 1988), Sweden (Laistal 1966 cited in Watson 1997), and Scotland (Dennis 1983). Few data on mate fidelity. Some pairs stay together for several years; a mated pair stayed together for ≥3 seasons in sw. Idaho (USGS unpubl.). Often assumed to mate for life, but research is needed to verify this assumption (Watson 1997). In sw. Idaho, following an unsuccessful breeding season, 1 adult female left her mate from the previous year to mate successfully with a male from another territory (Marzluff et al. 1994). One adult female and 2 adult males switched territories in California (G. Hunt pers. comm.). Lost mates replaced within a few days in 5 cases in Wyoming (Phillips et al. 1984), within 2–10 wk (Dixon 1937, USGS unpubl.), and within 3 d in California (Hunt et al. 1999); rapid replacement of mates may indicate surplus of nonbreeders in population (Haller 1982, Phillips et al. 1984, Tjernberg 1985; see Demography and populations: population regulation, below). No data on population sex ratio.

Pair Bond

In nonmigratory (resident) populations, appear to maintain pair bond year-round (Harmata 1982, Bergo 1987); no information on maintenance of pair bond in migrants. Pairs in w. Norway spent more time together during autumn, winter, and the prelaying period than during nesting season (Bergo 1987). Prenesting activities consisted of territorial defense, mutual stimulation by aerial displays, carrying materials to nest, and vocalizing (Hickman 1968). Copulation most frequent before egg-laying (Palmer 1988), but occurs year-round and may function in pair-bond maintenance outside breeding season (Gordon 1968, Ellis and Powers 1982, Harmata 1982). Copulation usually occurs on a conspicuous perch (Bergo 1987) or at the nest (Palmer 1988) and may be followed and/or preempted by mutual soaring, rolling and foot-touching, cliff-racing, and extended periods of perching close together (Harmata 1982); occasionally accompanied by food transfer (Ellis 1979). Undulating flight by male sometimes follows copulation (Gordon 1939). Prior to copulation, female leans forward with bill in line with body axis and nearly touches substrate; vocalizes prior to, during, and after coition. Droops wings laterally, possibly to balance; often deflects tail slightly to one side. Male either alights on female from flight or climbs upon her back from behind; drops to tarsi with feet closed and lowers tail under female's for cloacal contact. Male usually flaps wings to maintain balance but does not vocalize. Average time for copulation 11 s; occasionally followed by preening and Ruffle-Shaking (Ellis 1979). In Montana, copulated several times/d from beginning of Mar until 55 d after completion of clutch at a nest (Ellis and Powers 1982). Other courtship behaviors may include undulating flight by 1 or both pair members, chases, dives, mock attacks, presenting talons, mutual soaring, and circling (Ross 1941, Wood 1941).

Extra-Pair Copulations

No information.

Social And Interspecific Behavior

Degree Of Sociality

Typically solitary or in pairs (Watson 1997). Occasionally bathes in groups (Brandt 1951, Spofford 1964) and roosts communally in unique circumstances (rarely; e.g., extremely cold weather and abundant prey); maximum of 124 roosted along a stretch of 85 power poles on a very cold night in e. Idaho (Craig and Craig 1984a; see Spacing, above). Immatures in Utah often associate with one another during winter (Edwards 1969), and immatures also may roost with Bald Eagles during winter, sometimes on the same branch (Edwards 1969, T. and E. Craig unpubl.).

Before independence, social behavior of fledglings and adults nonaggressive; fledgling pairs may mutually preen or nibble when perched together and often follow one another or fly together (O'Toole et al. 1999). In California, 4 generations of 6 related individuals flew together without aggression on 6 separate occasions (D. Bittner pers. comm.). This suggests that related Golden Eagles may tolerate one another for extended periods of time; adult male in Arizona transferred prey to 8-mo-old juvenile (Palmer 1988). Related individuals staying with family groups may explain "trios" during nesting season, but further research is needed (see Breeding: fledgling stage, below).

Play

Individuals and pairs engage in behavior that involves repeatedly carrying an object (e.g., moss or dead prey) to great height, dropping it, then diving after it (Gordon 1955, Davies 1982). Both adult and young carry sticks, drop them, and then retrieve them again while in flight (Coomber 1977, Hardey 1977, Palmer 1988). One such sequence was followed by mutual undulating display of a male and female (Hardey 1977), possibly in the context of courtship.

Nonpredatory Interspecific Interactions

Often harassed by corvids and other raptor species, particularly near nests of the smaller species (Palmer 1988, USGS unpubl.). Occasionally smaller raptors (e.g., Prairie Falcons) will drive eagles to the ground (MNK). Typically ignores attacks from smaller species, but will roll and extend talons toward chasing individual without displaying predatory behavior (MNK); physical contact sometimes ends in injury or death of attacking species (Walker 1983). Interspecific interactions sometimes related to competition for food. Aggressive behavior toward Ferruginous Hawk in Montana involved undulating flight and aggressive chasing flight (Harmata 1982).

Sometimes attacks coyotes in defense of prey (Bowen 1980, Jordheim 1980). Wintering Bald and Golden eagles fed together at carcasses in Utah; no aggressive behavior observed (Edwards 1969). Dominated Bald Eagles at carcasses in Idaho (T. and E. Craig unpubl.), California Condors in California (Snyder and Schmitt 2002), and White-tailed Eagles (*Haliaeetus albicilla*) in Norway through threat displays; no physical contact (Halley and Gjershaug 1998). Distances from eagle nests to Common Raven, Gyrfalcon, Peregrine Falcon, and Rough-legged Hawk (*Buteo lagopus*) nests suggest interspecific competition for nest sites or space and imply these species avoided Golden Eagle nesting sites in the central Canadian Arctic (Poole and Bromley 1988).

Predation

No records of predation on eggs; predation on nestlings and adults is rare. Wolverines (*Gulo gulo*) preyed on nestlings in sw. Alaska (Petersen et al. 1991), and grizzly bears (*Ursus arctos*) killed and ate nestlings in Denali National Park, AK (L. and D. Keeler pers. comm.). A wolverine caught and killed a nesting adult during incubation in n. Sweden (Bjärvall and Franzen 1986).

Nest defense is mainly passive. Rarely defends nest against other avian species (USGS unpubl.), but agonistic encounters with corvids and other raptors common during the nesting season (Collopy and Edwards 1989). Killed and did not eat 3 Great Horned Owls in Utah (J. R. Murphy in Palmer 1988) and 1 Ferruginous Hawk in Wyoming (Buhler et al. 2000), possibly as territorial or nest defense. Nesting adult in Alaska vocalized and dove repeatedly on intruding grizzly bears, sometimes striking adult bear on back of head and neck with talons and feet (L. and D. Keeler pers. comm.). Not normally aggressive toward human intruders in nesting area; often leaves nest unseen and does not return to area for hours (Camenzind 1969); attacks on humans rare (Bent 1937, Gordon 1955).

Breeding

Fig. 3. Annual cycle of breeding, migration, and molt, Alaska.

Phenology

Pair Formation

In temperate areas, where pairs remain on nesting territory year-round, new pairs form throughout the year soon after lost mates are replaced (*n* = 13; Dixon 1937, Hunt et al. 1997, USGS unpubl.). Pair formation begins upon return to breeding areas in Denali National Park, AK, from late Feb to mid-Apr (CLM). Courtship and nest selection can last >1 mo (MNK). In sw. Idaho, aerial displays, stick-carrying, and vocalizing started in late Jan, with a peak in mid-Feb (Hickman 1968). Resident pairs in the Diablo Range, CA, participate in courtship and nest-building from Dec to Jan (Hunt et al. 1997).

Nest-Building

Residents add material to nests year-round; may begin refurbishing nests in autumn, with activity peaking from late Jan to early Mar (Watson 1997). In s. California, nest construction began in fall and continued through winter (Dixon 1937). Nest-building began in Dec in Oklahoma and Jan in Texas (Palmer 1988). Duration of nest-building varies, and is probably longer for residents than migrants. Nest construction usually begins 1–3 mo prior to egg-laying; nest-building began 95 d prior to incubation in Japan (Aoyama et al. 1988). Bowl construction (see Nest, below) is the last phase of nest-building and occurs in the last 3–4 wk before egg-laying (CLM).

First/Only Brood Per Season

Only 1 brood/season, but will renest when eggs fail to hatch (see Eggs, below). Laying dates vary among populations (Appendix 2) and among years (Hickman 1968, Camenzind 1969, Beecham and Kochert 1975, USGS unpubl.). Laying begins as early as late Jan and early Feb in sw. Idaho and s. California (Dixon 1937, Hickman 1968) and as late as late Mar–early May in central and n. Alaska (McIntyre 1995, Young et al. 1995; Fig. 3). Latitude and elevation may account for variation in laying dates among populations (Baglien 1975); eggs laid later at more northern latitudes and higher elevations (Appendix 2). Along Front Range of Rocky Mtns. in Wyoming, Colorado, and New Mexico, lays earlier in south and at lower elevations (Boeker and Ray 1971). In w. Arizona, laying dates may be synchronized with rainfall patterns and reproductive periods of prey (Millsap 1981). In sw. Idaho, hatching dates related to both winter severity and jackrabbit abundance; eagles hatched earlier when rabbits were abundant and later after severe winters (Steenhof et al. 1997). Hatching dates range from 10 Mar to 25 Jun in w. North America (Appendix 2). Young usually fledge when 45–84 d old (see Fledgling stage, below); young in nest from early May to late Aug in central and n. Alaska (McIntyre 1995, Young et al. 1995; Fig. 3). Postfledging dependence period varies (see Fledgling stage and Immature stage, below). Nesting chronology in Denali National Park, AK, closely parallels chronology of arctic ground squirrel populations: Eagles arrive at nesting areas before ground squirrels emerge from hibernation, but brood-rearing coincides with peak abundance of ground squirrels; onset of migration coincides with onset of hibernation in ground squirrels and hoary marmots (*Marmota caligata*) in Sep (CLM).

Nest Site

Selection Process

Unknown which sex selects nest site; females may have selected nest sites in San Diego Co., CA (Dixon 1937).

Microhabitat

Usually nests on cliffs; also in trees (Menkens and Anderson 1987), on ground (Menkens and Anderson 1987), clay cliffs (Houston 1985), river banks (Phillips and Beske 1990), and human-made structures, including windmills, observation towers (Camenzind 1969), nesting platforms (Phillips and Beske 1990), abandoned gold dredges (Petersen et al. 1991), and electrical transmission towers (Steenhof et al. 1993, Hunt et al. 1999). Many nests have a wide view of surrounding area (Beecham 1970) or are on prominent escarpments (Bates and Moretti 1994). Proximity to hunting grounds an important factor in nest-site selection (Camenzind 1969). In northern areas, weather conditions at beginning of nesting season are a critical factor in choice of nest-site location (Morneau et al. 1994). Average annual snowfall may limit distribution of nest sites; in sw. Montana, nests usually built below areas receiving >500 cm of snow (Baglien 1975).

Cliff nests are built on several rock substrates including sandstone, shale, granite gneiss, limestone, basalt, and granite (Schmalzried 1976, USGS unpubl., CLM). Usually avoids building nests on loosely cemented materials such as breccias, conglomerates, or agglomerate sluff (Baglien 1975).

Cliff nests most common throughout most of North America; trees nests more common in ne. Wyoming (Menkens and Anderson 1987, Phillips and Beske 1990), central Coast Range in California (Hunt et al. 1999), and coastal Washington (Eaton 1976, Bruce et al. 1982). Nests in a wide variety of trees, including ponderosa pine (*Pinus ponderosa*; Phillips and Beske 1990), several oak species, California laurel (*Umbellularia californica*), eucalyptus (*Eucalyptus* sp.), California sycamore (*Platanus racemosa*; Hunt et al. 1995), Douglas fir (*Pseudotsuga menziesii*; McGahan 1968), Fremont cottonwood (*Populus fremontii*; Bates and Moretti 1994), and white spruce (*Picea glauca*; Ritchie and Curatolo 1982, CLM). In n. Wyoming, prefers large pines rather than cottonwoods (Phillips and Beske 1990). Nesting trees usually the largest or one of the largest trees in a stand (Menkens and Anderson 1987), isolated or on the fringe of small stands of timber (Baglien 1975), and <500 m from large clearcuts or open fields (Bruce et al. 1982). In w. Washington, nests near clearcuts <10 yr old; may benefit from openings in dense timber formed by fire and logging (Thomas 1977, Servheen 1978, Anderson and Bruce 1980). Avoids building nests in dense stands (Phillips and Beske 1990). In Wyoming, nests usually in upper one-third of nest tree (Schmalzried 1976, Menkens and Anderson 1987, Phillips and Beske 1990). Larger trees may improve nest stability and longevity, and placement in upper portion of tree may improve accessibility for adults (Menkens and Anderson 1987).

Heights of nesting substrates range from 0 to 107 m. At 4 study areas, nesting cliffs averaged 35.5 m, height of cliff nests 20.7 m (Table 1). Nest-tree heights ranged from 38 to 72 m in w. Washington, with nests ranging from 20 to 64 m high ($n = 6$; Anderson and Bruce 1980). Occasionally nests on the ground where cliffs and trees are scarce, primarily in Nevada (Seibert et al. 1976), Wyoming (Menkens and Anderson 1987), and N. Dakota (Ward et al. 1983). Ground nests tend to be on hillsides (Ward et al. 1983).

Tree nests were close to water courses in ne. Wyoming (Menkens and Anderson 1987); nests in n. Wyoming and se. Montana were in large trees in the bottom of isolated drainages (Phillips et al. 1990). Cliff nests 9.1–60.9 m above Noatak River, AK (mean 37 m, $n = 25$; Amaral and Gardner 1986). All nests on Porcupine River, AK, were within 400 m of the river, with 84% within 100 m of the river ($n = 37$; Ritchie and Curatolo 1982). Nests 0.05–1.2 km from water in se. Wyoming (mean 0.3 ± 0.05 SE [$n = 30$]; MacLaren et al. 1988), 1.2–8.1 km from water in w. Washington ($n = 6$; Anderson and Bruce 1980), and 1.6–8.0 km from water in n. Utah (mean 2.1 ± 2.9 SD [$n = 7$]; Peterson 1988). In s. California, trees on slopes provide panoramic views of foraging habitat and may provide wind lift for flight; trees on valley floors rarely used as nest sites (Dixon 1937). Tree nests in w. Washing-ton were on slopes ranging from 30 to 88% (*n* = 6; Anderson and Bruce 1980, Bruce et al. 1982).

Nest

Construction Process

See Phenology, above. Usu-ally refurbishes and reuses existing nests; from 1980 to 2000, only 9.5% of breeding pairs nesting on Snake River Canyon cliffs used new nests each year (range 0–18, *n* = 841 nesting attempts). New nests may or may not be used the year constructed (Dixon 1937, MNK); some nests in sw. Idaho not used for up to 6 yr after construction (USGS unpubl.). Nest construction is sometimes rapid, but usually prolonged; nest-building took 4–6 wk in Texas (Palmer 1988). Brings sticks and branches to ≥1 nests in autumn and winter; approximately 1 mo before egg-laying, brings softer materials to a selected nest to form a "bowl" within the nest (Watson 1997). Sometimes adds material to alternate nests prior to laying eggs (Bergo 1987, MNK). Nest-building in San Diego Co., CA, usually occurred 10:00–13:00, or after morning hunt completed (Dixon 1937); nest-building in Texas occurred between dawn and 11:00 (Palmer 1988). Both sexes participate nearly equally in nest-building prior to incubation (Bergo 1987, Aoyama et al. 1988), and both sexes add fresh vegetation (greenery) to nest throughout nesting season; female makes most deliveries during brood-rearing (Bergo 1987, Aoyama et al. 1988). In sw. Idaho and se. Oregon, 50% of sites contained fresh nesting material during latter stages of nesting cycle (Hickman 1968). All sites in Denali National Park, AK, during brood-rearing stage (*n* = 189) contained fresh nesting material (CLM).

Structure And Composition Matter

Wide variety of vegetation for nest-building; usually reflects flora of immediate vicinity (Hickman 1968, CLM). Individual pulls at base of vegetation, breaking it off; uses a technique similar to tearing prey. Carries sticks and other vegetation to nest in bill or feet, depending on size of item. Often weaves sticks into existing nest structure. Less frequently uses animal bones, shed antlers (Ellis and Bunn 1998), and human-made objects, including wire and parts of fence posts (Schmalzried 1976), as nesting materials. Bowl lined with a wide variety of vegetation types, including shredded yucca (*Yucca* spp.), grasses, dry yucca leaves (Slevin 1929, Dixon 1937), strips of inner bark, dead and green leaves, soft mosses and lichens (Gabrielson and Lincoln 1959), and Douglas fir and pine boughs (Jollie 1943).

Dimensions

In Arizona and w. Washington, smaller than Bald Eagle nests. Arizona nests (*n* = 12; Grubb and Eakle 1987): 175.7 cm long (range 121.9–264.2), 119.8 cm wide (range 83.8–203.2), and 65.0 cm high (range 12.7–200.7). Lined portions of 8 nests 93.6 cm long (range 53.3–185.4), 79.0 cm wide (range 38.4–160.0). Tree nests in w. Washington: 0.9 m deep with 1.2–1.5 m diameters (*n* = 6; Anderson and Bruce 1980). Sticks in 12 Arizona nests: 58.4 cm long (range 7.6–177.8), 1.2 cm diameter (range 0.4–5.3); weighed 64.2 g (range 5–820). Largest nest on record, in Sun River, MT, was 6.1 m tall and 2.59 m wide (Ellis 1986).

Microclimate

Nest-site exposure may be a factor in nest-site selection (Mosher and White 1976); certain exposures may protect nests from prevailing inclement weather (Watson and Dennis 1992, Morneau et al. 1994), minimize intense (direct) sunlight that puts nestlings at risk of overheating (Mosher and White 1976, Watson and Dennis 1992), reduce exposure to cold (Mosher and White 1976, Poole and Bromley 1988), avoid prevailing winds (MacLaren et al. 1988, Poole and Bromley 1988), and minimize exposure to down-drafts (Eaton 1976). Usually nests on south-facing cliffs in northern areas (>60°N). Of 714 nests in Alaska (Mosher and White 1976, Ritchie and Curatolo 1982, CLM), Yukon (Hayes et al. 1980, Yukon Dept. Renew. Resour. 1982), Northwest Territories (Poole and Bromley 1988), and Quebec (Morneau et al. 1994), 54% were on south-facing cliffs, 18% on west-facing cliffs, 14% on north-facing cliffs, and 14% on east-facing cliffs. Pairs farther south less likely to select south-facing sites; of 423 nests in Montana (McGahan 1968, Baglien 1975), Wyoming (Schmalzried 1976), Idaho (Hickman 1968, USGS unpubl.), Oregon (Hickman 1968), and Nevada (Seibert et al. 1976), 37% on south-facing cliffs, 22% on north-facing cliffs, 21% on east-facing cliffs, and 20% on west-facing cliffs. Nest orientations can differ within study areas, with more south-facing nests at higher elevations (Craig and Craig 1984b). In many study areas, all exposures were used (McGahan 1968, Lockhart 1976, Seibert et al. 1976).

May use south-facing sites at northern latitudes simply because they are the only nesting habitat free of snow when territories are first occupied in spring (Amaral and Gardner 1986). Alternatively, selection for south-facing cliffs may be a strategy to minimize exposure of incubating birds to cold (Mosher and White 1976, Poole and Bromley 1988). Early in breeding season, south-facing sites in central Canadian Arctic benefit from direct radiation and high reflectance radiation, while being in the lee of prevailing northerly winds (Poole and Bromley 1988). Later in nesting season, nestlings in these poorly protected nest sites may be exposed to high temperatures unless the nest is provided with shade (Poole and Bromley 1988). Parents may spend more time brooding or shading to protect young from overheating in unshaded south-facing nests. In temperate areas, appears to select nest sites that avoid direct sunlight to protect nestlings from overheating and to decrease brooding time required of adults (Mosher and White 1976). Of 418 nests in the Snake River Canyon, ID, 12.7% had 5–25% shading, and 54.8% had 25–100% shading (USGS unpubl.). In Boulder Co., CO, no nest was in direct sunlight for >2–4 h/d (Jollie 1943), and 33% of nests in sw. Montana had exposures that provided shade from hot afternoon sun (McGahan 1968).

Sixteen of 30 nests (53.3%) in e. Hudson Bay had overhangs (Morneau et al. 1994). Percentage of nest covered by overhang averaged 38.3% at 41 nests in the central Arctic (Poole and Bromley 1988) and only 3.7% at 7 nests in n. Utah (range 0–20; Peterson 1988). Although overhangs protect nests from sun, rain, snow, and ice formation (Kochert 1972, Poole and Bromley 1988), falling rocks or soil can kill incubating or brooding eagles or nestlings (Phillips et al. 1990). Avoids building nests in areas with major down-drafts; selection of slopes with updrafts may conserve energy and thereby enhance reproductive success (Eaton 1976). Most nests inaccessible to humans and mammalian predators (requiring either a ladder or ropes to be reached by humans): 80.2% in sw. Idaho (USGS unpubl.) and 87.3% in Denali National Park, AK (CLM).

Maintenance Or Reuse Of Nests, Alternate Nests

Often constructs alternate nests. Number of supernumerary nests/territory ranges from 1 to 14, usually 2 or 3 (MNK). In a 2-yr study in Utah, 11 of 21 pairs had >1 nest (Camenzind 1969), and 20 of 36 pairs had alternate nests in a 5-yr study in Montana (McGahan 1968). All 65 pairs nesting on cliffs in the Snake River Canyon used >1 nest/territory during 30 yr (USGS unpubl.). Alternate nests can be separated by <1 m or >5 km (McGahan 1968); number of nests and distances between them may be related to terrain features and proximity of other nesting pairs (Boeker and Ray 1971). Some pairs use same nest every year but repair and add material to alternate nests until eggs are laid (McGahan 1968, Boeker and Ray 1971, USGS unpubl.). Other pairs switch nest sites from year to year; reuse of nests not apparently associated with previous year's success (Boeker and Ray 1971, USGS unpubl.).

Eggs

Shape

Short-ovate to ovate or rarely elliptical-oval (Bent 1937).

Size

Mean length 74.5 mm (range 67.5–85.7); mean breadth 58.0 mm (range 49.4–64.3, *n* = 63 eggs; Steinbeck 1884, Bent 1937); 20 clutches averaged 74.4 mm ± 3.40 SD × 57.3 mm ± 1.63 SD (Palmer 1988).

Mass

Averaged 141.4 g (range 113.9–176.6, *n* = 30; Hanna 1930).

Color

Base color varies from white to "cream-buff" or pinkish white. Usually evenly marked small blotches, spots, or fine dots unevenly distributed or concentrated at one end. Some are evenly sprinkled with small dots. Colors of markings are "bay" and various shades of browns. Some eggs have large blotches of drabs overlaid with browns (Bent 1937).

Surface Texture

Rough.

Eggshell Thickness

Thickness of eggshells collected pre-1947 differed little from those collected during the post-DDT era; mammal-feeding habits (see Food habits: diet, above) resulted in little biomagnification of organochlorine pesticides and minimal eggshell-thinning (Anderson and Hickey 1972, Kochert 1972). Shell thickness of pre-1947 clutches from w. North America averaged 0.583 mm ± 0.003 SD (*n* = 290). Shell thickness of eggs collected during the 1960s and 1970s (Reynolds 1969, Beecham 1970, Anderson and Hickey 1972, Kochert 1972) averaged 0.593 mm for Idaho (*n* = 51), 0.637 mm for Montana (*n* = 7), 0.580 mm for Alaska (*n* = 4), 0.605 mm for California (*n* = 9), and 0.623 mm for Utah (*n* = 17).

Mean empty shell weight, 13.04 g (range 11.02–14.30) based on 1,083 eggs (Reynolds 1969, Anderson and Hickey 1972, Kochert 1972).

Clutch Size

Typically 1–3, rarely 4 (DeGroot 1928, Ray 1928, Gordon 1955). A California nest contained 5 eggs, but 1 egg apparently laid prior to the others (DeGroot 1928). Number of eggs averaged 1.99 in 332 clutches from 8 studies in 5 western states (n. California, *n* = 21; n. Colorado *n* = 52, central Utah, *n* = 49; sw. Idaho, *n* = 160; sw. Montana, *n* = 50); 14% contained 1 egg, 76% 2 eggs, and 10% 3 eggs (Slevin 1929, Jollie 1943, Camenzind 1969, Reynolds 1969, Arnell 1971, Olendorff 1973, USGS unpubl.). Clutches with 3 eggs most common in years when prey is abundant (USGS unpubl.). No clinal variation in clutch size. Clutch size not related to laying date in sw. Idaho (*n* = 115; USGS unpubl.). No data on whether age of female affects clutch size.

Egg-Laying

In captivity, eggs laid at mostly 3- to 4-d intervals (mean 3.5 d, *n* = 35), with 2 cases of 7 and 10 d between second and third egg (Kish 1970, 1972; Hamerstrom 1971, Grier 1973). Laying intervals in the wild range from 3 to 5 d (*n* = 4; Gordon 1955, Aoyama et al. 1988). Incubation begins with first egg, leading to asynchronous hatching (Watson 1997). Renesting occurred in only 0.01% of 674 nesting attempts in sw. Idaho (USGS unpubl.), and in 1.0% of 200 attempts in Scotland (Watson 1997); average of 24 d after failure of first clutch (range 19–30, *n* = 13; Dixon 1937, Camenzind 1969, Morrison and Walton 1980, Dennis 1983).

Incubation

Onset Of Broodiness And Incubation In Relation To Laying

No information.

Incubation Patch

Present in both sexes; more developed and conspicuous in females (R. Jackman pers. comm.).

Incubation Period

Female settles in incubation posture on nest before first egg is laid (Ellis 1979). Estimated average incubation period 42.4 d (range 41–45, *n* = 11 clutches; Abbott 1924, Gordon 1955, Mitchell 1968, Camenzind 1969, Reynolds 1969, Beecham 1970, Aoyama et al. 1988, Watson 1997).

Parental Behavior

In sw. Idaho, females did all nocturnal and 82.6% of diurnal incubation (*n* = 11 nesting attempts); males relieved incubating females 2.1 times daily ± 0.1 SE. Male incubation bouts averaged 49.4 min ± 4.7 SE; 17 of 111 male-initiated change-overs (15.3%) involved food transfers to the female on or near the nest (Collopy 1984). Inattentiveness by male may force female off eggs to forage and ultimately abandon nesting effort (Collopy 1984).

Hardiness Of Eggs Against Temperature Stress; Effect Of Egg Neglect

Eggs can tolerate cooling, but the precise amount is unknown. At least 1 egg hatched from a clutch of 2 in sw. Idaho after being exposed to snowy and cold conditions (0° C) for at least 1 to 5 h during late incubation (MNK).

Hatching

Hatching asynchronous (Watson 1997); hatching interval between first and second eggs 96.5 h (*n* = 1; Aoyama et al. 1988). From Ellis 1979 (*n* = 1): Chick vocalizations (chirping) begin up to 53 h before hatching. First heard calling from egg 15 h 10 min before pipping; individual egg hatching may last >36 h. Eaglet activity increased from 26 h 50 min after pipping until emergence. Female may assist hatching by caving and separating egg. Eaglet surged against shell every few seconds at 35 h after pipping, and egg was broken completely around a belt about a third from the blunt end 35 h 15 min after pipping. Wing emerged at 35 h 19 min, ends of shell separated at 36 h 30 min, and nestling free 37 h 20 min after pipping.

Young Birds

Condition At Hatching

Average 110.6 g (range 105–115, *n* = 7) within 1 d of hatching in the wild (Sumner 1929a, 1929b; Ellis 1973). Down dries within 2 h of hatching (Watson 1997). At hatching, covered with short grayish-white "pre-pennae" down (Brown and Amadon 1968). Ear holes open, beak black, egg tooth prominent, feet and legs pale flesh colored, talons white to flesh colored (Sumner 1929a, 1929b; MNK). Capable of limited locomotion; weak and feeble, eyes partially open, unable to detect movement (Sumner 1929a, 1929b). Altricial; must be fed by parent.

Growth And Development

Increases in mass follow a general sigmoid growth pattern (Ellis 1979, Collopy 1986). Mass ranges from about 100 g at hatching to about 500 g at 10 d. From then growth is linear, reaching asymptote at 40–45 d. Female nestlings had slower growth rates but significantly higher asymptotic weights (mean 3,803 g; *n* = 102) than males (mean 3,233; *n* = 85; Collopy 1980, 1986). Nestlings attain maximum body mass at approximately 50–60 d after hatching (Collopy 1986).

Growth of alar, caudal, humeral, spinal, ventral, capital, crural, and femoral feather tracts linear with no apparent difference between sexes (*n* = 3 [Ellis 1979]; *n* = 23 [Collopy 1980]). Seventh primary 269 to 316 mm and left center rectrix 191 to 253 mm at 65 d. Alar and caudal tracts continue to grow to full length after fledging (Ellis 1979). Foot-pad growth linear between 6 to 31 d; reaching asymptote between 31 and 35 d (*n* = 23; Kochert 1972). Mean foot-pad size differed significantly between male and female nestlings beginning at 21–25 d. Foot-pad size averaged 148.6 mm for female and 134.9 mm for male nestlings 46–59 d old (*n* = 107; Kochert 1972).

Depends on parents to regulate body temperature (i.e., brooding and shading) for first 20 d after hatching (Watson 1997). Prone to heat stress and death in extreme conditions; responds to heat stress by moving to cool objects or shaded portions of nest, or by panting (Ellis 1979). Droops wings to dissipate heat and spreads wings to absorb radiant energy, dry plumage, or dissipate heat (Ellis 1979). Wing spread first seen around 7 wk of age.

Behavior

See Ellis 1979 for details on preening, scratching, defecation, and casting of pellets. Intersibling conflicts occur frequently and occasionally result in siblicide, particularly when food is limited (Edwards and Collopy 1983, Watson 1997). When attacked by sibling, subordinate chick turns away, partially spreads tail, lowers head, and remains still to suppress aggression; aggressive interactions wane between 10 and 13 d, but continue sporadically to late brood-rearing (Ellis 1979). Late-season agonistic behavior related to lack of food (Ellis 1979). Larger, most aggressive chick, typically a female, receives most food (Collopy 1980). Subordinate chick is some-times starved or forced from nest (Sakaguchi and Chiba 1988). Probability of siblicide depends on sex and order of hatching sequence, with siblicide more than likely to occur when a female hatches before a male in the brood (Edwards and Collopy 1983, Bortolotti 1989). In sw. Idaho, aggression occurred in all nests with 2-chick broods observed from blinds, and resulted in 1 death in 3 (43%) of 7 broods (Collopy 1980). Siblicide accounted for 7% of 41 nestling mortalities in sw. Idaho (Beecham and Kochert 1975) and 6 (40%) of 15 nestling losses in central Europe (Kropil and Majda 1996).

From Ellis 1979 . Aggressive interactions with parents increase with nestling age. Nonaggressive billing of adults begins around 20 d of age, but is aggressive by day 40 and continues until fledging. As fledging age approaches, regularly engages in rush attacks (running and flapping wings) when parents enter nest; occasionally foot-stabs parents. Mantles prey to protect food from parent and nest mate, beginning about 40 d of age. Occurred in all nests with >1 young (*n* = 3 nests) and is associated with development of self-feeding.

Locomotion

From Ellis 1979 (*n* = 4 chicks) and Collopy 1980 (*n* = 12). Able to distinguish objects at 7 d, but probably incapable of acute visual discrimination at <10 d (Sumner 1929a, Ellis 1979). During first week, spends >95% of the day in lie position; subsequently, proportion of day spent lying decreases. Begins sitting at 1 d old; begins to stand at 17–20 d. No difference between male or female chicks in development of lying, sitting, or standing. Wing-flapping, performed while sitting, first seen about 9–10 d old. Performed while standing, as chicks grow older. Flapping begins to increase during week 5, with frequency increasing linearly until fledging. Males developed flapping at a significantly greater rate than females. See Ellis 1979 and Collopy 1980 for details.

Parental Care

Brooding

Males in Idaho spent 74% of perched time at locations away from nest. Male almost never broods; female broods and shades young from hatch to about 45 d of age (observed once at 50 d; Ellis 1979, Collopy 1984). Time spent brooding to 19 d related to wind chill (Ellis 1979). Percentage of day brooding/shading decreases linearly from >80% at 1–10 d of age to <5% at 40 d (Collopy 1984). Female broods young nightly until 17–42 d after hatch (mean 29) and roosts on nest until 17–54 d (mean 40; Collopy 1984).

Feeding

From Ellis 1979 and Collopy 1984 . Both parents bring prey to nest, but male rarely feeds young directly. Adults may not feed young on hatch day; mean number of adult-fed meals/d increased rapidly during week 1 and decreased significantly during the nesting season (*n* = 10 broods). Biomass fed directly by female increased until fifth week; then decreased with linear increase of self-fed meals by young. Young begin self-feeding at 34–37 d old, and successfully tear carcasses at 45–55 d; by week 8, young consume more by self-feeding than fed by adults; increases in self-feeding coincide with development of standing behavior. No direct feeding after fledging.

Meal size increases throughout the nesting season; estimated morsel size fed ranged from 6 mm at hatching to 15 mm at fledging (Ellis 1979; Collopy 1980). Although chicks in multiple-chick broods received more food from adults than 1-chick broods, they had lower consumption rates from self-fed meals during late brood-rearing (Collopy 1984). Adult exhibits no chick bias in apportioning food, but dominant chick usually receives food first by intimidating subordinate chick (Collopy 1980, Edwards and Collopy 1983).

From Collopy 1984 . Both sexes hunt throughout brood-rearing period. Over entire nesting season, males delivered significantly more prey/d (1.2 deliveries ± 0.28 SE; 1,030 g/d ± 284.6 SE; *n* = 8) than females (0.6 deliveries ± 0.44 SE; 387 g/d ± 270 SE; *n* = 8). Male provided almost all food during first 2 wk (83% of deliveries and 95% biomass). Female increased prey deliveries in third week of brood-rearing, with maximum contribution in seventh–ninth weeks (43% of biomass); similar delivery rates for sexes during weeks 7–10. Prey size did not differ between male and female, but differed among nests.

Overall prey-delivery rates averaged 1.8 items/d in sw. Idaho (range 1.0–3.1) and 0.9/d in w. Texas during brood-rearing (Lockhart 1976, Collopy 1984). Delivered larger prey in Idaho (1,153 g) than in Texas (947 g). Mean delivery rates in sw. Idaho increased from 1.5/d during first 5 wk of brood-rearing to 2.6/d during sixth–seventh weeks, then decreased to 1.6/d during final 2 wk; delivery rates did not differ between 1- and 2-chick broods (Collopy 1984).

Nest Sanitation

Young expel feces several centimeters outside nest cup as early as 1 d, and consistently defecate over nest rim by 30 d (Ellis 1979). Food accumulates at nests, and nests may contain prey in various stages of decomposition (MNK). Adults sometimes remove or consume prey remains uneaten by young (Macpherson 1910, Hunsicker 1972, Hoechlin 1974), but uneaten prey not removed in 1,012 h of observation of 8 broods in Idaho (Collopy 1983a). May remove dead nestlings <3 wk old (Palmar 1954, USGS unpubl.). Brings in green plant material throughout the season to cover debris or perhaps repel ectoparasites (Wimberger 1984, Watson 1997). Ectoparasites can be abundant in nest material (see Demography and populations: disease and parasites, below). Several species of nonparasitic arthropods occur in eagle nests (Hickman 1968). Most have no effect on eagles, but Ellis (1979) reported retarded growth and weight loss of nestlings from a Montana nest where dermestid beetle larvae (*Dermestes* sp.) consumed prey items in the nest.

Carrying Of Young

Reports of parents carrying fledging-age young are rare and anecdotal (*n* = 4; Palmer 1988). Not recorded during intensive studies of fledging behavior (Dunstan et al. 1978, Ellis 1979, Collopy 1980, Walker 1987, Bahat 1992, O’Toole et al. 1999).

Cooperative Breeding

Occasional reports of trios (see Behavior: sexual behavior, above).

Brood Parasitism

None reported.

Fledgling Stage

Departure From Nest

For several weeks prior to fledging, nestlings flap wings and hop in practice flights; intensity increases as fledging approaches (see Young birds, above). Young leave nest as early as 45 d of age (USGS unpubl.) and as late as 81 d (Gordon 1955). In sw. Idaho, 101 chicks from 61 broods averaged 64.4 d (range 45–77) old at departure from nest (USGS unpubl.). Mean age at first flight was 10.1 wk (*n* = 28) in w. North Dakota (O’Toole et al. 1999). Departure from nest includes falling, jumping, walking, or flying. Departure can be abrupt, with young jumping off and using a series of short, stiff wing-beats to glide downhill or being blown out of nest while wing-flapping; often includes a short flight on unsteady wings followed by an uncontrolled landing (Camenzind 1969, CLM). Many departures before capable of flight are associated with chicks exposed to thermal stress or nest parasite infestations (USGS unpubl.). Occasionally young fledge unsuccessfully and are grounded; in most cases, parents feed and care for grounded young (Hickman 1968, MNK, CLM). No evidence, other than an anecdotal report (Miller 1918), that adults force young out of nests to encourage fledging. Adults may facilitate fledging by decreasing prey deliveries during last few weeks of brood-rearing (Collopy 1984). Self-sustained flight not usually achieved until >64 d of age (Brown and Amadon 1968).

Growth

During post fledging, muscle mass of juveniles develops, and flight feathers reach full growth (Jollie 1947). Because mass and skeletal growth reaches asymptote prior to fledging (Collopy 1980), mass fluctuates depending on food intake, and skeletal growth and development are minimal during postfledging (M. Collopy pers. comm.).

Association With Parents Or Other Young

Associates with parents and siblings for varying times after fledging; migrants may break association sooner than residents. Young stay with parents 1–6 mo after fledging (USGS unpubl.). At 1 nest in United Kingdom, fledglings stayed ≤70 m from nest for 2 wk, and male delivered food at safe perches near nest (Walker 1987). Females rarely provided food to fledged young in sw. Idaho; females made <5% of prey deliveries during postfledging period (M. Collopy pers. comm.). Siblings moved together after fledging in w. North Dakota, and usually stayed within 300 m of each other up to 121 d postfledging (O'Toole et al. 1999). Before independence, fledglings exhibit nonaggressive social behavior (O'Toole et al. 1999). Fledglings mutually preen or "nibble" when perched together (Ellis 1979), display "play" catching and plucking of prey together (O'Toole et al. 1999), and stoop, talon-touch, and talon grapple (Grant and McGrady 1999). Agonistic interactions between parents and offspring or between siblings rare, except just before or after fledglings gain independence (Walker 1987, 1988; Bahat 1992; Watson 1997; Grant and McGrady 1999; O'Toole et al. 1999).

Ability To Get Around, Feed, And Care For Self

Flying ability develops slowly, partly a consequence of incomplete flight-feather growth (Walker 1987). In Israel, females developed flying skills, flew longer distances, and moved farther from nest site sooner than males (Bahat 1992). Distance of fledglings from their nest increased significantly with time in w. North Dakota, but sexes did not differ in distance moved (O'Toole et al. 1999). Movements >5 km not observed until >29 d after fledging; movements >10 km not observed until >98 d after fledging in N. Dakota (O'Toole et al. 1999). First hunting attempts 28–68 d after fledging in Alaska, Israel, and England (Walker 1987, Bahat 1992, CLM). Fed at carcasses 35 d after fledging, and bathed 30 d after fledging (Walker 1987). Juveniles seek shade or lie prostrate in the sun with wings open and tail fanned during exceptionally hot weather (Walker 1987).

Immature Stage

In United Kingdom, independence estimated 75–85 d after fledging, when adults began territory defense displays toward their young (Walker 1988). Dependency on parents probably reduced to

≤2 mo at northern end of range in Alaska (Brooks Range and Seward Peninsula; Kessel 1989). Fledgling dispersal and independence 32–70 d (mean 56 d) after fledging in Denali National Park, AK, and coincided with in-itiation of migration. Most fledglings left natal areas in Denali within 20 d of one another (*n* = 48), but no evidence that young accompanied parents at onset of autumn migration or that siblings moved together (CLM).

Annual movements of first-year eagles from Denali averaged >5,500 km, with individuals migrating south to w. Canada and w. U.S. in autumn and north to w. Yukon and Alaska in spring (CLM). First-year eagles from Denali remained on wintering areas longer than adults and returned to northern latitudes 5–12 wk after adults (CLM). Most first-year eagles from Alaska showed tenacity to wintering areas; most did not wander once they reached the end of autumn migration (CLM). First-year eagles from Alaska returned to Alaska and Yukon during their second summer, but did not return to their natal areas (CLM).

Postindependence movements at temperate latitudes involve nonlinear wandering beyond the natal area (O'Toole et al. 1999). First-year eagles banded in Snake River Canyon, ID, dispersed from natal areas in nearly all directions (Steenhof et al. 1984). Most individuals did not move beyond boundaries of adjacent states; 78% of encounters were <100 km, and 1% of encounters were >1,000 km from banding locations (Steenhof et al. 1984). First-year eagles from sw. Idaho did not move significantly farther than older birds; 8 of the 9 most distant (>500 m) encounters were of birds >1 yr old (Steenhof et al. 1984). Subadults in the Altamont Pass area, CA, tend to be sedentary, showing only local or intrarange movements during the year (Hunt et al. 1999).

Radio-telemetry and banding data from Scotland suggest that as subadults reach breeding age, they tend to return to natal areas (Grant and McGrady 1999). May gain territories by killing territory holders (Hunt et al. 1995, Grant and McGrady 1999).

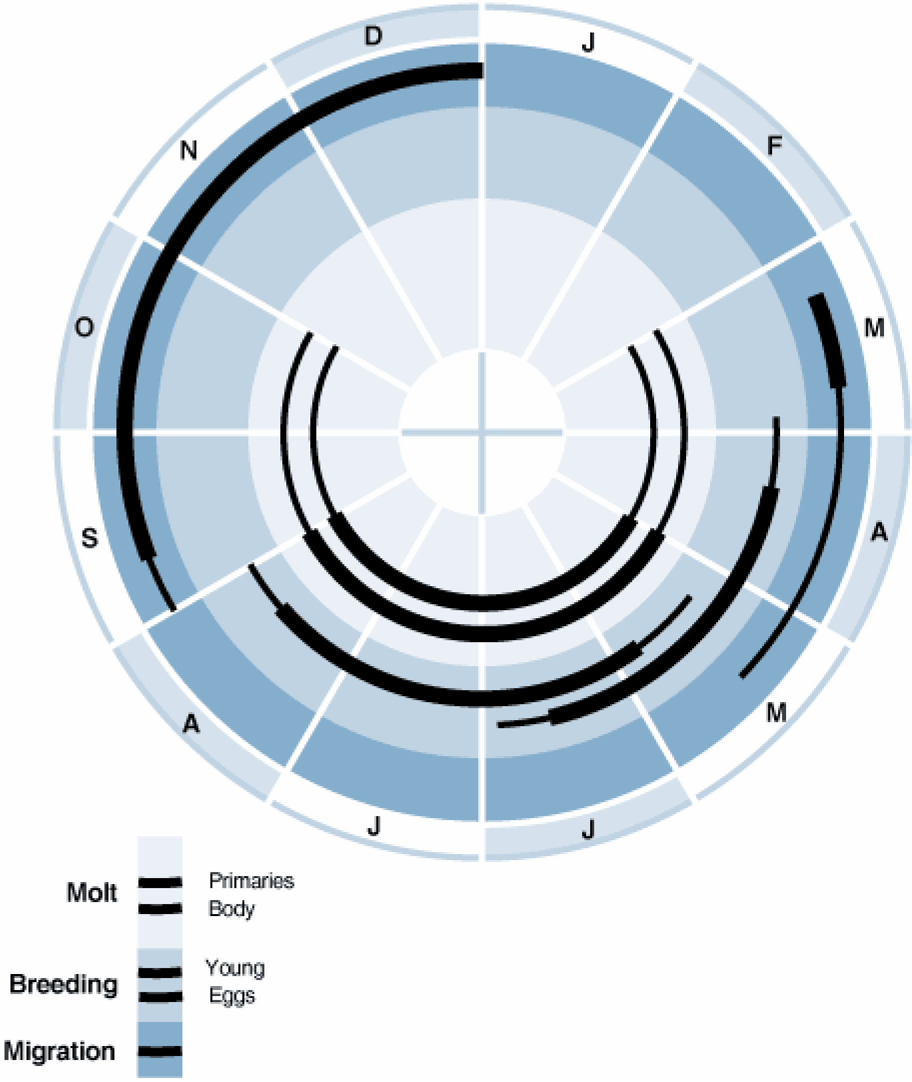

Fig. 3. Annual cycle of breeding, migration, and molt, Alaska.

of migratory Golden Eagles in Alaska. Thick lines show peak activity; thin lines, off-peak.

Demography and Populations

Measures Of Breeding Activity

Age At First Breeding

Six eagles marked as nestlings in sw. Idaho were 4–7 yr old when first detected on breeding territories (Steenhof et al. 1984). Generally breeds after attaining adult plumage, which is usually acquired in fifth summer, but capable of breeding earlier (see Distinguishing characteristics, above, and Appearance, below). In sw. Idaho, 0–13% of nesting pairs had 1 subadult (≤4 yr old) from 1970 to 1981; percentage of pairs with subadults related inversely to adult densities in preceding winter (Steenhof et al. 1983). In Denali National Park, AK, percentage of nesting pairs with subadults averaged 2% per year (range 0–6, *n* = 14 yr); all 7 breeding subadults were females (CLM). In central California, 1 pair had 2 subadults; percentage of pairs with ≥1 subadults ranged from 0 to 6% between 1996 and 2000 (G. Hunt pers. comm.). However, 51% of pairs in Norway had ≥1 subadult members (Bergo 1984). Territorial adults usually prevent subadults from nesting; most sub-adults nest in territories with high disturbance and high turnover rates (Steenhof et al. 1983) or where persecution has been high (Bergo 1984).

Clutch

See Breeding: eggs, above. Renests rarely when first clutch is destroyed (Watson 1997). No records of pairs producing >1 brood/yr.

Annual And Lifetime Reproductive Success

Long-term (≥10 yr) annual reproductive success (number of young reared to nest-leaving/pair): 0.78 in Montana and Wyoming (Phillips et al. 1990), 0.79 in sw. Idaho (Steenhof et al. 1997), 0.80 in Scotland (Watson 1957), 0.82 in Utah (Bates and Moretti 1994), 1.08 in Oregon (Thompson et al. 1982), and 0.66 in Alaska (McIntyre and Adams 1999). Annual reproductive success varies with prey abundance and weather in sw. Idaho: percentage of females that lay eggs each year related positively to jackrabbit abundance and inversely to winter severity; percentage of laying females successful related positively to rabbit abundance and inversely to frequency of hot spring days, when nestlings are susceptible to heat stress; see Causes of mortality, below (Steenhof et al. 1997). Prey abundance also influences annual reproductive rates in Utah, Alaska, and Europe (Smith and Murphy 1979, Tjernberg 1983, Bates and Moretti 1994, Watson 1997, McIntyre and Adams 1999).

Populations at northern end of range have smaller broods and produce fewer fledglings than those in temperate areas; mean brood size 12% lower in northern populations (*n* = 4 study areas) compared to temperature latitudes (*n* = 5 study areas; 1.38 vs. 1.56 fledglings/successful pair); population productivity 25% lower for northern populations (*n* = 2 study areas) compared to temperate latitudes (*n* = 3 study areas; 0.66 vs. 0.87 fledglings/occupied nesting area; McIntyre and Adams 1999). See Population regulation, below.

From Steenhof et al. 1997 and McIntyre and Adams 1999 . Percentage of pairs that lay eggs each year was the most variable reproductive component in both sw. Idaho and interior Alaska, varying from 38 to 100% in Idaho (mean 79% ± 15.5 SD [*n* = 22 yr]) and 33–90% in Alaska (mean 62% ± 8.7 SD [*n* = 10 yr]). Percentage of laying pairs successful ranged from 32 to 80% in sw. Idaho (mean 60% ± 13.9 SD [*n* = 23 yr]) and 42–82% in Alaska (mean 71%, *n* = 10 yr). Mean brood size at fledging ranges from 1 to 2 and averaged 1.56 ± 0.22 SD in sw. Idaho (*n* = 23 yr) and 1.43 in Alaska. Broods of 3 at fledging are relatively un-common and occur mainly in years of high prey abundance (Jenkins and Joseph 1984, USGS unpubl.).

Percentage of eggs that hatch: 57% in central Utah (*n* = 87 eggs, 44 clutches; Smith and Murphy 1979), 65% in sw. Idaho (*n* = 282 eggs, 145 clutches; USGS unpubl.), and 86% in s.-central Montana (*n* = 28 eggs, 14 clutches; Reynolds 1969). Percentage of nestlings that survive to leave nest: 77% in sw. Idaho (*n* = 302 young, 168 broods; USGS unpubl.), 80% in central Utah (*n* = 50 young, 35 broods; Smith and Murphy 1979), and 46% in s.-central Montana (*n* = 24 young; Reynolds 1969).

Few data on lifetime reproductive success. A marked male began occupying a nesting territory in Snake River Canyon, ID, at age 4; continued to occupy it for 14 consecutive years, was successful in 10 yr, and produced a total of 15 young (USGS unpubl.).

Life Span And Survivorship

Varies with age and geographic area. Postfledging mortality in Denali National Park, AK, estimated at 2%, and first-year survival after independence estimated at 18–46%, based on satellite telemetry (*n* = 48; CLM). Near a wind turbine facility in w.-central California, estimated survival rates, based on conventional telemetry of 257 individuals, were 84% ± 4 SE for first-year eagles, 79% ± 2 SE for 1- to 3-yr-olds and adult floaters, and 91% ± 2 SE for breeders; no difference in survival rates between sexes (Hunt 2001). Regression analysis of banding data suggested 50% of eagles in the Rocky Mtns. lived 3 yr, 25% lived 6 yr, 5% lived 13 yr, and 1% lived 20 yr (Harmata 2002).

Longevity record in North America, determined via banding encounters: 23 yr 10 mo (Klimkiewicz 1997). In Europe, life span 46 yr in captivity (Gordon 1955) and 32 yr in the wild (Staav 1990). Average life expectancy of adults in wild estimated at 39.5 yr in w. Scotland and 12 yr in Germany (Watson 1997).

Disease And Body Parasites

Diseases

Bacterial infections include avian cholera (*Pasteurella multocida*; Rosen et al. 1973), tuberculosis (*Mycobacterium avium*; Waterston 1959, Wilson and MacDonald 1965), and erysipelas (*Erysipelothrix insidiosa*; Bigland 1957). Cholera affects eagles that ingest waterfowl that have died from the same infection (Rosen et al. 1973). Although bacterial infections cause individual mortalities, their significance at the population level is unknown. At least 1 viral disease, avian pox (*Avipoxvirus*; Moffatt 1972), and 1 fungal disease, aspergillosis (*Aspergillus*), affect Golden Eagles. Pox is apparently rare, but 13% of 30 Golden Eagles presented for treatment at the University of Minnesota had symptoms of aspergillosis (Redig 1981). Most eagles with aspergillosis have some other debilitating injury or illness (P. Redig pers. comm.).

Infectious protozoans include hematazoa (*Leucocytozoon*; Stabler and Holt 1965), intestinal coccidia (*Isospora buteonis*; Mathey 1966), and flagellates (*Trichomonas gallinae*). Cysts from benign protozoan (*Sarcocystis* spp.) occur frequently on necropsy specimens (P. Redig pers. comm.). Trichomonads cause the most well-known and widespread protozoan infections. Eagles become infected with Trichonomas after feeding on pigeons and doves. Symptoms of trichomoniasis, or “frounce,” include yellow, caseous lesions in the oral cavity (Stabler 1941) that can block the esophagus and cause starvation. Four of 10 dead fledglings examined in Idaho died from trichomoniasis (Beecham and Kochert 1975); deaths from frounce affected at least 4% of 107 young that fledged from sw. Idaho in 1970 and 1971 (Kochert 1972).

Capillariasis, a disease caused by nematode worms, has been documented only in Scottish Golden Eagles (Watson 1997), but strongeid trematodes and nematodes were found in a dead eagle from Washington (Mathey 1966).

Body Parasites

Ectoparasitic arthropods that occur in nests include 2 species of ticks (*Ornithodoros concanensis* and *Haemaphysalis leporispalustris*; Hickman 1968, Knight and Marr 1983), 3 species of cimicids (Mexican chicken bugs [*Haematosiphon inodorus*]; Lee 1954, McFadzen et al. 1996; human bed bugs [*Cimex lectularius*]; and cliff swallow bugs [*Oeciacus vicarius*]; Hickman 1968), and a biting midge (*Leptoconops herteszi*; Hickman 1968). As many as 48 ticks were on a single eaglet, primarily around eyes and ears (Hickman 1968). Neither ticks nor cimicids seem to cause significant problems for eagles, but chicks in nests heavily infested by *H. inodorus* sometimes fledge prematurely (MNK). Ears and nostrils of nestlings sometimes infested by bird blowfly, *Protocalliphora* (Diptera: Calliphoridae), larvae that live in nest material and periodically suck blood of nestlings (Hill and Work 1947, Hill 1948); infestations appear as black crusts in and around ear openings and usually subside before eagles fledge, as larvae pupate; eagle mortality rarely results (Kochert 1972).

Feather lice (Phthiraptera) infect adults, primarily on head and neck (Pfaffenberger and Rosero 1984). Parasitic tromidiform mite larvae (*Harpyrhynchus*) also can cause progressive feather loss on head and neck (Schulz 1990).

Causes Of Mortality

Most recorded deaths result from human-related causes (Franson et al. 1995; see Conservation and management, below). Starvation was the most common cause of death among instrumented juvenile Golden Eagles from Denali National Park after postfledging period (CLM). Some eagles killed by intraspecific aggression in California and Scotland (Grant and McGrady 1999, Hunt et al. 1999). Some deaths result from injuries sustained when attacking porcupines (*Erethizon dorsatum*; Bortolotti 1984b).

Exposure

Susceptible to thermal stress during first 6 wk after hatching (Mosher and White 1976; see Breeding: nest site, above). Heat stress a significant mortality factor for nestlings in Idaho (Beecham and Kochert 1975). Nesting success and brood size at fledging inversely related to number of days with temperatures >32°C during brood-rearing (Steenhof et al. 1997).

Range

Initial Dispersal From Natal Site

Few data. See Breeding: immature stage, above. Known distances between hatching site and breeding area in the Snake River Canyon, ID, ranged from 6.7 to 64.7 km (1–12 territory widths) and averaged 39.6 km ± 24.1 SD (*n* = 4; Steenhof et al. 1984, USGS unpubl.). Males may be more likely to breed near their natal areas than females are; 5 of 6 eagles marked as nestlings in Snake River Canyon and later encountered there as breeders were males (Steenhof et al. 1984, USGS unpubl.).

Fidelity To Breeding Site And Winter Home Range

Generally faithful to breeding site; one individual remained on same nesting territory for ≥12 yr in Idaho (Snake River Canyon; USGS unpubl.).

Both residents and migratory individuals show fidelity to wintering areas. Ten eagles wintering in central Idaho were recaptured within 1.6 km of sites where they were first captured 1–5 winters earlier (T. and E. Craig unpubl.). Three of 4 immatures from Denali National Park wintered in the same areas in Alberta, Washington, and Montana in 2 consecutive winters (CLM), and adult migrants from Montana (*n* = 1 male) and Alaska (*n* = 1 female) returned to their respective wintering sites in Idaho for ≥2 consecutive years (T. and E. Craig unpubl., L. Schueck and J. McKinley unpubl.).

Dispersal From Breeding Site

Few data. A radioed female used nesting territories 15 km apart in consecutive years in Snake River Canyon (USGS unpubl.). Three individual radio-tagged breeders (1 female, 2 males) switched territories in California; settled in different territories within 8 km of their old ones 10 d–3 mo after leaving their original territories; construction of a new reservoir may have precipitated the female's move (G. Hunt pers. comm.).

Home Range

In w. U.S., forages over home ranges that average 20–33 km^2 during breeding season. Year-round home range size, based on radio telemetry, averaged 20.4 km^2 ± 7.1 SD (range 21.7–27.9) for 8 nesting pairs in ne. Wyoming and 32.5 km^2 ± 20.0 SD (range 15.1–61.3) for 4 pairs in se. Wyoming (Phillips and Beske 1982, Platt 1984); breeding-season range size varied from 26.1 to 54.0 km^2 for 5 pairs in n. Wyoming (Tyus and Lockhart 1979). Nesting-season range size averaged 23.1 km^2 ± 2.2 SE (range 16.9–30.2) in n.-central Utah, based on observations of 6 unmarked pairs (Smith and Murphy 1973).

Most comprehensive information on home range comes from Snake River Birds of Prey National Conservation Area in sw. Idaho. Breeding-season home range averaged 25.5 km^2 ± 22.0 SD (range 1.9–83.3) for 17 pairs in 13 territories during 3 studies conducted between 1975 and 1994. Range size for each study averaged 28.6 km^2 ± 20.5 SD (range 4.9–48.7, *n* = 4 radioed pairs;

Dunstan et al. 1978), 32.8 km^2± 17.7 SD (range 11.8–49.0, *n* = 1 radioed pair, 3 unmarked pairs; Collopy and Edwards 1989), and 20.8 km^2± 25.3 SD (range 1.9–83.3, *n* = 9 radioed pairs; Marzluff et al. 1997). Home-range boundaries at 4 territories remained fairly consistent over >20 yr; ranges in 1970s and 1990s were similar in size and configuration (Marzluff et al. 1997). Some pairs, however, expanded their ranges into neighboring vacant territories; the home range of a pair radio-tagged in sw. Idaho (Marzluff et al. 1997) included 90% of the former home range of its neighboring territory, determined by radio telemetry before the territory became vacant (Dunstan et al. 1978, Collopy and Edwards 1989).

Resident pairs maintain home range year-round with shifts in intensity of use from breeding season to winter (Dunstan et al. 1978, Marzluff et al. 1997). Al-though some pairs used smaller ranges in winter (mainly within nesting season home range), others used much larger winter ranges. A pair in se. Wyoming used a 13.6-km^2area in winter compared to 24.0 km^2in nesting season (Platt 1984), and 3 pairs in sw. Idaho used a mean winter range of 8.9 km^2± 7.4 SD (range 3.3–17.3) compared to 32.0 $km^2$for nesting (Dunstan et al. 1978). Range sizes of 8 resident pairs in sw. Idaho varied during nonbreeding season but were about 10 times larger than breeding-season range (mean 304.8 km^2± 599.1 SD [range 13.8–1,760.0]; Marzluff et al. 1997). These larger ranges resulted from periodic excursions outside core areas; 95% harmonic-mean ranges that excluded these excursions were similar in size to other reported home ranges (Marzluff et al. 1997). These excursions represent searches for breeding and foraging opportunities. A female in sw. Idaho included a territory 15 km from her nest (a move of 3 territories) in her excursions 1 winter; she settled and bred in the new territory the next spring (Marzluff et al. 1997, USGS unpubl.).

Individuals do not use all areas within their home range but instead concentrate activity within core areas (Platt 1984, Marzluff et al. 1997). Core areas contained 95% of locations of radio-tagged eagles but only 14.4% ± 3.1 SE of the breeding-season home range and 25.3% ± 5.8 SE of the nonbreeding-season range in sw. Idaho (*n* = 9; Marzluff et al. 1997). Ranges of neighboring pairs in sw. Idaho overlapped only slightly in the breeding season (mean 3.7% ± 1.7 SD; *n* = 10) but overlapped more during nonbreeding season (mean 22.1% ± 9.4 SE; Marzluff et al. 1997). Distance traveled from nest did not differ among years or between sexes, but mean distance traveled during breeding season (1,047 m ± 367 SE) was significantly less than during nonbreeding season (3,036 m ± 241 SE; Marzluff et al. 1997). Breeding-season range size was similar for males and females of a pair (Dunstan et al. 1978) and tended to increase with total number of young fledged (Marzluff et al. 1997).

Wintering migrants sometimes occupy large areas and may wander nomadically. Juvenile males (*n* = 3) from central Alaska tracked via satellite telemetry occupied wintering areas in w. U.S that ranged from 1,700 to 262,000 km^2; 5 juvenile females used 2,200–59,000 km^2(CLM). Average 90% core use areas based on a combination of locations from conventional radio and satellite telemetry of migrants differed significantly between adults and immatures during 2 winters in sw. Idaho: 43.6 km^2± 31.0 SD for 6 adults and 248.1 km^2± 96.6 SD for 3 immatures (L. Schueck et al. unpubl.). These ranges did not include long excursion flights made by tagged individuals. Size of area used by males and females did not differ. Winter home ranges of adults overlapped considerably (mean 36.3% ± 15.7 SE in 1993 and 58.3% ± 12.8 SE in 1994). One adult female used same home range (100% overlap) in 2 successive winters.

Population Status

Density

Amount of area/nesting pair varies from 29 to 251 km^2/pair in w. U.S. habitats. Densities are highest in Denali National Park, AK: 28 km^2/pair (McIntyre and Adams 1999); total area/pair ranges from 34 to 89 km^2/pair (mean 60) in Wyoming (Phillips et al. 1984), 100–119 km^2/pair in Utah (Camenzind 1969, Edwards 1969), 66 km^2/pair in sw. Idaho (Kochert 1972), 65–192 km^2/pair in Montana (Reynolds 1969), and 252 km^2/pair in Nevada (Page and Seibert 1973). Densities in Hudson Bay much lower than in w. U.S.: 961 km^2/pair (Morneau et al. 1994).

Year-round densities vary by state. Government biologists reported the following number of eagles encountered/1,000 km driven from 1970 to 1972: Wyoming, 10.4; Utah, 5.0; Colorado, 3.3; New Mexico, 1.6; Arizona, 1.2; Texas, 0.3; Oklahoma, <0.1 (Boeker 1974). Note: Watson (1997) converted these data in-correctly and misreported them as aerial-survey results.

Winter densities along aerial transects were greater in parts of New Mexico (0.2–3.5/100 km^2) than in the Trans-Pecos region of Texas (0.16–1.4/100 km^2), 1963–1968 (Boeker and Bolen 1972). New Mexico counts were more variable during winter, reflecting arrival and departure of migrants. Mean densities along aerial transects in 6 western states averaged 5.5/100 km^{2}from 1973 to 1979 (yearly range 4.8–7.3/100 km^2). Wyoming and nw. Colorado had greatest densities (up to 18/100 km^2), followed by Utah, Montana, Idaho, and New Mexico (USFWS 1981). Winter densities in s. Idaho correlate strongly with black-tailed jackrabbit abundance (Kochert 1980, Craig et al. 1984).

Numbers

Up to 100,000 individuals in North America during the 1970s (Braun et al. 1975). Between 2,000 and 10,000 breeding pairs in Canada (Kirk and Hyslop 1998). Few data on abundance in U.S. since mid-1980s. Olendorff et al. (1981) estimated 63,242 wintering individuals in 16 w. U.S. states. Estimated number of breeding pairs: 3,381 in Wyoming (Phillips et al. 1984), 1,200 in Nevada (Herron et al. 1985), and 500 in California (Thelander 1974). Number of known territories, 1977–1986: Wyoming, 804; Oregon, 506; Colorado, 500; Nevada, 430; Washington, 190; Idaho, 156; and Montana, 50 (Harlow and Bloom 1989).

Trends

Long-term surveys show declines in nesting populations in w. U.S. but not Alaska or Canada (Kochert and Steenhof 2002). Number of occupied nesting territories declined significantly from 35 to 29 (average annual change: –0.71%) in Snake River Canyon between 1971 and 1994 (Steenhof et al. 1997); declines associated with loss of shrubs and jackrabbit habitat due to widespread fires (Kochert et al. 1999). Nesting populations in San Diego Co., CA, decreased from an estimated 85 pairs in 1900 to 40 occupied territories in 1999 due to extensive residential development (D. Bittner and J. Oakley unpubl.). Number of nesting pairs in a Colorado study area declined from 10 in 1972 to 7 in 1990 (Leslie 1992). Number of nesting pairs in ne. U.S.

declined from 8 pairs in 1951 (Todd 1989) to 2 pairs in 1999 (C. Todd pers. comm.). Nesting populations and productivity in Canada likely stable (Kirk and Hyslop 1998).

Breeding Bird Surveys (BBS) and Christmas Bird Counts (CBC) have limited value for detecting trends because of few routes in Golden Eagle habitat and low number of individuals counted. BBS data show no trend for nesting Golden Eagles either on a regional or continental scale (Sauer et al. 2001); CBC data suggest Golden Eagles increased significantly at 2.8%/yr throughout U.S. and Canada from 1955 to 1999 (J. Sauer and W. Link unpubl.).

Migration counts in e. U.S. and e. Canada suggest a decline in Golden Eagle passage rates from 1930s to early 1970s, with stable or increasing trends since early 1970s (Bednarz et al. 1990, Titus and Fuller 1990, Hussell and Brown 1992, Hawk Mountain Sanctuary unpubl., L. Goodrich pers. comm.). No significant trends at migration sites in w. North America since mid-1980s, but increases in adult detection rates and a decrease in migratory immatures may indicate lowered reproduction in parts of w. U.S. in response to habitat changes (J. Smith pers. comm.).

Population Regulation

Availability of food and nesting sites ultimately determines nesting density (Hunt et al. 1995). Territorial behavior apparently limits number of nesting pairs in stable environments (Brown and Watson 1964, Watson and Langslow 1989). Most populations include nonterritorial adults known as “floaters,” individuals that cannot nest because all suitable territories are occupied; floaters fill vacancies as they occur and thereby contribute to population stability (Hunt et al. 1995). Number of territorial pairs in sw. Idaho and interior Alaska did not fluctuate with annual changes in prey abundance and weather (Steenhof et al. 1997, McIntyre and Adams 1999), but long-term habitat change may affect number of pairs that an area can support. Some pairs abandoned territories after wildfires destroyed jackrabbit habitat adjacent to Snake River Canyon; remaining pairs expanded their ranges and subsumed neighboring vacant territories, resulting in a smaller nesting population (Kochert et al. 1999).

Reproductive rates fluctuate with prey densities and weather conditions (Smith and Murphy 1979, Tjernberg 1983, Bates and Moretti 1994, Steenhof et al. 1997, McIntyre and Adams 1999). Jackrabbit abundance limited reproduction in sw. Idaho during 15 of 23 yr, and weather influenced how severely reproduction declined in those years. Annual reproductive output is influenced most strongly by proportion of pairs that lay eggs (Steenhof et al. 1997). Many pairs do not lay eggs during periods of low prey abundance (Smith and Murphy 1979, Steenhof et al. 1997, McIntyre and Adams 1999). Laying rates related to conditions prior to nesting season. Females lay eggs if they are able to gain body mass and mobilize reserves for egg production; insufficient food supplies and/or increased energy needs due to cold weather will prevent egg-laying (Tjernberg 1983). Well-fed eagles can withstand cold better than food-stressed individuals (Stalmaster and Gessaman 1984). Percentage of pairs laying eggs in sw. Idaho was related positively to black-tailed jackrabbit abundance and inversely to winter severity (Steenhof et al. 1997). Migratory populations that nest in northern parts of range produce smaller broods and fewer fledglings than resident eagles in temperate regions, possibly due to energetic costs of migration and a combination of severe climate and low prey diversity on breeding grounds (McIntyre and Adams 1999). Spring weather may affect survival of nestlings in more southern areas: young are susceptible to thermal stress during first 6 wk after hatching (Mosher and White 1976). Nesting success and brood size at fledging were related positively to jackrabbit abundance and inversely to frequency of hot spring days in sw. Idaho; inadequate food interacted with high temperatures to cause nestling mortality in years with low rabbit populations (Steenhof et al. 1997). Frequent interactions between floaters and territory holders in areas of the Swiss Alps with high floater densities apparently reduce reproductive success of territorial pairs (Haller 1996), but no evidence for this in North America.

Conservation and Management

Effects Of Human Activity

Humans cause >70% of recorded deaths, directly or indirectly (Franson et al. 1995). Accidental trauma (collisions with vehicles, power lines, or other structures) is the leading cause of death (27%), followed by electrocution (25%), gunshot (15%), and poisoning (6%; Franson et al. 1995).

Shooting And Trapping

Traditionally shot in parts of North America where depredation of domestic sheep was suspected. Unregulated aerial hunting of eagles began in California as early as 1936, with >200 killed that winter. From 1941 to 1961, 20,000 may have been shot from airplanes in southwestern states (Spofford 1964). Hunting clubs in w. Texas shot nearly 5,000 from 1941 to 1947; shooting may have reduced number of breeding pairs in parts of Texas and New Mexico (Phillips 1986). In 1971, >500 killed in Colorado and Wyoming by helicopter gunmen hired by sheep ranchers (Beans 1996). Illegal shooting continues to occur; no information on recent trends or levels.

Incidentally trapped and poisoned throughout w. North America by attempts to bait and kill mammalian carnivores (Bortolotti 1984b). At least 10 died in 1971 from eating thallium sulfate–laced antelope set out by sheep ranchers in Wyoming; despite public outcries, poisoning by sheep ranchers continued into 1980s (Beans 1996). Attracted to exposed bait associated with snares, leg-hold traps, and strychnine sets designed to catch or kill wolves (*Canis lupus*), foxes, bobcats, and coyotes. Most trapping/poisoning deaths have occurred in winter; females more susceptible to incidental trapping/poisoning than males, possibly due to spatial/geographic segregation of sexes in winter (Bortolotti 1984b).

Native Americans have harvested young Golden Eagles for religious purposes in southwestern states for many years (Fewkes 1900, Hough 1971); harvest was widespread historically (Palmer 1988). Members of the Hopi tribe remove nestlings from nests in Apr, raise them in captivity, and sacrifice them when they are fully feathered in Jul. Since 1986, the U.S. Fish and Wildlife Service has issued a permit to the Hopi to legally conduct these activities. Reported take has varied from 3 to 28 each year (J. Bart pers. comm.).

Pesticides And Other Contaminants/Toxins

Less susceptible than most raptors to organochlorine pesticides because of mammal-feeding habits. Eggs collected after 1946 had shell thicknesses similar to (<10% difference) those collected in earlier years (Anderson and Hickey 1972). From 1964 to 1975, when many organochlorine pesticides were still legal, DDE and dieldrin levels in eggs and tissues from Golden Eagles in w. North America were below thresholds known to cause reproductive problems (see Reynolds 1969, Kochert 1972, Reidinger and Crabtree 1974, Noble et al. 1993 for exact levels). From 1990 to 1993, 48% of migrant eagles in w.-central Montana had detectable levels of DDE in their blood, but maximum concentration was <0.021 ppm wet weight (Harmata and Restani 1995). No dieldrin detected.

Secondary poisoning occurs when individuals consume prey killed or sickened by chemicals used to protect crops or kill rodents. Golden Eagles susceptible to phorate (Mineau et al. 1999), carbofuran (Mineau 1993), strychnine (Littrell 1990), and anticoagulant rodenticides (Stone et al. 1999). From 1977 to 1980, 3 dead in Oregon had lethal (>8 ppm) levels of heptachlor epoxide; poisoned eagles apparently ate prey that had eaten heptachlor-treated seed (Henny et al. 1984). From 1990 to 1993, heptachlor epoxide levels in plasma of vernal migrants in w.-central Montana were <0.039 ppm wet weight (Harmata and Restani 1995).

Mercury contamination occurs infrequently and at low levels. Mercury detected at low levels (<1 ppm) in only 22% of 77 migrants sampled in Montana, 1985–1992 (Harmata and Restani 1995), and no wintering eagles sampled in Idaho from 1990 to 1995 had elevated mercury levels (Craig and Craig 1998). Eggs collected in Canada from 1968 to 1975 contained mercury at levels too low (<0.35 mg/kg) to affect reproduction (*n* = 22; Noble et al. 1993). Mercury residues in eggs and tissue from Idaho were below lethal levels (<1 ppm), but some nestlings from agricultural areas had elevated mercury residues in feathers, apparently because they ate Ring-necked Pheasants that had eaten seed treated with methyl mercury (Kochert 1972).

Ingestion Of Lead

Elevated blood-lead levels (>0.20 ppm) occurred in 36% of 162 eagles from s. California, 1985–1986 (Pattee et al. 1990), 46% of 281 wintering eagles from Idaho, 1990–1997 (Craig and Craig 1998), and 56% of 86 spring migrants in Montana, 1985–1993 (Harmata and Restani 1995). Sources of lead have not been definitively documented; likely ammunition in hunter-killed upland game birds and mammals (Wayland and Bollinger 1999), particularly deer (Pattee et al. 1990) and ground squirrels (Harmata and Restani 1995), with waterfowl as a secondary source. Blood-lead levels vary with season (Pattee et al. 1990). Eagles that consume prey items contaminated with lead may experience only temporary elevations in blood lead (Harmata and Restani 1995). However, blood-lead levels of recaptured wintering individuals in Idaho did not decrease over 1–5 yr, suggesting repeated or continual exposure to lead in the environment (Craig and Craig 1998). Chronic subclinical lead exposure may weaken eagles and predispose them to injury, predation, starvation, disease, or reproductive failure (Kramer and Redig 1997, Craig and Craig 1998). Mortality from ingested shot and bullet fragments occurs occasionally (P. Redig pers. comm.). Four of 31 dead eagles from Canadian Prairie Provinces (13%) had been lead poisoned from 1990 to 1996 and 3 (10%) were sublethally exposed to lead (Wayland and

Bollinger 1999). In Idaho, 7 of 16 eagles necropsied between 1977 and 1986 were lead-poisoned (Craig et al. 1990).

Collisions/Electrocutions

Killed by collisions with cars, fences, wires, and wind turbines. Nearly 1,000 killed on highways near Rock Springs, WY, in winter 1984–1985 (Phillips 1986). At least 28–43 killed annually by turbine blade strikes in the Altamont Pass Wind Resource Area, CA. Of 61 mortalities in the Diablo Range, CA, 1994–1997, 37% were turbine strikes, 5% car strikes, 3% fence collisions, and 16% electrocutions (Hunt et al. 1999).

Vulnerable to electrocution when landing on power poles. Less-adept immatures are most susceptible. Risk increases when inclement weather hampers flight or when wet feathers increase conductivity (Avian Power Line Interaction Committee 1996). Most mortalities occur during winter in western states where natural perches are lacking; poles with cross arms diagonal or parallel to prevailing winds are most lethal (Benson 1981, Harness and Wilson 2001). From 1986 to 1996, ≥272 electrocution deaths occurred in w. North America; 3-phase and single-phase transformers caused most electrocutions (Harness and Wilson 2001). See Management, below, for information on efforts to reduce electrocutions.

Degradation Of Habitat

Fires since 1980 have caused large-scale losses of shrubs and jackrabbit habitat in areas used by eagles throughout the Intermountain West. Wildfires that burned >40,000 ha of shrublands between 1981 and 1987 in the Snake River Birds of Prey National Conservation Area affected nesting populations adversely. Nesting success at burned territories in Snake River Canyon declined after major fires. Abandoned burned territories have been subsumed by neighboring pairs, resulting in a decreased number of nesting pairs (Kochert et al. 1999).

Mining and various types of energy development occur in eagle nesting and wintering habitat. Surface coal mines threaten limited nesting sites in Wyoming (Phillips and Beske 1984). Mine high walls provide new nesting habitat, but reclamation laws require that high walls be eliminated (Fala et al. 1985). Nests with broods have been relocated up to 1.4 km in Wyoming to move young from proposed mining areas or existing mine high walls scheduled for elimination (Postovit et al. 1982, Fala et al. 1985). Pairs at relocated nests have been successful for >20 yr (H. Postovit pers. comm.).

Urbanization and human-population growth have made areas historically used by eagles unsuitable, particularly in s. California (Scott 1985) and the Colorado Front Range (Boeker 1974). Extensive agricultural development reduces jackrabbit populations and makes areas less suitable for nesting and wintering eagles (Beecham and Kochert 1975, U.S. Dept. of the Interior 1979, Craig et al. 1986).

Disturbance At Nest And Roost Sites

Recreation and other human activity near nests can cause breeding failures, but most evidence is anecdotal or correlative. Nesting success in Scotland was related inversely to human disturbance around nests (Watson 1997). Adults spent less time at nests and fed young less food less frequently when observers camped 400 versus 800 m from nests in Alaska (Steidl et al. 1993). Abandoned territories in San Diego Co., CA, had more dwellings within 1.6 km and higher human populations within 4.8 km than territories that continued to be occupied (Scott 1985). Not particularly sensitive to sonic booms or low-level jets in Arizona (*n* = 1 nesting pair; Ellis et al. 1991).

Direct Human/Research Impacts

Climbers sometimes kill eggs/young when they: (1) spend too much time at nest and cause parents to abandon eggs or young; (2) keep parents off nest long enough to subject eggs or young to overheating or cooling; (3) flush an adult, who kicks an egg or young out of nest; (4) cause a nest to collapse; or (5) cause young to fledge prematurely. These cases are rare and can be avoided with proper precautions (USGS unpubl.). Nestlings in Montana experienced loss of mass when parents temporarily abandoned nests following a prolonged visit to nest by researchers, but all nestlings later fledged at or above normal weights (Ellis 1973). Pairs whose young were banded in 3 Rocky Mtn. states (*n* = 23) were more likely to move to alternate nests or not breed the following year than pairs whose young were not banded (*n* = 53; Harmata 2002).

Fixed-wing aircraft surveys of nests in Rocky Mtns. caused no desertions or mortalities; attempts to drive eagles from nests during low passes were unsuccessful (Boeker 1970). Close approaches with fixed-wing aircraft and helicopters never caused adults or nestlings to flush from Montana cliff nests (DuBois 1984). During 906 helicopter passes by nests with incubating adults in sw. Idaho and interior Alaska (*n* = 20 yr), only 11 adults flushed from nests. Adults perched off nests were more likely to flush: 121 of 227 adults observed perched near sw. Idaho nests flushed during helicopter checks throughout nesting season. No young fell or flushed prematurely from nests during 778 helicopter checks of nests with young in sw. Idaho and Denali National Park, AK (USGS unpubl., CLM).

Wing markers had no adverse effects on individuals marked as nestlings in sw. Idaho (Kochert et al. 1983), and adults wearing colored wing markers in Wyoming (*n* = 6) exhibited normal reproductive behavior and above-average reproductive success (Phillips et al. 1991a). In sw. Idaho, 9 nesting pairs with adults wearing backpack radio transmitters had similar productivity and success rates as control pairs (*n* = 3 yr; Marzluff et al. 1997).

Management

Adults, young, eggs, and nests protected since 1962 in U.S. by Bald and Golden Eagle Protection Act. Amendments passed in 1978 authorize and regulate “taking” of unoccupied nests on resource development sites. Federal regulations outlawed use of aircraft to kill eagles in U.S. in fall 1962. Protected in Canada, Mexico, and U.S. by Migratory Bird Treaty Act. Used for falconry by a few individuals; rigorous standards limit the number taken from the wild (USFWS

1987). U.S. Fish and Wildlife Service authorizes permits to allow Native Americans to take and possess eagles and their parts for religious purposes (see Effects of human activity, above).

Biologists, engineers, and government officials have cooperated in developing and publicizing power-pole designs that reduce raptor electrocutions. Since early 1970s, utility companies have modified poles to prevent eagle electrocutions; some new power lines in nonurban areas have been built to raptor-safe construction standards (Avian Power Line Interaction Committee 1996).

Hacking techniques used to establish or re-establish populations in parts of the range. Hacking involves placing 6- to 8-wk-old nestlings in artificial cages. Humans care for young until they are 12 wk old, when the cage is open and birds are allowed to leave and begin feeding themselves; fledglings continue to be fed at hack sites for 4–6 wk until young achieve independence. Efforts to establish breeding populations in the s. Appalachians began in 1981 at the Pisgah National Forest, NC (Hammer and Reed 1983). Eagles subsequently reintroduced to Kansas (May and Weigel 1989), Tennessee (B. Anderson pers. comm.), and Georgia (Touchstone 1997), using both captively bred birds and young from nests in Wyoming and Colorado. At least 1 individual hacked in Georgia later successfully fledged 7 young between 1991 and 2000, 5.4 km from the hacking site (T. Touchstone pers. comm.), and another successfully fledged 4 young between 1993 and 1996 in Tennessee >200 km from the hacking site (B. Anderson pers. comm.).

Occasionally responsible for losses of young domestic sheep in several western states during lambing season (Phillips et al. 1991b), particularly in cool, wet springs when rabbit populations are low (Matchett and O’Gara 1987). Federal agents assist livestock operators by trapping and relocating eagles suspected of killing livestock. In 1975, 145 eagles were trapped and relocated (USFWS 1982). Most residents returned to their original territories after relocation (Phillips et al. 1991b). Relocation of migratory eagles as far as 322 km was successful in reducing depredation on a short-term basis (Waite and Phillips 1994), but translocations are expensive and may only transplant the problem (Matchett and O’Gara 1987). Scarecrows, combined with harassment, may be another way to protect lambs from eagles (Matchett and O’Gara 1987).

Management of healthy eagle populations requires maintaining prey habitat in foraging areas. In shrub-steppe habitats, this involves sustaining native shrub communities, which are prime habitat for black-tailed jackrabbits (Marzluff et al. 1997, Kochert et al. 1999). Shrub communities should be protected within 3 km of nests, and communities can be maintained primarily through active fire suppression and secondarily by restoring shrubs in burned areas (Kochert et al. 1999).

Appearance

Adult Golden Eagle, Goshute Mountains, Nevada, October 1999.

Juvenile Golden Eagle, Cape May Point, New Jersey, October 1994.

Golden Eagle Sub-adult I, Goshute Mountains, Nevada, September 1999.

Golden Eagle Sub-adult II, Goshute Mountains, Nevada, October 1998.

Molts And Plumages

Hatchlings

Mostly covered in down at hatching. Prepennae down short, pale gray with dark tips (Jollie 1947) or white (Hoechlin 1974); patches of skin exposed along vertebrae and ventral surface (Jollie 1947). Down darker on nape, back, and upper surface of wings. Dark down around eye and edge of eyelid; short, thick, white down rims ear (Jollie 1947, Nakajyo et al. 1983). Long, white, preplumulae down emerges about day 6, progressively obscuring prepennae down by about day 15 (Jollie 1947). Preplumulae down grows for about 30 d, forming dense, nearly waterproof covering on chick (Palmer 1988).

Juvenal Plumage

Primaries break skin around 15 d, followed by secondaries, scapulars, and rectrices at 18 d (Sumner 1929a, Ellis 1979, Watson 1997). Primaries rupture sheaths at 21 d followed by secondaries, scapulars, and rectrices. Greater upper wing-coverts break skin between 22 and 25 d and burst sheaths around 27 d (MNK). Dorsal and ventral tracts emerge through skin between 22 and 28 d and break sheaths 29–35 d (Seidensticker 1968). Capital, femoral, and crural tracts break skin between 29 to 35 d and rupture sheaths between 36 and 42 d (Seidensticker 1968). Capital feathers continue to rupture sheaths until about 49 d. At about 56 d, preplumulae down begins to be replaced by plumules of Juvenal plumage (Jollie 1947). Juvenal feathering essentially complete about 60 d (Watson 1997). Full feather growth complete by 80–105 d (Jollie 1947, Nakajyo et al. 1983).

Juvenal plumage retained about 9 mo. Distinctive because all feathers same age, show same amount of wear, and are uniform in color, shape, and length (Bent 1937, Jollie 1947); exception is possible replacement feathers, which usually are not at molt centers, or molted symmetrically (P. Bloom and W. Clark unpubl.). All feathers dark brown with the following exceptions: Lanceolate feathers on head and nape often golden brown and contour feathers dark brown to blackish on recently fledged eagles (Bent 1937, Watson 1997). Primaries dark brown; inner primaries occasionally have white at base. Secondaries usually have white bases which always lack grayish marbling (Jollie 1947, Palmer 1988). Occasionally some upper wing-coverts also white (Johnsgard 1990), and some also have small white "epaulet" at upper end of scapulars (Spofford 1961). Rectrices predominantly white with dark terminal band of varying width; distinct border between white and dark part of feather (Jollie 1947, Tjernberg 1988). Dark flecks or grayish lines sometimes present in white area, particularly near irregular border between white and dark (Jollie 1947, Watson 1997). Under tail-coverts paler than remaining underparts, but feathered tarsi may also be paler approaching whitish (Jollie 1947, Clark and Wheeler 1987). Sexes similar.

Molt Patterns After Fledging

After Jollie 1947, Watson 1997, P. Bloom and W. Clark unpubl., and others as noted. Annual molt is incomplete, with 2–3 yr required to replace complete set of feathers. Molt usually occurs from Mar/Apr through Sep/Oct, and transition from one plumage class to another occurs during this time. Molt usually suspended during winter and migration, but occasionally 1 or 2 feathers grow during this period. First molt (Prebasic I) begins at 10–12 mo, continues through summer, and resumes the following summer. Replacement of all Juvenal feathers usually complete by end of third molt. From then on, molt proceeds in a continuous cycle in which there are ≥3 ages of feathers: fresh, the previous molt, and the molt before that. These different ages of feathers are recognizable by their color and wear. Juvenal secondaries and rectrices narrower, longer, and more pointed than replacement feathers in subsequent molts.

Molt occurs in predictable pattern, but rate may vary among individuals, depending on environmental factors and physiological conditions. Body molt usually begins before flight-feather molt and generally proceeds anterior to posterior; begins at head and neck, progressing to back and belly. Head, neck, back, throat, scapular tracts, and alulae usually replaced each year. Molt of flight feathers begins with primaries, starting with P1 and progresses outward, usually stopping at P4 or P5 by end of first molt. Next molt continues from where it left off previous year and proceeds in subsequent molts in a progression of waves; third molt usually begins at innermost primary again, at the same time that remaining outermost primaries are replaced. Molt of secondaries begins sometime in midsummer (May–Jul), well after primary molt has begun. Usually 3 different molt centers in secondaries, all molting simultaneously; generally starting with S1 and molting inward, S4 or S5 and molting inward (but occasionally outward), and S14 and molting outward. From second molting season onward, normally has at least 3 ages of secondaries, with molt proceeding from where it left off the previous year. Tail molt often begins with R1 and continues symmetrically outward, but variation in order of rectrix molt common. As many as 9 rectrices may be replaced annually; some are molted every year and others every 2 yr. Tail-feathers replaced more frequently than secondaries and primaries.

Size of white area in wings and tail once thought to be indicator of relative age, with white decreasing over time (Bent 1937). However, this character is highly variable among individuals (Tjernberg 1988); age cannot be determined solely by amount of white in flight feathers (Clark and Wheeler 1987).

An alternative method to age individuals in the hand through the fourth year is based on pattern of molt in remiges and rectrices. Most eagles reach adult plumage soon after they are 4 yr old, but some may still retain some white in the tail through the fifth or sixth molt; differences in plumage characteristics are subtle after the fourth year (Tjernberg 1988). Individuals vary in plumage and rates of molt; variation in molt increases with age, making it more difficult to assign age reliably, particularly beyond the second summer. General patterns of molt for an "average" eagle have been identified and are described in the following plumage classes (Jollie 1947, P. Bloom and W. Clark unpubl.). Because n. Alaskan birds fledge later than eagles in the lower 48 states, they may not fit molt categories described below.

Basic I Plumage

Usually attained by end of second summer of life. Characterized by 2 ages of feathers: new ones dark and shiny; old ones faded and worn. Older primaries appear lighter at the base than new ones; P1–6 may be new. New rectrices retain extensive white areas, have grayish marbling in the dark tip, and are shorter and blunter than the pointed Juvenal feathers. Border between white base and dark tip often less defined than in Juvenal plumage. Two to 9 rectrices new; usually includes R1 and r2. New secondaries at 3 molt centers are darker and wider and have more blunt tips and varying amounts of grayish marbling toward the base than Juvenal feathers. Usually replaces 1–6 secondaries, but some eagles don't molt secondaries the first molt. Median and lesser upper wing-coverts are light colored and evenly worn; under wing-coverts begin to be replaced in this plumage and have a characteristic rusty-brown color. May have somewhat mottled appearance caused by new body-feathers.

Basic II Plumage

Usually attained by the third summer and characterized by 3 ages of primaries; 1 or both P10s usually old (retained Juvenal). Molt of primaries appears as a wave proceeding outward on the wing; newest feathers outermost. Most secondaries have been replaced at least once and have grayish marbling with dark tips; may still have some white at the base. Most secondaries usually replaced, although 1–5 Juvenal secondaries may be retained; S9 often replaced last. Normally 2 ages of non-Juvenal rectrices with gray marbling and white bases; shorter and wider than Juvenal rectrices. Border between white and dark in tail more diffuse and jagged than in younger birds. Molt pattern for rectrices irregular for this and subsequent age classes; asymmetrical molt common. Some may have a few adult-type remiges and rectrices. Most upper wing-coverts dark, but with scattered, light, older feathers or groups of feathers.

Basic III Plumage

Attained during fourth summer. Three ages of feathers: both P10s new. Most secondaries "adult" with grayish marbling and dark tips; usually lack white at base. Juvenal secondaries usually no longer present. White pattern under wing, if present, divided by dark primaries and secondaries. New rectrices have marbling in dark areas, lack white, or have reduced white areas at base; others may still show extensive white areas. Tail typically has dark central "pillar" where "adult-type" R1 and r2 have grown in; still suggests Juvenal tail at a distance. Upper wing-coverts predominantly faded but interspersed with groups of new, dark feathers.

Definitive Basic Plumage

Usually attained during fifth summer. Adult plumage characterized by 3 ages of feathers. Entire plumage dark brown except area encompassing rear crown, postocular region, nape (extending forward to rear border of to ear-coverts), and sides of lower neck golden brown; rear underparts (mainly under tail-coverts) and some upper wing-coverts paler and buffier (Watson 1997). Paler wing-coverts usually mainly include median-coverts, larger lesser-coverts and innermost 1 or 2 greater-coverts. All flight feathers marbled with dark tips. Usually lack white areas on bases of tail or flight feathers. Feather-tips form dark band on trailing edge of wing. Rectrices marbled with wide, black terminal band; may have uniform gray base or dark bars on dark gray; background rarely white or light gray (Tjernberg 1988, Watson 1997). A few individuals retain some white in base of tail for many years (T. and E. Craig unpubl.).

Sexes similar in coloration. Suspected sexual dif-ferences in pattern and number of bands on tails of adults (Wheeler and Clark 1995) not verified by studies; may not be a reliable method for distinguishing sexes (W. Clark pers. comm.).

Aberrant Plumages

A few cases of partial albinism have been reported (Clark and Wheeler 1987), and a melanistic specimen (taxidermy mount) has been described (Aiken 1928).

Bare Parts

Bill And Cere

Bill and cere tricolored (Clark and Wheeler 1987); bill black at tip, lightening to bluish gray at base. Cere fleshy, yellowish white in nestlings and yellow in juveniles and adults (Brown and Amadon 1968).

Iris

Dark brown in juveniles. Eyes of adults vary from dark brown, hazel, or light yellow to flecked gold and brown; a few even appear white (D. Bittner pers. comm.); uniform colors of brown or hazel are most common (T. and E. Craig unpubl.).

Bare Skin On Head

Orbital-ring yellow.

Legs And Feet

Feet yellow, but lighter in nestlings (Brown and Amadon 1968). Legs feathered to toes. Talons black to blackish slate colored.

Measurements

Linear

Sexes differ significantly in length of wing-chord, tail, culmen, middle toe, foot pad, and hallux claw; females larger in all respects (Appendix 3). Foot pad accurately sexed 100% of the sample, males <138.5 mm; females >138.5 mm (Edwards and Kochert 1986). Combination of culmen and hallux talon lengths accurately sexed 97% of adults and 100% of immatures; wing-chord and body mass alone are not reliable predictors of sex (Bortolotti 1984a, Edwards and Kochert 1986).

Hallux claw significantly longer in adults than in immatures, and tails significantly longer in immatures than adults (Appendix 3). Differences in adult and immature culmen and wing-chord lengths equivocal; significantly longer for only adult males (Bortolotti 1984a). Age-class differences in tail and wing not as great as for Bald Eagles and other sea eagles (Amadon 1980, Bortolotti 1984a). See Bortolotti 1984a for eighth-primary and first-secondary lengths and bill depth, width, and length; see Friedmann 1950 for tarsus width. Geographic variation in size not documented in North American populations (Bortolotti 1984a).

Mass

From necropsy of adults and immatures from Idaho: 31 males averaged 3,477 g ± 101.0 SE (range 2,495–4,281), and 18 females averaged 4,913 g ± 163.9 SE (range 3,374–6,124; Edwards and Kochert 1986). Masses of adults/immatures trapped in sw. Idaho ranged from 3,000 to 4,475 g (mean 3,900 ± 335 SD) for 34 males and from 4,075 to 5,280 g (mean 4,627 ± 420 SD) for 14 females (USGS unpubl.). See Breeding: fledging stage, above, for mass of nestlings at fledging.

Priorities for Future Research

Development of a population monitoring strategy should be a priority for the western United States, where population declines are suspected. In addition, factors that influence population trends are not well understood. Information on effects of environmental contaminants (for example, heavy metals) and habitat alteration on populations is lacking for both breeding and wintering grounds. More information is needed on population dynamics to answer questions raised by pending proposals to harvest this species for Native American religious ceremonies; for example, if and how survival rates vary across geographic areas and whether human-caused mortality is additive or compensatory. The size of the floating segment of populations needs to be estimated more accurately, and additional information is needed on how floaters interact with territorial breeders. To determine if there is interchange among nesting populations, more data are needed on natal and breeding dispersal. Genetic analyses could provide insights on relatedness of individuals from different regions.

Acknowledgments

We thank Mary Jean Cowing for obtaining references and assembling the reference list; Courtney Frost for assistance with literature reviews and in tabulating data; Tim Craig for sharing his knowledge, editorial comments, and unpublished data; and the Borror Laboratory of Bioacoustics, The Ohio State University, for the sonograms. Pete Bloom, William Clark, Grainger Hunt, Ron Jackman, and Charlie Todd allowed us to use unpublished data. We thank Jeff Smith (HawkWatch International), Laurie Goodrich (Hawk Mountain Sanctuary), and Peter Sherrington for sharing migration data; Dan Gibson and Kevin Winker, University of Alaska Museum, for information on breeding distribution; Bob Ritchie for information on distribution, food habits, and nesting in Alaska; Kim Titus for information on nesting in maritime areas. Cathryn Wise, Arizona Game and Fish Department, provided unpublished breeding-bird atlas information, as did Pam Sinclair, Canadian Wildlife Service, for the Yukon. Eduardo Inigo-Elias provided information on distribution in Mexico, and Bruce Anderson and Ted Touchstone provided information on reintroductions and eagle distribution in the eastern U.S. Linda Schueck and John Marzluff provided data on winter ranges in southwest Idaho. Mike Collopy shared observations and reviewed a section of the draft. We are grateful to several other individuals who provided information about Golden Eagle biology via personal communication, and we thank the numerous Bureau of Land Management, National Biological Service, and U.S. Geological Survey technicians and biologists who collected data (cited herein as USGS unpubl.) on eagles in the Snake River Birds of Prey National Conservation Area. Alan Poole, Keith Russell, Louis Bevier, David Buehler, Bill Dawson, and Don Kroodsma provided helpful com-ments and review of the draft manuscript.

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The Auk 114(4):673–687, 1997

SPATIAL USE AND HABITAT SELECTION OF GOLDEN EAGLES IN SOUTHWESTERN IDAHO

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ABSTRACT.—We measured spatial use and habitat selection of radio-tagged Golden Eagles (*Aquila chrysaetos*) at eight to nine territories each year from 1992 to 1994 in the Snake River Birds of Prey National Conservation Area. Use of space did not vary between years or sexes, but did vary among seasons (home ranges and travel distances were larger during the nonbreeding than during the breeding season) and among individuals. Home ranges were large, ranging from 190 to 8,330 ha during the breeding season and from 1,370 to 170,000 ha outside of the breeding season, but activity was concentrated in small core areas of 30 to 1,535 ha and 485 to 6,380 ha during the breeding and nonbreeding seasons, respectively. Eagles selected shrub habitats and avoided disturbed areas, grasslands, and agriculture. This resulted in selection for habitat likely to contain their principal prey, black-tailed jackrabbits (*Lepus californicus*). Individuals with home ranges in extensive shrubland ($n = 3$) did not select for shrubs in the placement of their core areas or foraging points, but individuals in highly fragmented or dispersed shrublands ($n = 5$) concentrated their activities and foraged preferentially in jackrabbit habitats (i.e. areas with abundant and large shrub patches). As home ranges expanded outside of the breeding season, individuals selected jackrabbit habitats within their range. Shrubland fragmentation should be minimized so that remaining shrub patches are large enough to support jackrabbits. *Received 1 May 1996, accepted 6 May 1997.*

IN SOUTHWESTERN IDAHO, the demography and behavior of Golden Eagles (*Aquila chrysaetos*) are closely associated with variation in the abundance of black-tailed jackrabbits (*Lepus californicus*). Jackrabbit populations fluctuate, peaking at 7-to-12 year intervals (Johnson and Peek 1984). More eagles lay eggs and produce more offspring when jackrabbits are abundant than when jackrabbit populations crash (Steenhof et al. 1997), and eagles use alternative prey when jackrabbits decline (Steenhof and Kochert 1988). The importance of jackrabbits to eagles suggests that eagles should locate territories and concentrate foraging activities in habitats most likely to contain jackrabbits. We tested this hypothesis by relating spatial-use patterns of eagles to habitats associated with black-tailed jackrabbits. We then could indirectly describe habitat use by eagles relative to their main prey and quantify habitat characteristics meaningful to land managers.

Although descriptions of average behavior may be most easily understood by biologists and translated into management policy, they do not capture variation among individual animals. If such variation is substantial and ignored by focusing on population averages, conservation strategies and biological descriptions will be inaccurate and rarely effective. Describing individual variation, attempting to understand it, and using this to provide context-specific management recommendations would be preferable. Furthermore, many animals select and use resources at various scales (Allen and Starr 1982, O'Neill et al. 1988, Wiens 1989).

Here, we explore individual variation in Golden Eagle diet, spatial use, and habitat selection and show that, although certain habitat types are consistently preferred, the scale at which individuals exhibit selection for them is variable and dependent on landscape attributes and possibly individual experience. This is likely to be common in long-lived, permanent residents that maintain year-round, all-purpose territories, such as Golden Eagles (Beecham and Kochert 1975, Dunstan et al. 1978,

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TABLE 1. Golden Eagle territories where behavior, productivity, and home-range characteristics were studied, Snake River Birds of Prey National Conservation Area, 1991 to 1994.

Number of eagles		Individuals used in home-range estimation			Years locations were used in home-range estimation			
Captured	Instrumented	Sex	Age	Capture date	1991	1992	1993	1994
				Black Butte				
2	1	M	Ad	12 Nov 91		X	X	X
				Beercase				
2	2	M	Ad	18 Jan 92		X	X	X
				Wildhorse				
2	2	F	Ad	14 Oct 91		X	X	X
		M	Ad	16 Dec 92			X	X
				PP&L 119				
5	4	M	Ad	19 Feb 91	X	X	X	
		F	Ad	23 Oct 92		X	X	X
		M	Subad	11 Mar 94				X
				Pole 369[a]				
0	0	F	Subad	17 Dec 91			X	
				Grand View Sand Cliff				
2	2	F	Subad	17 Dec 91	X			
		M	Ad	24 Oct 92		X	X	X
				Ogden				
1	1	M	Ad	14 Dec 92		X	X	X
				Beecham				
1	1	M	Ad	22 Nov 91	X	X	X	X
				Cabin				
12	2	F	Ad	06 Dec 91	X	X	X	X
		M	Ad	12 Apr 94				X

[a] Individual moved from Grand View Sand Cliff to Pole 369.

Collopy and Edwards 1989), because learning and experience may shape behavior (Mayr 1974).

METHODS

Site selection and trapping.—We studied Golden Eagles on 9 of 20 historically occupied territories (defended areas including nesting and foraging sites) along a 140-km stretch of the Snake River canyon (from Walter's Ferry to C. J. Strike Reservoir) within the Snake River Birds of Prey National Conservation Area (NCA). Approximately 75% of historically occupied territories were actually occupied during our study. We selected our subsample of territories to provide a representative sample of currently occupied landscapes in the NCA (none was inactive for more than 5 years from 1970 to 1991, four had >50% of the area within a 2.66-km radius circle centered at traditionally used nests burned by wildfires during the previous 10 years, and four had <30% of this area burned). One territory was added in 1993 when a radio-tagged female left her territory and joined an untagged eagle at a new site.

From 1991 to 1994, we captured 27 individuals in target territories (Table 1). Sex was determined by observations of copulation and measurements of body mass and footpad length (Edwards and Kochert 1986). Thirteen birds were instrumented with 65-g, solar-assisted transmitters secured by a 10-g harness of 19-mm wide Teflon webbing and a leather sternum patch; two were instrumented with 15-g tail-mounted transmitters. Transmitters may have reduced productivity in one year of study but did not influence behavior and spatial use (Marzluff et al. 1997). More than one individual was captured and radio-tagged in some territories because of transmitter failure or removal, eagle dispersal, and deliberate attempts to catch both breeders.

We monitored the behavior and productivity of radio-tagged Golden Eagles at eight territories during 1992, nine during 1993, and eight during 1994 (Table 1). Both the male and female were tagged in one of the eight territories in 1992, in two of the nine territories in 1993, and in three of the eight territories in 1994. To avoid concerns over pseudoreplication, we used the territory, not the individual on the territory within a year, as the experimental unit unless otherwise noted.

We captured eagles with radio-triggered bow nets (1991 and 1994), noosed lures (1991), and padded leghold traps (1991, 1992, 1993, 1994; Bloom 1987). We observed traps from 1 to 2 km away and broadcast noises from two-way radios buried near traps to reduce the frequency of catching nontarget species.

Location estimates and behavior.—Instrumented eagles were selected randomly and followed for 6-h observation periods, three to four days per month. Eagles in each territory were followed approximately weekly to balance observation effort across territories. We located eagles for visual observation, then continuously recorded time and activity data, particularly noting where hunting forays occurred and characterizing habitats in those areas. Locations were plotted (± 100 m) in the field on 1:24,000 scale topographic maps assisted by aerial photographs. Locations were obtained for all perched birds, all extreme points used by birds each day, and most points where birds soared. Perched locations included roost sites as well as hunting and resting sites. We also estimated the location of all copulations, undulating flights, and hunting attempts. Travel routes among perches or soaring areas were recorded, but estimates of point locations along these routes were not made. We used all observations on both members of the pair to determine the location of hunting attempts and prey captures. Hunting forays were any flights that included an attempt to capture prey (i.e. a steep dive or chase of potential prey).

Breeding status and habitat.—We considered eagles to have laid eggs if one member of the pair was seen in an incubating posture, or if eggs were seen. In 1992 and 1993, nestlings at sites tended by radio-tagged parents were banded and marked with uniquely numbered patagial tags to aid in observations within territories during the winter and to identify these birds within their parents' territories.

In a concurrent study, Knick et al. (1997) determined areal coverage of habitats from Landsat thematic mapper satellite imagery classified into big sagebrush (*Artemisia tridentata*)/green rabbitbrush (*Chrysothamnus viscidiflorus*), winterfat (*Ceratoides lanata*), salt-desert shrub (*Atriplex confertifolia, A. canescens, Sarcobatus vermiculatus*), grassland (*Poa secunda, Bromus tectorum, Sitanion hystrix*), cliff, and water. They also delineated all areas used for agriculture since 1979 (including fallow fields) from a composite of the 1979 Snake River Birds of Prey vegetation map (USDI 1979), 1993 Bureau of Reclamation agriculture maps, and the classified satellite imagery. Resolution of the habitat map was 50 m (resampled from 30-m pixels in the satellite image). Knick et al. (1997) used >5% ground cover of shrubs to separate shrub and grassland classes. Accuracy of the classification in separating shrub and grassland areas was 80%; accuracy in separating individual habitat classes was 64% (Knick et al. 1997).

Knick and Dyer (1997) developed an index of black-tailed jackrabbit habitats from a multivariate analysis that included number of agriculture cells, a habitat diversity index, number of shrub cells, shrub patch characteristics, and an index of landscape patchiness. The habitat index, scaled into 10% intervals, represented the probability of similarity of the habitat at each 50-m gridded cell in a Geographical Information System map to the mean habitat vector associated with jackrabbits. We used habitat associations of jackrabbits during low population phases and spring/early summer seasons. These were the conditions during the majority of our eagle observations, but jackrabbit population phases and season have little effect on jackrabbit habitat associations (Knick and Dyer 1997). We emphasize that the map of the jackrabbit habitat index did not predict the actual presence of jackrabbits, but rather the similarity of a given cell to habitats used by jackrabbits.

Analyses.—We used all unique locations visited by eagles during an observation session in home-range analyses rather than using a time interval to select "independent" locations. Use of unique locations reduced dependency by removing repeatedly visited locations within a sampling day, but it did not reduce the estimation of the maximum area used by an eagle. However, because many locations within a range were visited repeatedly each day and these tended to be near the center of the range, the exclusion of repeat locations resulted in an expansion of core areas. Because different radio-tagged individuals breeding within a given territory showed similar ranging habits, we used all unique locations from both eagles to define the home range associated with a territory. The nest site constituted a single observation for home-range analyses, even though it was visited multiple times.

We separated our locations into two seasons, breeding and nonbreeding. We defined breeding as the time from when eagles were first observed building nests or incubating until the end of the postfledging dependency period or the breeding attempt failed; nonbreeding included all times not within the breeding period. Therefore, seasons were of different duration for each individual territory.

We analyzed all four years of data using a two-factor repeated-measures ANOVA, with travel distances by year and season as the repeated measures. In this analysis we used only the five territories that were observed every year and where transmitter failure did not limit observations. Mean seasonal travel distances did not differ among years ($P = 0.95$); therefore, we pooled data across years and used data from eight territories to examine seasonal and territorial differences in travel distance using a two-factor (season and territory) ANOVA.

We used Ranges V software (Kenward and Hodder 1995) to calculate a variety of home-range estimates for comparative purposes, but we used only selected methods for analysis of habitat use and seasonal differences in home-range size. We used concave polygons with edge length restricted to half the minimum range diagonal to represent eagle home ranges. Concave polygons were most appropriate for estimation of habitat available to foraging eagles within their home ranges because they minimized territory overlap, included all known locations of eagles, and did not rely upon statistical distributions of locations. Harmonic-mean and convex-polygon methods were less satisfying because their reliance on the statistical distribution of locations resulted in extrapolation beyond locations we knew eagles visited, and, as a consequence, included extensive overlap between adjacent territories that we did not observe in the field.

We investigated habitat selection at three scales. First, we determined if eagles selected or avoided certain habitats in establishing a home range by comparing habitat used in concave polygon home ranges with habitat available within the study area. We defined available habitat as that area on either side of the Snake River canyon within the maximum travel distances observed for radio-tagged birds. Buffer areas, derived from maximum travel distances, were determined separately for the breeding and nonbreeding seasons. Second, we determined if eagles selected or avoided certain habitats within their home range by comparing the habitat used within core areas defined by hierarchical, incremental cluster analysis with a "nearest neighbor" joining rule (Kenward 1987) with habitat available within each individual's concave home range. We examined habitat in clusters that included 90 and 95% of locations separately. Most territories showed little change in the rate of area increase for cluster polygons that included from 20 to 90% of the locations but typically increased sharply thereafter, both in area within ranges and size variation between ranges, which indicated that the remaining 5 to 10% of locations were outliers. Third, we determined if foraging habitat was selected from within high-use areas by comparing the habitat within 100 m of locations where we saw eagles attempt to capture prey with the habitat available within core areas.

We determined the importance of habitat use with selection ratios (proportion of habitat class used/proportion of habitat type available) for each habitat type (Manly et al. 1993). We normalized selection ratios by using their natural logarithm. We viewed the individual territory as our sampling unit and calculated average selection ratios for our sample of territories. We calculated a 95% confidence interval around each ratio average after a Bonferroni adjustment for multiple comparisons. Selection ratios that did not include 0 in their confidence interval were evidence of significant ($\alpha = 0.05$) avoidance (ratio < 0) or selection (ratio > 0). We used compositional analysis (Aebischer et al. 1993) to test for individual differences in selection or avoidance of habitats.

RESULTS

SPATIAL-USE PATTERNS

Travel distance.—Distance traveled from the nest varied among individuals and between seasons. Eagles traveled farther from their nests outside of the breeding season ($\bar{x}$ = 3,036.1 ± SE of 241.6 m, $n = 248$) than during the breeding season ($\bar{x}$ = 1,046.8 ± 366.6 m, $n = 121$; repeated-measures ANOVA, $F = 9.1$, df = 1 and 4, $P = 0.04$). Annual variation in distance traveled was not significant (multivariate $F = 0.05$, df = 2 and 3, $P = 0.95$). However, individuals differed in travel distance between seasons (interaction of individual and season in two-way ANOVA without repeated measures, $F = 2.29$, df = 7 and 353, $P = 0.03$). Males ($\bar{x}$ = 1,963.7 ± 251.0 m, $n = 253$) and females ($\bar{x}$ = 2,094.2 ± 401.0 m, $n = 116$) traveled similar distances ($F = 0.08$, df = 1 and 365, $P = 0.78$).

An individual's travel distance from the nest was related to behavior (Fig. 1). Most of the extreme travel distances were hunting forays or undulating flights. A few individuals did most of their hunting ($n = 2$) and undulating ($n = 2$) near the nest.

Home range.—Similar patterns of travel also were reflected in individually and seasonally variable home ranges. Home-range estimators in Table 2 are for comparative purposes; we limited our discussion to concave polygons, which best described the total area used by eagles, and to clusters that removed extreme travels and defined high use (i.e. "core") areas.

Eagle breeding ranges encompassed 190 to 8,330 ha and expanded to 1,370 to 170,000 ha outside of the breeding season (Table 2). The average size of ranges was 2,280 ± SD of 2,625 ha ($n = 8$) during the breeding season and 30,484 ± 59,909 ha ($n = 8$) during the nonbreeding season. The large standard deviations resulted from extreme variation among individuals.

Home-range boundaries have remained fairly consistent for many years. Three of the territories we studied (a, b, i) also were studied

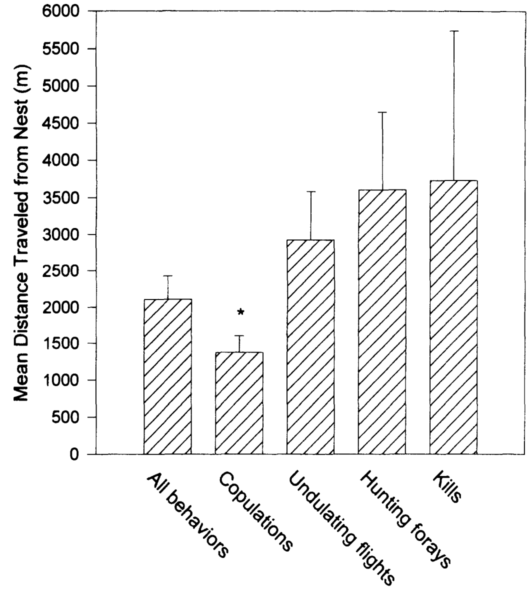

FIG. 1. Distances traveled by adult Golden Eagles where copulations, undulating flights, hunting forays, and kills were observed. Travel distance was calculated for each individual (n = 9) and averaged (± SE) across individuals. Significantly (*, $P < 0.05$) extreme average travel distances are indicated when the 95% confidence interval around the travel distance for a particular activity does not include the average travel distance to all locations.

with radiotelemetry in the 1970s (Dunstan et al. 1978). Home-range sizes in the 1970s and 1990s were similar (two ranges were larger and one was smaller in the 1970s than in the 1990s; $\bar{x}$ absolute difference in convex polygons = 1,256 ± SE of 413 ha), and ranges in the 1990s overlapped those from the 1970s by an average of 57.6 ± SE of 15.8%.

Breeding ranges of neighboring pairs overlapped only slightly ($\bar{x}$ = 3.7 ± 1.7%, n = 10; Fig. 2A), suggesting territorial behavior. Interactions between neighbors were rarely observed because of the mutually exclusive territories. Expanded ranges outside of the breeding season overlapped neighboring ranges more than during the breeding season ($\bar{x}$ = 22.1 ± 9.4%, n = 10; Fig. 2B) and included foraging areas frequented by wintering and nonbreeding eagles.

Nonresidents were captured in three territories (a, d, i) outside of the breeding season. Ten were captured in one territory (i), and only two offspring of residents were among those captured (one in territory d and one in i). Aggression between residents and nonresidents was extremely rare within and outside of the breeding season.

Eagles concentrated their activity within several frequently used cores. Cores defined by clusters of similar use indicated that 95% of the eagle locations were within 14.4 ± 3.1% of their breeding ranges and 25.3 ± 5.8% of their nonbreeding ranges (Fig. 2A, B). Ninety percent of the locations were within 6.9 ± 1.7% of breeding ranges and 12.6 ± 3.2% of nonbreeding ranges.

PREY

Black-tailed jackrabbits, Townsend's ground squirrels (*Spermophilus townsendii*), and Rock Doves (*Columba livia*) were the most commonly observed prey taken by eagles during our years of study (Fig. 3). Prey taken within and outside of the breeding season differed, with ground squirrels dominating the breeding season and jackrabbits dominating the nonbreeding season (comparing numbers of jackrabbits, ground squirrels, Rock Doves, and other prey for 1992 to 1994; Fisher's exact test, P = 0.02). Use of jackrabbits peaked in 1992 and then declined. Rock Doves, reptiles, yellow-bellied marmots (*Marmota flaviventris*), and Nuttall's cottontails (*Sylvilagus nutallii*) were taken more frequently as jackrabbit use declined.

Jackrabbits varied in importance among individual eagle pairs (pooled data from 1992 to 1994; Fisher's exact test, $P < 0.001$ for six pairs with $n \geq 6$ captures). One pair (b) took predominantly (8 of 10 captures) jackrabbits. However, the other pairs took jackrabbits much less frequently (jackrabbits comprised ≤7% of the prey taken by pairs a, f, g, and h). Rock Doves, waterfowl, and marmots comprised the remainder of the prey taken.

HABITAT SELECTION

Vegetation.—Eagle territories occurred along a gradient of shrubsteppe habitats from big sagebrush, winterfat, and green rabbitbrush to salt-desert shrubs. Additionally, wildfires burned significant portions of some territories prior to our study, resulting in varying amounts of grassland among territories (Fig. 2A, B).

Selection of habitat classes.—The variation in

TABLE 2. Estimated areas (ha) of home ranges (concave and convex polygon, harmonic mean) and core areas (cluster analysis) of Golden Eagle territories (letters denote territories in Figures 2 and 5). Data combined across years and birds but analyzed separately for nonbreeding (N) and breeding (B) seasons.

Season	*n*	Concave 100%	Convex 100%	Harmonic 100%	Harmonic 95%	Core 95%	Core 90%
Black Butte (a)							
N	489	1,376	1,610	2,373	847	485	102
B	312	1,071	1,175	2,670	827	289	161
Beercase (b)							
N	298	11,261	18,541	61,792	10,110	2,581	938
B	325	8,331	9,759	22,929	5,536	1,535	565
Wildhorse (c)							
N	261	36,925	36,925	109,280	29,073	2,729	2,115
B	96	663	875	1,314	1,021	127	74
PP&L 119 (d)							
N	250	6,076	6,762	16,621	6,110	1,535	755
B	112	1,032	2,290	13,686	4,206	254	120
Pole 369 (e)							
N	22[a]	318	450	559	254	159	136
B	94	506	985	2,331	446	53	35
Grand View (f)							
N	297	176,010	207,069	614,675	86,810	6,387	2,035
B	116	194	336	877	94	30	5
Ogden (g)							
N	233	4,443	4,697	9,135	3,352	1,125	738
B	121	2,576	4,304	15,046	3,251	658	366
Beecham (h)							
N	453	3,721	4,625	16,582	2,001	487	194
B	277	3,055	3,471	29,818	323	86	31
Cabin (i)							
N	167	4,061	4,332	9,721	3,698	1,314	494
B	95	1,321	3,793	11,155	1,311	337	127

[a] Range sizes suspect owing to small sample size.

vegetation among territories was evident when we compared habitat classes found within breeding and nonbreeding ranges with available habitats within 4.5 km (the average maximum travel distance during the breeding season) or 9.5 km (the average maximum travel distance during the nonbreeding season) of the canyon rim. Most eagle home ranges had more sagebrush/rabbitbrush, more cliff/rock outcrop, less grassland, and less agriculture than expected from availability (see Table 3). Variation in selectivity among eagles was large (Table 3), and the resulting habitat composition of home ranges varied significantly among individuals (compositional analysis; breeding season, $\lambda = 0.16$, $\chi^2 = 16.5$, df = 5, $P < 0.01$; nonbreeding season, $\lambda = 0.20$, $\chi^2 = 14.4$, df = 5, $P < 0.05$). Most variation was due to varying amounts of sagebrush/rabbitbrush, salt-desert shrubs, grassland, and rock outcrop in home ranges. Individuals were more consistent in including less winterfat, agriculture, and water than expected based on availability in their ranges, especially during the breeding season (Table 3).

Eagle selection for shrubland and avoidance of grassland and agriculture was accentuated when we compared habitats in core areas with those available within each individual's home range (see Table 3). Avoidance of agriculture was significant and consistent among individuals during both seasons, especially within 90% core areas. Most individuals avoided grassland and selected shrubland, but individual variation precluded overall significance (Table 3).

Use and availability of habitats.—Selection coefficients are proportions and can mistakenly

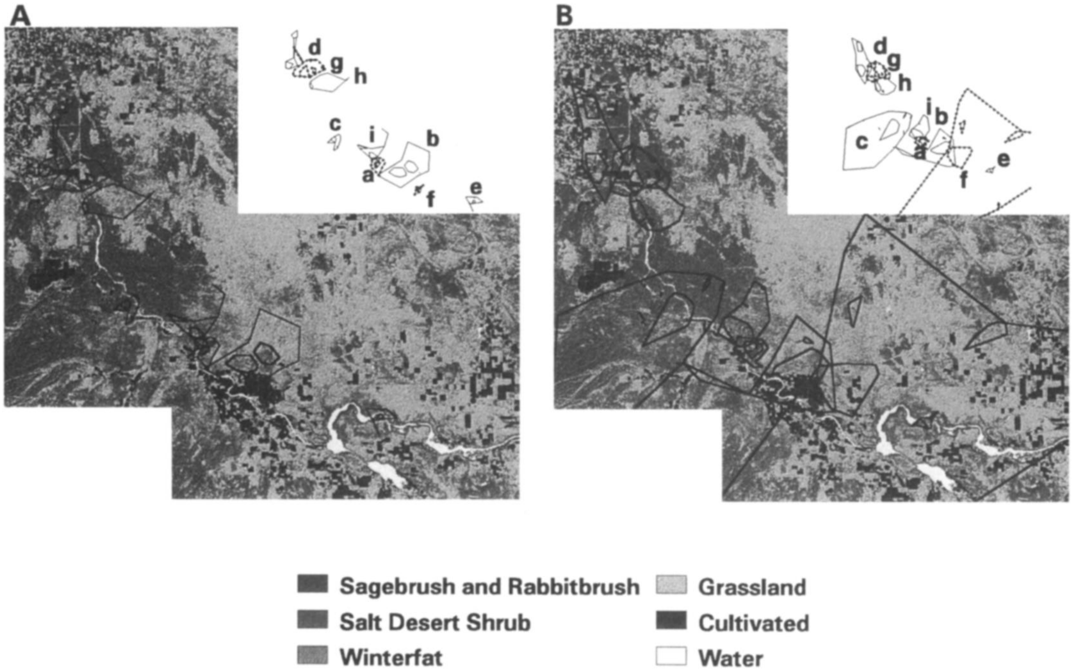

FIG. 2. Home range (solid lines, concave polygons) and core area (polygons within home ranges, 95% use area, cluster analysis) of eagles during (A) and outside of (B) the breeding season. Habitat of the study area is shown in the background to illustrate variation in shrub, grassland, and agriculture among territories. Small letters denote territory identification.

indicate strong selection or avoidance of very rare habitats because small absolute differences in use and availability are proportionately much larger than are similar absolute differences between common habitats. This potential problem contributed to the general avoidance of winterfat and water, and selection for cliff habitats (Table 3). The availability and use of these three habitats were very low (Fig. 4A, B, C).

Avoidance of agriculture was unlikely to be an artifact of habitat rarity (Fig. 4). Agriculture was avoided by all but one eagle, even though it represented as much as 24% of the available habitat. The individual that selected a core area with a relatively large amount of agriculture during the breeding season (Individual d) appeared to select agriculture because its territory had a substantial amount (18%) of agriculture available. Selection for agriculture in the nonbreeding season (Fig. 4A, B) and around foraging points (Fig. 4C) was suspect because the availability of agriculture used to compute those selection coefficients was very small.

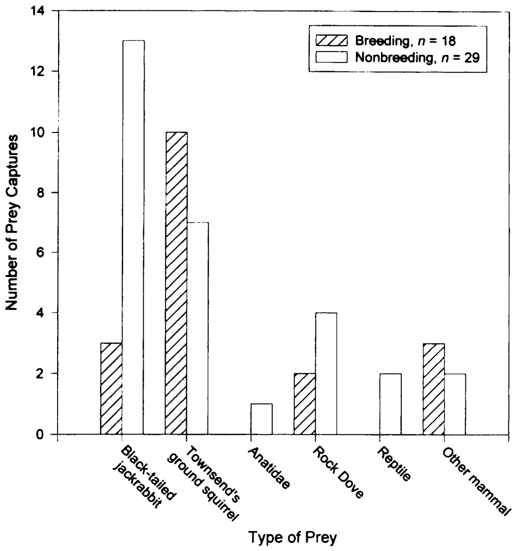

FIG. 3. Prey items captured by Golden Eagles, 1991 to 1994.

TABLE 3. Average selectivity ($\bar{x} \pm$ SE) by nine Golden Eagles for habitat types at three scales. The mean selection coefficient (ln[habitat use/habitat availability]) indicates general avoidance (negative values) or preference (positive values) for each habitat class. The number of eagles selecting each class (use > availability) is shown to indicate consistency of habitat selection among individuals.

	Nonbreeding season		Breeding season	
Habitat class	Selection coefficient	No. eagles	Selection coefficient	No. eagles
Home range				
Sagebrush/rabbitbrush	−0.03 ± 0.23	6	0.12 ± 0.21	7
Salt-desert shrub	−0.49 ± 0.42	4	0.05 ± 0.53	3
Winterfat	−0.84 ± 0.55	4	−1.92 ± 0.82	2
Grassland/disturbed	−0.13 ± 0.09	3	−0.14 ± 0.13	3
Agriculture	−1.84 ± 0.96	3	−2.27 ± 0.94	3
Cliff	0.75 ± 0.48	5	0.29 ± 0.62	6
Water	−0.49 ± 0.42	3	−1.73 ± 0.85	2
95% Core area				
Sagebrush/rabbitbrush	0.13 ± 0.12	6	0.22 ± 0.16	7
Salt-desert shrub	0.24 ± 0.14	7	0.24 ± 0.32	5
Winterfat	−0.66 ± 0.31	2	−1.07 ± 0.51	2
Grassland/disturbed	−0.03 ± 0.09	5	−0.10 ± 0.09	2
Agriculture	−0.40 ± 0.21	1	−2.43 ± 0.80*	1
Cliff	0.55 ± 0.29	7	0.72 ± 0.21*	7
Water	−0.85 ± 0.80	6	−0.68 ± 0.91	3
90% Core area				
Sagebrush/rabbitbrush	0.26 ± 0.12	7	0.17 ± 0.22	7
Salt-desert shrub	0.20 ± 0.28	6	0.54 ± 0.40	5
Winterfat	−1.34 ± 0.51*	3	−1.69 ± 0.77	2
Grassland/disturbed	−0.13 ± 0.08	2	−0.20 ± 0.20	3
Agriculture	−3.16 ± 1.01*	0	−3.11 ± 0.85*	0
Cliff	0.86 ± 0.45	7	0.26 ± 0.70	7
Water	−1.72 ± 0.99	3	−1.93 ± 1.16	3

*, $P < 0.05$ (avoidance or preference different from availability).

Our evidence that sagebrush/rabbitbrush and salt-desert shrub habitats were selected was strengthened because these habitats were common yet included in home ranges, core areas, and around foraging points at frequencies that exceeded general availability. Sagebrush/rabbitbrush appeared to be more important than salt-desert shrub because it comprised a larger percentage of used habitats at all levels of comparison (Fig. 4).

Individual variability in selectivity for sagebrush/rabbitbrush tended to be correlated with the availability of those shrubs within a home range. Individuals tended to be more selective for sagebrush/rabbitbrush when it was relatively rare within their home range (depending upon season and level of comparison, r values ranged from -0.68 to -0.39, $n = 9$ in each case), but this relationship was only significant during the breeding season when selectivity within the 95% core area was compared with availability in the home range ($P = 0.04$, all other P-values < 0.29).

Avoidance of grassland by most individuals at all levels of comparison, especially during the breeding season, was not due to the rarity of grassland. Grassland was the most common habitat type regardless of season or level of comparison (Fig. 4). Even though it was used less than expected based on availability, grassland remained a dominant feature of eagle home ranges, core areas, and foraging locations, regardless of season. Individual variability in avoidance of grassland was not correlated with the abundance of grassland within home ranges. In most seasons and levels of comparison, eagles with the largest amount of grassland in their home range avoided it, but these relationships were weak (all r-values < 0.50, P-values > 0.17).

Selection for jackrabbit habitat.—Jackrabbit habitats varied significantly among territories (compositional analysis; breeding season, $\lambda = 1.29 \times 10^{-16}$, $\chi^2 = 329.3$, df $= 9$, $P < 0.001$; nonbreeding season, $\lambda = 2.57 \times 10^{-14}$, $\chi^2 = 281.6$, df $= 9$, $P < 0.001$). Five territories (a, b, f, h, i)

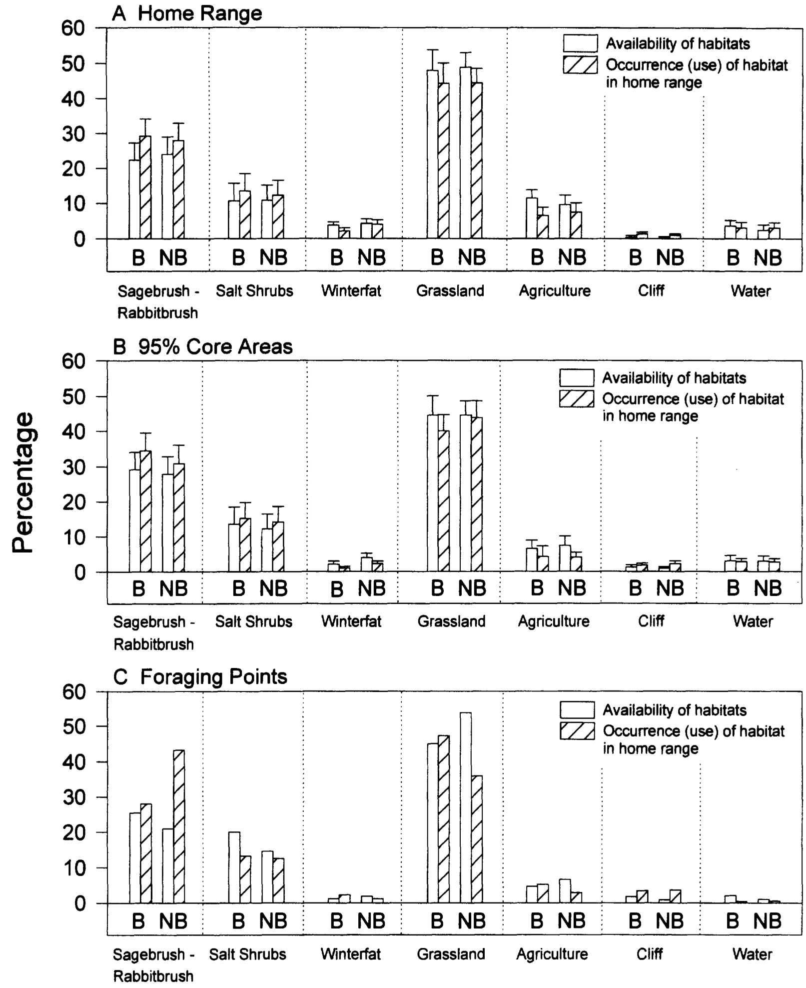

FIG. 4. Availability and use of habitat classes during the breeding and nonbreeding season. Use and availability is plotted for all nine territories in comparisons of home ranges with the study area (A) and of core area with home range (B). Data were insufficient to analyze habitat around foraging points separately for individuals, so all individuals were pooled (C). Values are $\bar{x}$ ± SE.

contained lower indexes of jackrabbit habitat, three territories (c, d, g) contained higher indexes, and one territory (e) contained intermediate indexes compared with availability in the study area (Fig. 5A, B).

Overall, eagles in the nine territories studied did not select or avoid habitats based on the probability of supporting jackrabbits (Table 4). However, some individuals were more selective than others. Five pairs (a, b, c, f, i) centered their 95% core areas within the best jackrabbit habitat available within their home range during the breeding season (Fig. 5A). All five pairs had territories containing less sagebrush/rabbitbrush than expected based on availability ($\bar{x}$ selection coefficient = -0.23 ± SE of 0.29) and less absolute occurrence of sagebrush/rabbitbrush ($\bar{x}$ = 20.8 ± 5.95%) than the other four pairs ($\bar{x}$ selection coefficient = 0.56 ± 0.12; Mann-Whitney $U = 19$, $P = 0.03$; $\bar{x}$ abundance = 39.6 ± 4.08%; $U = 19$, $P = 0.03$). Territories of pairs that selected for jackrabbit habitat had lower jackrabbit habitat indexes ($\bar{x}$ index = 0.34 ± 0.07) than territories of other eagles ($\bar{x}$ = 0.48 ± 0.06), but this difference was not significant ($U = 14$, $P = 0.33$).

In contrast to the breeding season, few eagles selected for jackrabbit habitats within core areas outside of the breeding season. Only one pair (i) had a 95% core area that included the best jack-

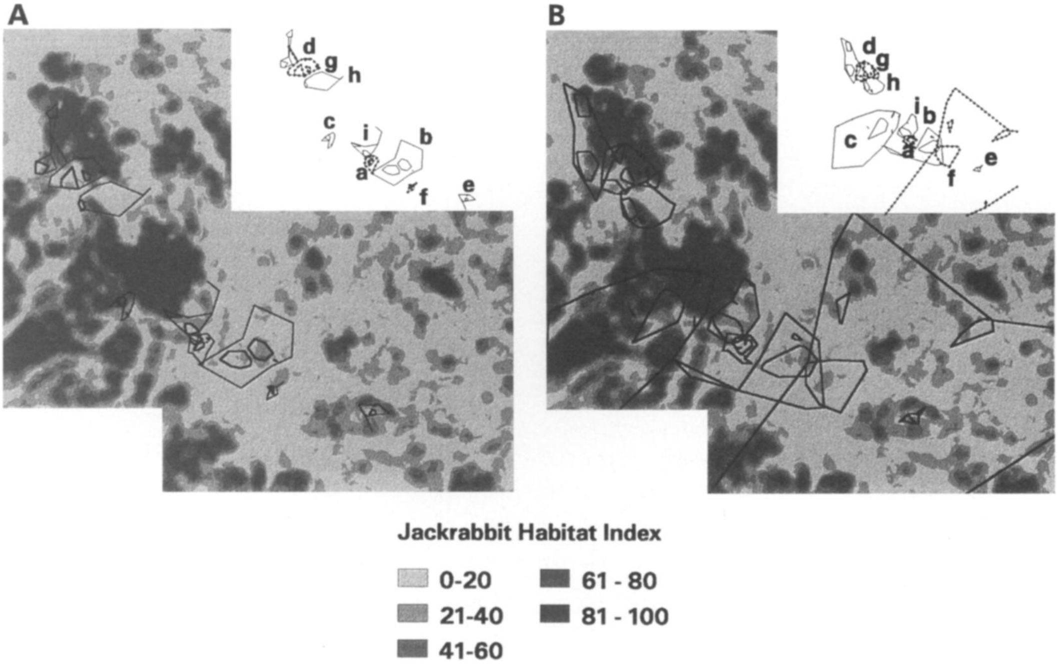

FIG. 5. Occurrence of black-tailed jackrabbit habitat in Golden Eagle home ranges (solid lines, concave polygons) and core areas (polygons within home ranges, 95% use area, cluster analysis) during (A) and outside of (B) the breeding season. Shading indicates the similarity of habitat at a given location to habitat used by jackrabbits. Progressively darker shading indicates habitats of progressively higher quality for jackrabbits. Small letters denote territory identification.

TABLE 4. Average selectivity ($\bar{x}$ ± SE) by nine Golden Eagles for black-tailed jackrabbit habitat types at three scales. The mean selection coefficient (ln[habitat use/habitat availability]) indicates general avoidance (negative values) or preference (positive values) for each habitat class. The number of eagles selecting each class (use > availability) is shown to indicate consistency of habitat selection among individuals.

Jackrabbit index class	Nonbreeding season Selection coefficient	Nonbreeding season No. eagles	Breeding season Selection coefficient	Breeding season No. eagles
		Home range		
Highest 30%	−2.50 ± 1.15	3	−2.43 ± 1.23	3
Middle 40%	−0.03 ± 0.18	5	−0.64 ± 0.64	3
Lowest 30%	−0.16 ± 0.23	5	−0.23 ± 0.29	5
		95% Core area		
Highest 30%	−0.98 ± 0.65	1	−1.59 ± 1.00	2
Middle 40%	−0.02 ± 0.24	4	0.03 ± 0.28	5
Lowest 30%	0.01 ± 0.17	6	−0.61 ± 0.86	4
		90% Core area		
Highest 30%	−1.15 ± 0.64	1	−2.23 ± 1.23	2
Middle 40%	−0.58 ± 0.82	6	−2.00 ± 1.19	2
Lowest 30%	−0.01 ± 0.13	4	−0.48 ± 0.86	7

rabbit habitat available in its home range, and one other (b) had a 90% core that included some of its best jackrabbit habitat (Fig. 5B).

Foraging locations.—Selection of foraging locations within core areas differed between the breeding and nonbreeding season (Fig. 6). During the breeding season, individuals used winterfat shrublands, cliffs, and agriculture more frequently than expected; sagebrush/rabbitbrush was used in proportion to availability. As a result, eagles did not select foraging points in jackrabbit habitat within core areas during the breeding season. In contrast, during the nonbreeding season foraging points were primarily in sagebrush/rabbitbrush and along cliffs. Eagles also foraged within the best jackrabbit habitat inside their core areas during the nonbreeding season.

INTERRELATIONSHIPS OF HABITAT QUALITY, RANGE SIZE, AND EAGLE PRODUCTIVITY

Home-range size was not significantly related to eagle productivity. Breeding-range size tended to increase as the total number of young fledged from 1992 to 1994 increased ($r = 0.56$, $n = 9$, $P = 0.12$). Size of the nonbreeding range and size of core areas, regardless of season, were less closely correlated with productivity (all $Ps > 0.25$).

Two distinct groups of territories were evident during the breeding season. Pairs a, b, f, h, and i had a scarcity of shrubland associated with jackrabbits in their territories (Figs. 2, 5). In contrast, pairs c, d, and g had an abundance of shrubland associated with jackrabbits (Figs. 2, 5). Variation in habitat quality was not significantly related to differences in home-range size during the breeding season (high-quality territories, $\bar{x} = 1{,}423 \pm 586$ ha, $n = 3$; low-quality territories, $\bar{x} = 2{,}794 \pm 1{,}460$ ha, $n = 5$; $U = 5$, $P = 0.46$) or during the nonbreeding season (high-quality territories, $\bar{x} = 15{,}814 \pm 10{,}566$ ha, $n = 3$; low-quality territories, $\bar{x} = 39{,}286 \pm 34{,}221$ ha, $n = 5$; $U = 10$, $P = 0.46$). Territories in poor jackrabbit habitats had similar productivity compared with those in good jackrabbit habitats (total number of young fledged from 1992 to 1994; high-quality territories, $\bar{x} = 0.67 \pm 0.67$, $n = 3$; low-quality territories, $\bar{x} = 2.4 \pm 0.81$, $n = 5$; $U = 3$, $P = 0.17$).

DISCUSSION

Golden Eagles in our study varied considerably in patterns of spatial use. Size of the home range, size of the core area, and travel distances for various activities varied by two orders of magnitude among individuals. Habitat composition, potential prey abundance, and individual preferences developed by long-lived, permanent residents likely account for much of this variation. Eagles do not simply maximize home-range size, nor should they, because their breeding success was only weakly correlated with range size. Rather, eagles adjusted their ranging and foraging behavior to take advantage of the types and configuration of prey habitat found in the vicinity of their nest. Where high-quality jackrabbit habitat was abundant, pairs foraged evenly throughout the shrublands and had relatively small home ranges (e.g. pairs c, d, g; Figs. 2, 5). However, pairs in territories with little sagebrush/rabbitbrush (where jackrabbits were expected to be scarce) showed two patterns of space use that may reflect individual experiences: they either ranged over large areas and concentrated their use in the better habitats for jackrabbits (pairs b, f; Figs. 2, 5), or they restricted their activities to a small area of cliff and riparian habitat around their nests (pair a; Figs. 2, 5). Pairs that maintained small territories took fewer jackrabbits and more alternate prey, notably Rock Doves, waterfowl, and marmots found in the cliff and riparian habitats. Thus, quality of habitat is more important than quantity, but "quality" habitat comes under a variety of guises depending upon habitat availability and eagle prey selection (riparian habitat [Pair a], agricultural lands [Pair d], or shrublands [other pairs]).

Consistencies in habitat selection became more apparent as we refined our assessment of selection from the scale of the territory, to the scale of the core area, to the foraging point. This may indicate the scale at which eagles actually select habitats, or it may reflect the progressive reduction in use of excursive travels in our analysis. At progressively finer scales, where excursions are not included in the analysis, the majority of eagles selected shrubland and avoided grassland and agriculture. Sagebrush/rabbitbrush was the most important shrub type. Thus, habitat selection by resident

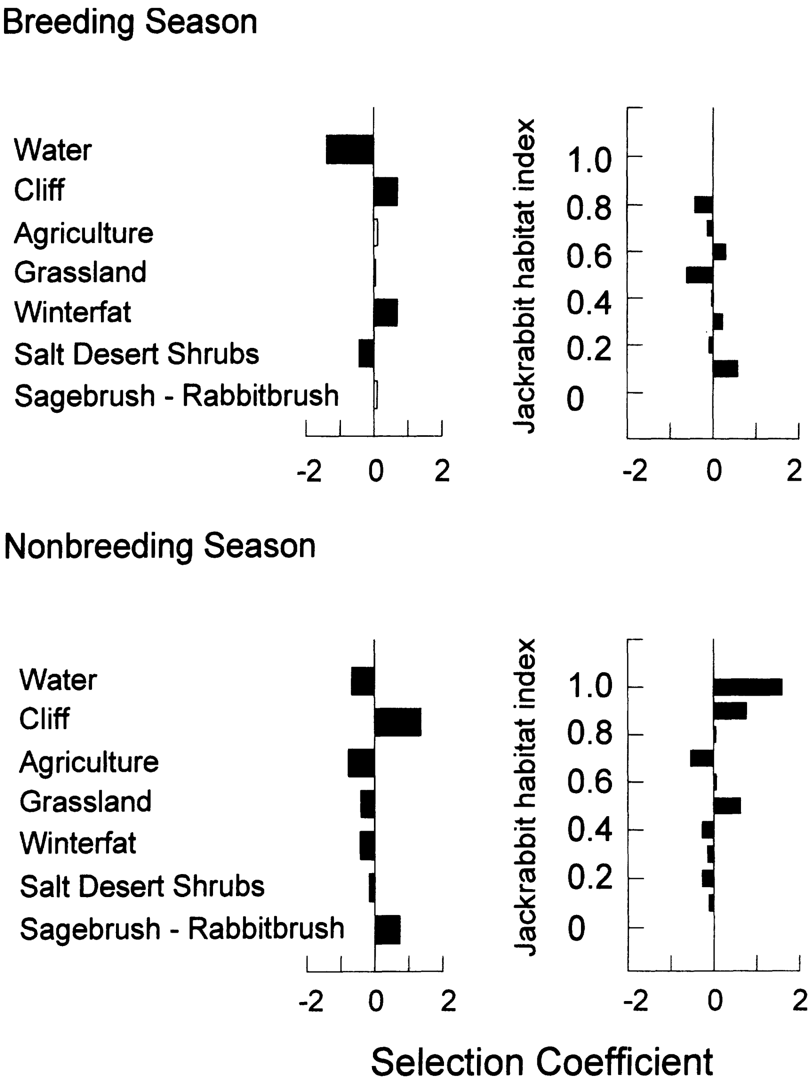

FIG. 6. Selection of foraging habitat within core areas by Golden Eagles. Selection coefficients (ln [percent habitat used / percent habitat available]) compare habitat within 100 m of foraging points with habitat available in 95% core areas during and outside of the breeding season. Selection is plotted separately for habitat classes and habitat quality for jackrabbits (0 is worst habitat, 1 is best habitat for jackrabbits). Vertical histograms show the relative preference (selection coefficient > 0) and avoidance (selection coefficient < 0) of each habitat or jackrabbit habitat-index category.

eagles was similar to selection previously documented for wintering vagrants (Craig et al. 1986).

Selection for sagebrush/rabbitbrush and the avoidance of agriculture and grassland resulted in most eagles foraging in habitats that had the potential to contain jackrabbits. Although our measure of habitat potential to support jackrabbits comes from the spring/summer season during a low population phase of jackrabbits, this is unlikely to influence our assessment of habitats because jackrabbits are found in the habitats rated as highest quality throughout the year, regardless of population cycling (Knick and Dyer 1997). However, the scale at which eagles selected jackrabbit habitats differed depending on the season and the characteristics of the home range. Outside of the breeding season, when even core areas were large, eagles selected foraging points in the best available jackrabbit habitat. During the breeding season, when ranges were smaller, entire core areas were in jackrabbit habitat, and foraging points within cores were in cliff, winterfat, and agriculture where other prey types (notably Townsend's ground squirrels and Rock Doves) occurred. Jackrabbit habitat was used frequently within breeding-season core areas, but use at the scale of foraging points was not selective because territories or core areas were already in the best jackrabbit habitat available. Eagles may be selective in good jackrabbit habitat, but our inability to partition habitat quality more finely precluded testing selection within the best jackrabbit habitat. The importance of selection at one scale to selection at other scales was further illustrated by the lack of selectivity for sagebrush/rabbitbrush within territories that already had a high percentage of sagebrush/rabbitbrush. Habitat selection needs to be investigated at several levels to understand fully how animals allocate their time among various habitats (Wiens et al. 1986, Aebischer et al. 1993).

Although the use of area varied widely among individuals in the nine territories, the use of area by eagles in a given territory varied little regardless of nest location, prey abundance, or identity of breeders. All of these factors varied among years, but home range size and range boundaries did not vary significantly among years. In fact, home-range boundaries changed little from the 1970s to the 1990s. Continued residency by at least one, and usually both, members of the pair, their individual use of perching and foraging habits, and the constraining effects of neighboring pairs on territory shape likely contributed to the stable patterns of spatial use within a territory. Long-term studies of marked individuals are necessary to accurately contrast variation in use of space between territories with variation within territories.

Despite annual stability in territory size and shape, physical defense of territories was rarely observed. Defense of boundaries against neighboring breeders was adequately accomplished by undulating flights (Harmata 1982, Collopy and Edwards 1989). Undulating flights were most often given at the edge of territories, rather than near nests (Fig. 1) and were least frequently given by pairs that had just formed (territory d, e; individuals were banded), suggesting that their function was territory maintenance rather than pair bonding. We routinely captured eagles that were not the tagged offspring of the present territory owners at food items we placed in territories during the nonbreeding season for trapping. Rather, these eagles were vagrant nonbreeders or winter residents. Lack of defense against nonterritorial eagles also was observed in Wyoming (Phillips and Beske 1982) and may be rare because eagles are not breeding and the risks of injury from fighting (Harmata 1982) outweigh any costs of losing foraging opportunities.

We documented the largest home-range sizes reported for this species. Many of the ranges in our study were within values previously reported for this study area and elsewhere (i.e. 500 to 9,000 ha; Dixon 1937, Tjernberg 1977, Dunstan et al. 1978, Phillips and Beske 1982, Collopy and Edwards 1989), but three individuals occupied much larger areas (individuals b, c, f; Fig. 2A, B). Increased size of home ranges often resulted from excursions, especially during the nonbreeding season. Core areas and 95% harmonic-mean ranges, which exclude excursions, are more similar in size to published home ranges. Excursions may have been accentuated during our study, which included a period (winter 1992–93 through 1994) when jackrabbit numbers were low and declining (Steenhof et al. 1997). However, excursions also may represent searches for breeding, as well as foraging, opportunities. They were not synchronized forays by the pair, and in one case the female from territory "f" included territory "e" in her travels; she settled and bred there the following spring. Like any estimate of home range, ours is dependent upon decisions made during data collection and selection of individual points for inclusion in analyses. However, our intensive, long-term observations that include several individuals occupying a given territory allowed us to make realistic estimates of actual space use by eagles.

MANAGEMENT IMPLICATIONS

Management of a healthy population of Golden Eagles in shrubsteppe habitats must focus on maintaining the native shrub community. Stands of sagebrush/rabbitbrush interspersed with grassland harbor sizeable populations of an important prey item, black-tailed jackrabbits (Knick and Dyer 1997). Our analysis demonstrates that eagles forage in areas without shrubs less than expected based on availability. Eagles were especially dependent upon shrub habitats when these shrub habitats were rare in the landscape.

Managers must recognize that although eagles range over large areas (>170,000 ha were used by one eagle), many concentrate their foraging in shrub habitats. Shrub (especially sagebrush / rabbitbrush) patch size appears to be an essential feature of all home ranges. Mean patch size for jackrabbit use of this habitat type was 5,000 ha, and the likelihood of observing jackrabbits increased with both increasing patch size and number of patches in the landscape (Knick and Dyer 1997). In managing the remaining large shrub areas in the landscape for eagles, we recommend that fragmentation by any disturbance not reduce the size of shrub patches below the mean patch size selected by jackrabbits. Patches slightly larger than this also should be maintained to accommodate maximum core areas during the nonbreeding season (6,387 ha; Table 2) and to provide habitat for vagrant and wintering eagles (observed in patches averaging 2,117 to 3,502 ha; Atkinson et al. unpubl. data). Individual variation in space use by eagles argues against using average values of home-range size in management recommendations. Rather, a variety of large and small areas could be suitable for eagles if they are managed to provide large shrub patches or rich alternative foraging areas (e.g. riparian zones).

ACKNOWLEDGMENTS

This study was funded primarily by the Idaho Army National Guard (IDARNG) under U.S. Army contract DAAD05-90-0135 and numerous agreements administered by W. S. Seegar. The U.S. Bureau of Land Management (BLM) and the U.S. National Biological Service provided additional funding and support. This study was part of the cooperative BLM / IDARNG project. J. McKinley, R. Townsend, B. Kimsey, and M. McFadzen were invaluable with data collection and analysis. A. Harmata kindly guided our trapping efforts. K. Steenhof, M. Kochert, R. Kenward, J. Rotenberry, M. Collopy, and K. Martin made valuable comments on the manuscript.

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Associate Editor: K. Martin

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ABSTRACTS

THIRTY-FIFTH ANNUAL MEETING AND SYMPOSIUM
THE DESERT TORTOISE COUNCIL

Doubletree Hotel, Ontario, CA
February 25–28, 2010

(Abstracts arranged alphabetically by last name of first author)
*Speaker, if not the first author listed

Defenders of Wildlife 2010 Abstract: Desert Tortoise

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Defenders of Wildlife first launched its locally-based California Desert Campaign in 2005. This work focused on the Western Mojave Desert, which is currently undergoing the most intense development pressure. Desert Tortoise work is a key component for Defenders. We have established a permanent presence in the California desert to work with the public, local governments, and management agencies. We have staff based in both Sacramento and Joshua Tree to accomplish this objective.

The California Desert is under tremendous pressure from renewable energy proposals. Defenders is committed to protecting the natural habitat of the California Desert. We have hired additional staff, Jeff Aardahl, to work on renewable proposals. America needs to get away from burning the fossil fuels that are polluting our planet and causing global warming. Renewable power from solar and wind are key elements in the transition to a clean-energy future, but we must make sure that renewable energy development doesn't also ruin irreplaceable landscapes such as the scenic Mojave desert, or impact sensitive wildlife such as desert tortoises, burrowing owl, Mohave ground squirrel and migratory birds.

Defenders work on renewable energy projects in the California Desert includes solar thermal, photovoltaic, geothermal, and wind projects. The environmental values and biological integrity of much of the California Desert Conservation Area (CDCA) is at risk because of recent commercial interest in building and operating industrial-scale solar and wind energy projects. Beginning in 2007 and continuing through 2010, commercial solar and wind energy companies filed over 130 right of way applications with the Bureau of Land Management for solar and wind energy projects covering one-million acres of public land in the CDCA. This abrupt interest in using public lands for solar and

wind energy production coincided with two renewable energy utilization mandates from the State of California in 2006 and 2008.

In addition, Defenders, in an effort to reach out to Latino communities, have translated our educational brochures into Spanish both in print and on our website. We also have participated in a Native American Lands Conservancy Symposium, Raven Management Group, Mohave Ground Squirrel Conservation Plan, the Desert Managers' Group, Desert Tortoise Education Group, and the Desert Tortoise Recovery Plan.

Defenders is also working on climate change adaptation. This work includes land conservation planning, wildlife linkages and sponsoring the third annual Climate Change Seminar on March 12.

Impacts of Anthropogenic Nitrogen Deposition on Invasive Species and Fire Risk in California Deserts

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Invasive species have had major impacts on the California deserts, having such high productivity in some regions that they may both exclude native vegetation and be responsible for increased fire frequency. One of the anthropogenic factors that increases productivity of annual vegetation is nitrogen deposition that originates from urban (oxidized N, primarily from automobile emissions) and agricultural (reduced N) areas. Most of the N pollution occurs as dry deposition that accumulates on plant and soil surfaces and is available for plant uptake in mineral form at the beginning of the rainy season. The amounts of N deposition are as high as 16 kg N ha^{-1} yr^{-1} in the Coachella Valley, declining to background levels of <2 kg ha^{-1} yr^{-1} in the eastern Mojave and Sonoran Deserts. We used three approaches to test the impacts of N deposition. We 1) measured annual vegetation response to N along a N deposition gradient from 3-12 kg N ha^{-1} yr^{-1} (east to west) at Joshua tree National Park, 2) fertilized plots at four sites in the Park at levels of 0, 5 and 30 kg N ha^{-1} yr^{-1}, and 3) used a biogeochemical model, DayCent, to model the productivity of annual vegetation under varying precipitation and N deposition, and to assess the risk for fire assuming at least 1 T/ha of fine fuel is needed to carry a fire. We measured the responses of native and invasive plant species at the field sites over 5 years and in an experimental garden under varying soil moisture levels to parameterize the DayCent model. We also assessed diversity of native herbaceous vegetation in response to changes in invasive species in the field sites.

The dominant invasive species were *Schismus barbatus* and *Erodium cicutarium* at the lower elevations in creosote bush scrub (CB), and *Bromus madritensis* at the higher elevations in pinyon-juniper woodland (PJ). Some 90 species of native herbaceous species were recorded in fertilized plots over the 5 years. Each of the two fertilized vegetation types were located in a relatively high and a low N deposition area. Exotic grass biomass increased significantly with 30 kg N/ha at three of the four sites during a year with moderate precipitation, and under 5 kg N/ha at two sites during a year with high precipitation. The response of native forbs to fertilizer was related to the amount of exotic grass present initially. The richness of native forbs declined with fertilization at a site with high initial exotic grass cover, but native richness and cover increased with fertilization at a site with low grass cover. Sites with low air pollution were not necessarily the sites with lowest invasive cover, as soil texture (rockiness and clay) also controls ability of invasive species to colonize and the N supply to plants, and further work is underway to test the relationship between soil texture and invasive species dominance.

The DayCent model showed that fire risk, calculated as the probability that annual biomass exceeds the fire threshold of 1 T/ha, increased with increasing N and precipitation, and was also controlled by soil texture. Critical loads of N deposition were determined as the amount of N deposition at the point when fire risk began to increase exponentially. Average critical loads for all soil types and precipitation < 21 cm/yr, representing the majority of our study region, were 3.2 and 3.9 kg N/ha for CB and PJ, respectively. Fire risks approached their maximum at 9.3 and 8.7 kg N/ha in CB and PJ; precipitation is the driver of fire above these N deposition levels. Levels of N deposition at the maximum fire risk load, a mean value of 9 kg ha^{-1} yr^{-1}, occur over 1.5% of the California deserts, mainly in the western Mojave and Coachella Valley, while the minimum critical load, 3.6 kg ha^{-1} yr^{-1}, occur over 32% of the deserts. This indicates that one-third of the desert is potentially subject to increased productivity of invasive species because of N deposition, coupled with decreased native diversity and increased fires. Vegetation recovery from fire is slow in deserts, and burned areas are often dominated by exotic annuals for decades after a burn. Additional work is underway to determine the relationship of past fire occurrence with areas of varying N deposition. Control of N deposition from air pollution may be an important management goal in reducing productivity of invasive grasses and their negative effects on desert ecosystems.

Continuing Efforts to Protect and Recover the Desert Tortoise

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For over a dozen years, the Center for Biological Diversity has focused its desert tortoise conservation and recovery efforts first in the California Desert Conservation Area (CDCA) and now expanded into Nevada, Utah and Arizona through advocacy, participation in administrative processes and, when necessary, litigation. Using the best available science, the Center has supported increased protection for the desert tortoise as a stepping stone towards desperately needed recovery of the species. Habitat protection for desert tortoise also protects innumerable other species, both rare and common that make the iconic western deserts their home. Our campaigns have changed the dialogue for desert tortoise conservation and resulted in on-the-ground actions from ORV route designation review in key tortoise habitat, to improvements in tortoise translocation efforts, to increasing meaningful conservation strategies for tortoise. Looking forward, these efforts will be even more important as we work to protect the desert tortoise and its remaining habitat from destruction and fragmentation threatened by the glut of currently proposed renewable energy projects across the southwestern states.

We still believe that more protection and recovery efforts need to be focused on the desert tortoise because of the continuing and troubling population declines. Updates on the current legal challenges including the BLM's CDCA plan amendments and related actions and the Arizona strip case will be discussed. The on-going tragic failures of the Fort Irwin “first phase” translocation and our efforts to carefully craft renewable energy projects to avoid impacts to desert tortoise throughout its range will be reviewed. Our National Monument or Conservation Area campaigns for Gold Butte and the upper Las Vegas Wash will be highlighted as a model for desert tortoise conservation. Other ORV issues, water issues and development plans will also be discussed.

Progress Report on the Desert Tortoise from the Desert Tortoise Recovery Office, U.S. Fish and Wildlife Service

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No Abstract available.

Effects of Sahara Mustard, *Brassica tournefortii*, on a Desert Landscape

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Given the abundance of non-native species invading wildland habitats, managers need to employ informed triage to focus control efforts on weeds with the greatest potential for negative impacts. My objective was to determine the level of threat Sahara mustard, *Brassica tournefortii*, represents to meeting regional goals for protecting biodiversity. Sahara mustard has spread throughout much of the Mojave and lower Sonoran Deserts. It has occurred in southern California’s Coachella Valley for nearly 80 years, punctuated by years of extremely high abundance following high rainfall. In those years the mustard has clear negative impacts on the native flora. Using mustard removal experiments I identified reductions in native plant reproduction, shifting composition increasingly toward Sahara mustard while decreasing the fraction of native species.

Without control measures the long-term impacts to desert biodiversity will be an increasing decline in native annual plants, with potential broad trophic impacts. High between-year variance in precipitation may be a key to maintaining biodiversity as the mustard is less abundant in drier years. Without control, the fate of Sahara mustard and the desert's biodiversity may rest on a changing climate. Drier conditions will keep the mustard from becoming dominant but will likely have other negative consequences on the native flora and fauna.

Renewable Energy Development and Desert Tortoise Conservation: Is Industrial Development of the Desert Compatible with Survival and Recovery?

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The Center for Biological Diversity has consistently advocated for the enforcement and expansion of protections for the threatened desert tortoise in the media, the administrative process and, when necessary, through litigation for over 20 years. The Center remains focused on science-based advocacy to ensure that land use planning and management on public lands as well as site specific decisions on both public and private lands provide effective protection for the desert tortoise and other imperiled species that will support recovery. To that end, the Center focuses our efforts on using existing environmental laws, including NEPA and ESA as well as state laws, to ensure that public agencies prioritize the survival and recovery of listed species in their management of public lands and in funding or carrying out projects.

As of September 2009, there were over 150 proposals for large industrial-scale renewable energy projects pending in the California Desert alone with dozens more proposed in Nevada, Arizona and Utah within the range of the listed population of the desert tortoise. A subset of about 18 of these projects (12 in the California Desert), called the "fast track" projects, are racing to be permitted and "shovel ready" by the end of 2010 to secure federal stimulus grant funding. In addition, new utility line proposals to service new generation facilities have the potential to further fragment habitat and act as a magnet drawing development into inappropriate areas.

The solar proposals on public lands in the CDCA alone (about 63 applications) cover over 500,000 acres, including many thousands of acres of occupied desert tortoise habitat. The scale of individual projects is unprecedented with many proposals covering 4,000-6,000 acres or even up to 10,000 acres of contiguous lands. The proposed projects run the gamut from previously disturbed private lands formerly used for farming in the desert to intact high quality occupied desert tortoise habitat on public lands. At least one wind generation proposal would impact over 1,500 acres of occupied desert tortoise critical habitat on Daggett ridge in the Ord-Rodman DWMA near a long term desert tortoise study site.

The Center is concerned that direct impacts to tortoises and habitat, as well as indirect and cumulative impacts from multiple projects, may undermine ecosystem integrity causing the collapse of subpopulations across the range. One example of an areas of concern is the Ivanpah Valley, much of which was identified for desert tortoise conservation in the 1994 Recovery Plan (see map at page 41) and supports a diverse and biologically rich suite of plants and animals, including the threatened desert tortoise. Presently, five large solar projects are proposed in the Ivanpah Valley, two in the northern Ivanpah Valley in California and three on the eastern side of the valley in Nevada. After taking a detailed look at the biological resources of northern Ivanpah Valley, including new information from surveys conducted by the solar companies that want to develop the area, it is clear that this area should be secured for long-term conservation and recovery of the desert tortoise and other species. Indeed, once again, we can see the foresight and accuracy of those scientists who drafted the 1994 Desert Tortoise Recovery Plan which identified this area for protection for the benefit of the desert tortoise. Unfortunately the BLM declined to follow the direction of the 1994 Recovery Plan in managing the public lands and excluded large areas of the Ivanpah Valley from protection in the DWMA, as a result, the Center and other conservation groups have needed to step up to fight for protection in this area.

As many of you know, the Center for Biological Diversity has also worked diligently to press government agencies to take the threat of global warming seriously, to utilize existing laws and enact new laws to move us towards significant reductions in greenhouse gas emissions. The Obama administration and the State of California have recently taken significant steps in that direction which we applaud.

The need to replace energy sources that emit large amounts of greenhouse gases is clear. We need to develop renewable energy *but we need to do it right*. We need to put large industrial-scale projects in *appropriate* places not in areas where they will displace significant populations of desert tortoise, destroy habitat and highly functioning ecosystems. Certainly some compromises will need to be made at the margins, but siting of large scale industrial facilities must take into account the facts on the ground, not only the preferred design of the developers. Alternative sites and alternative ways of meeting energy demand, including conservation and distributed renewable energy development, must all be fully explored as well.

Planning efforts by the BLM, state, and local agencies for the California Desert never contemplated this level of large scale industrial development, and, as a result, no planning was done. As a result, while many project proposals are moving forward in a scatter shot fashion and sprawling across the landscape, the BLM is at the same time undertaking planning efforts to find areas (or zones) to group projects near existing or approved transmission and to the extent possible in areas that are already disturbed. We applaud the BLM's new planning effort but fear it may be far too late if projects are approved piecemeal and "zones" are created by the momentum of industry lobbying instead of by rational planning principles. As those who have studied the desert well know, the impacts to the land and habitat are long term – if not permanent— even where there is funding for restoration efforts and the will to undertake them. Before any more desert tortoise habitat is lost, thoughtful and careful environmental review and planning must be completed.

Finally, there is also a new planning effort to support desert tortoise recovery through mitigation funds that will be acquired from large industrial scale development in the desert. The Renewable Energy Action Team ("REAT") which includes BLM, FWS, CDFG, and CEC, is currently developing a conservation plan, the Desert Renewable Energy Conservation Plan ("DRECP"), that will identify high priority land acquisitions and recovery actions to help coordinate and potentiate future mitigation efforts. The Center applauds any efforts to increase recovery actions for the desert tortoise and provide more protection of critical habitat and other conservation lands, and to increase the land base that is protected for conservation. To that end, the Center intends to work closely with the agencies to develop a robust science-based plan with meaningful enforceable protections for many species across the desert landscape. However, *mitigation cannot replace conservation.* First and foremost, impacts to high quality occupied desert tortoise habitat must be avoided. Only after all avoidance measures have been explored and put in place (including alternative siting where necessary) should mitigation measures be implemented.

In sum, the Center for Biological Diversity supports renewable energy development in the right places which can be identified through an open public process using the best available science and good planning principles. The Center will continue to advocate for the protection of the desert tortoise and all imperiled species on both the local and regional level and advocate for science-based efforts to recover this keystone species of the southwestern deserts.

A Model of the Invasion and Establishment of Sahara Mustard (*Brassica tournefortii*) in the Western Sonoran Desert

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We studied the invasion and establishment of Sahara mustard, *Brassica tournefortii* Goan, at a 4.66 km^2 site in the Chemehuevi Valley of the western Sonoran Desert, California, USA. We used mixed data sets of photographs, transects for biomass of annuals, and densities of *B. tournefortii* collected at irregular intervals between 1979 and 2009. We suggest that *B. tournefortii* may have been present along the main route of travel, a highway, in low numbers in the late 1970s, and invaded the site from the highway and along a major microphyll woodland wash. In 1999 *B. tournefortii* density ranged from 0.55 plants/m^2 at the highway edge to 0 per transect at ~1700 m from the highway. By 2009, *B. tournefortii* density ranged from 33 plants/m^2 at the highway to 1.59 plants/m^2 ~1700 m from the highway. In addition, *B. tournefortii* had become established throughout the valley.

To develop a predictive model for invasibility of this region by *B. tournefortii*, we evaluated relationships of surficial geology/soils, habitat type, and distance to the highway on *B. tournefortii* density in 1999 and 2009. *Brassica tournefortii* densities differed significantly by surficial geology/soils and distances to the highway. During the initial invasion, significant predictor variables were proximity to the highway and to the microphyll woodland wash, as well as number of nearby washlets. However, once *B. tournefortii* was well established, proximity to the highway and number of washlets were the only significant predictor variables. Microhabitats also influenced density of *B. tournefortii. Brassica tournefortii* densities were higher under shrubs in washlets than in open desert under shrubs or intershrub spaces. Overall, *B. tournefortii* thrives in disturbed areas along road edges, in poorly developed soils, and on young geological surfaces. It is highly successful in naturally disturbed areas, such as within shrubs in washes and washlets. The ability of *B. tournefortii* to rapidly colonize and become established in the desert Southwest poses severe threats to the well-being of desert ecosystems.

Highway 58 Fence Study Reloaded: Effectiveness of a Highway Barrier Fence after 19 Years

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Roads and highways pose a threat to many vertebrates due to natural movements and dispersal patterns of these animals. In some cases, this mortality may be compensatory, but in others the rates of mortality may be high enough to cause population declines. Barrier fences, if properly designed and maintained, can effectively mitigate against such mortality, and if they do, they can be viable mitigations to the impacts ofsolar and wind energy developments. We conducted surveys for desert tortoise sign within 1.6 km of the edge of Highway 58, where a barrier fence was constructed in 1990, and Highway 395, where no tortoise barrier fence exists. We compared the results to similar surveys conducted in 1991 and 1994. In 2009, we documented a decline by 83% in tortoise sign, and by inference, tortoise relative density, within 1.6 km of both highways. However, we also documented an increase in the number of burrows and proportion of sign occurring within 400 m of the edge of fenced Hwy 58 since 1991. In 2009, there was more sign within 200 m of fenced Hwy 58 compared to unfenced Hwy 395. Even after 19 years of the fence being in place, there is still a road effect; however that effect appears to have diminished. The amount of habitat “reclaimed” by tortoises along 1.6 km of Highway 58 is equivalent to 30 hectares of habitat not directly affected by the highway.

Is Translocation a Viable Option for Desert Tortoises: Measuring Short- and Medium-term Effects of a Large-scale Translocation Project

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Translocation is a highly controversial management strategy, because success of most projects is relatively low. More troubling is that translocations of threatened, endangered, and sensitive species have resulted in lower success rates than other groups. Translocation of desert tortoises was a tool approved to mitigate the acquisition of 110,000 acres for the expansion of Fort Irwin to facilitate more realistic training scenarios. Tortoises are being translocated from two areas: the Southern Expansion Area (23,000 acres) and the Western Expansion Area (69,500 acres). We are studying six primary measures of success (survival, dispersion, burrow use, reproduction, genetic assimilation, and habitat use) using up to 216 translocated, 108 resident, and 109 control animals. We are also comparing various modes of translocation (soft-release, hard-release, pens, and short versus long-distance). Preliminary trends revealed by some of these studies will be reported.

Reducing Raven Predation on Desert Tortoises: Does Removing Nests Prevent Ravens from Continuing to Nest?

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The common raven is an important predatory species that is hampering the recovery of threatened desert tortoise populations in the Mojave Desert. Habitat Conservation Plans and Biological Opinions for alternative energy and other developments usually include stipulations designed to reduce the probability that a development will facilitate an increase in raven presence and their predation on nearby tortoise populations. One of those conditions is the removal of raven nests. Here I report on the experimental removal of raven nests to determine if this is a viable management option. For three years, nests were searched for and removed on the 13-km^2 Hyundai Automotive Test Site Facility. Nests were also monitored within approximately 1.6 km of the perimeter to serve as references. A total of 35 to 62 raptor nests were observed each year. Thirty-eight (12.7 per year) were removed from the test site. A total of 53% were rebuilt within 1- 3 months of when the originals were removed and a few were removed more than once in a season. Annual nest removals resulted in 44% fewer nests occurring on the site. During the same time, there was a 15% reduction in nests off site,

where we did not remove nests. This indicates that birds probably did not simply move into the area surrounding the test site to nest, but rather skipped nesting altogether for the year. Annual nest removals did reduce the number of ravens nesting in the area, but the removals would have little effect if not coupled with other actions.

Management of Desert Tortoise Habitat on Public Lands Managed by the Bureau of Land Management – Nevada

Sandra Brewer, PhD., Program Lead

Fisheries, Wildlife, Threatened and Endangered Species
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The BLM administers about 4.5 million acres of desert tortoise habitat in Clark, Lincoln, and Nye counties in Nevada of which 1,085,000 acres are designated as Critical Habitat. The Battle Mountain, Ely, and Southern Nevada District offices coordinate and conduct the majority of BLM's management activities for desert tortoise. The following are highlights from NV BLM's 2009 accomplishments. The BLM has successfully created a 20-year mineral withdrawal on 24 Areas of Critical Environmental Concern (ACECs) totaling nearly 945,000 acres in Clark and Nye counties in southern Nevada. Additionally, BLM is working with Partners in Conservation and the Southern Nevada Site Stewardship Program to monitor designated roads in desert tortoise ACECs over the next two years. This effort will reduce and repair resource injuries across 700,000 acres. The NV BLM continues to implement recovery actions including: (a) monitoring locations for desert tortoise habitat conditions and desert tortoise populations in Lincoln Co.; (b) reclaiming over 17 miles of roads and (c) installing over 15 miles of fencing at numerous locations that were being continually disturbed by motorized vehicles; (d) successfully obtaining competitive funding from the Mojave Desert Institute to create about 13 miles of fuel breaks in desert tortoise habitat to prevent large habitat losses due to fire; and (e) continued implementation of the Ely District Resource Management Plan that includes creating management plans for three ACECs within the next three years. Section 7 consultation remains a major workload for the Districts. Wildfires in desert tortoise habitat will continue to receive priority response; this includes emergency stabilization and restoration plans developed to rehabilitate the burned areas as quickly as possible. The BLM is continuing to monitor post-fire vegetation treatments.

San Diego's Renewable Energy Future is Bright

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San Diego Gas & Electric Company (SDG&E) is committed to providing safe, reliable energy to our customers in the most environmentally responsible manner possible. Using the power of the sun, wind and geothermal sources are ways that SDG&E is fulfilling this commitment. SDG&E's programs and services help promote energy-efficiency, sustainability, and renewable energy solutions.

SDG&E supports the state's priority of making California the nation's leader in solar energy. Our regional energy plan is a balanced plan that includes energy-efficiency and demand-response programs, more energy from renewable sources, as well as new electric transmission and generation. We will meet the state requirement of delivering 20 percent of the power from renewable sources by this year, and 33 percent by 2020 as required through an executive order issued by Governor Arnold Schwarzenegger.

With the California Public Utilities Commission's ("CPUC") approval, up to $250 million will be invested in solar installations throughout the greater San Diego area over the next five years as part of San Diego's largest solar initiative. This innovative program will spark a partnership between businesses, municipalities, and institutions to dramatically increase the use of photovoltaic (PV) tracking technology at shopping centers, schools, open places and landfills.

SDG&E has a 20-year contract with Stirling Energy Systems' (SES) to purchase up to 900 megawatts of solar energy generated by up to 36,000 SunCatcher dishes spread across ten square miles in the Imperial Valley. This will be one of the world's largest solar power projects. SDG&E has signed other contracts and continues to solicit and review several thousand megawatts of proposed generation facilities to deliver energy from various sources including solar trough technology, wind, geothermal, and biomas.

One of the difficulties encountered by the renewable energy providers is having adequate transmission capacity for delivering their energy to market. Without a delivery source the energy providers are not able to secure adequate funding. SDG&E has recognized this issue and is seeking to permit and construct a new high-voltage transmission line between San Diego and Imperial Valley called the Sunrise Powerlink. The Sunrise Powerlink is a key element of SDG&E's regional energy plan to improve the reliability of the power grid and increase the use of renewable energy. The 120-mile transmission line is expected to be completed in 2012 and will deliver new supplies of needed electricity to homes and businesses and connect the region to clean solar, wind and geothermal projects located east of San Diego.

The future looks bright for renewable power in San Diego. Vast supplies of solar, wind and geothermal energy are sitting untapped in eastern San Diego County and the sunny deserts of Imperial Valley. Together, these regions could become a leading producer of renewable power and help reduce polluting greenhouse gas emissions in California.

Update on Desert Tortoise Protection Efforts by Western Watersheds Project

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Western Watersheds Project (WWP) works to protect and conserve the public lands, wildlife, and natural resources of the American West through education, public policy initiatives and litigation. In October 2008, WWP and WildEarth Guardians petitioned the Secretary of the Interior to list the Sonoran desert tortoise population as a Distinct Population Segment under the Endangered Species Act and to designate Critical Habitat. On August 28, 2009 the USFWS issued a positive 90-day finding on that petition. The Sonoran desert tortoise occurs in southwest Arizona and northern Mexico. The USFWS found that Sonoran desert tortoises qualify as a distinct population, different from other tortoises found in the Mojave Desert west of the Colorado River that were federally listed in 1990. The USFWS finding also addressed the unlisted population of Mojave type desert tortoises that live in the Black Mountains in northern Arizona. The USFWS determined that the Sonoran desert tortoises may be threatened by all five factors the agency uses in deciding whether a species qualifies for Endangered Species Act protection: 1) habitat loss and destruction; 2) overutilization; 3) disease or predation; 4) inadequate legal protections; and 5) other factors. Under the Act, the tortoises needed to qualify under a minimum of just one of these factors. The full list of threats noted in the 90-day finding include: habitat loss from livestock grazing, urbanization, border activities, off-road vehicles, roads, mining, harm to individual tortoises from shooting, collection for pets or food, diseases such as upper respiratory tract disease, shell disease, and other pathogens; increased predation by ravens, coyotes, and feral dogs; inadequate legal protections, including on federal and state public lands; altered fire patterns due to exotic weeds; crushing and killing of tortoises by off-road vehicle users; and prolonged drought, exacerbated by the climate crisis. WWP and WildEarth guardians are working with USFWS to ensure that the one year status review triggered by the 90-day finding is completed in a timely manner.

WWP is currently engaged in litigation with the Bureau of Land Management (BLM) over cattle grazing on the Sonoran Desert National Monument. WWP's litigation on the Sonoran Desert National Monument hopes to attain improved interim management for desert tortoise habitat pending the completion of the Monument Resource Management Plan. Elsewhere in Arizona, WWP has been protesting proposed grazing decisions within desert tortoise habitat based on BLM Determinations of NEPA Adequacy tiered to Environmental Impacts Statements completed over two decades ago.

WWP continues its efforts to conserve listed Mojave desert tortoise populations and to ensure that recovery measures are based on best available science. WWP is challenging an experimental restoration project proposed within Mojave desert tortoise habitat in Arizona, Utah, and Nevada where the BLM is proposing using non-native vegetation. WWP is concerned that effects to tortoise and other habitats were not properly considered. WWP is actively involved in reviewing many of the industrial-scale renewable energy projects that have been proposed in desert tortoise habitat throughout the Mojave Desert. In addition to massive direct loss of habitat, these projects threaten to further fragment habitat and disrupt connectivity between the evolutionarily significant units identified in the 1994 Recovery Plan.

STUDENT PAPER

Potential Conservation Benefits of Multiple Paternities in the Threatened Desert Tortoise, *Gopherus agassizii*

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Conservation of the desert tortoise (*Gopherus agassizii)* depends largely on maintaining the maximum amount of remaining genetic and individual diversity in the species. One of the factors which affect the expression of genetic variation is the number of sires whose genes are expressed in each clutch. Thus, understanding paternity patterns improves our ability to develop effective plans for tortoise conservation. We analyzed paternity of desert tortoise clutches at Edwards Air Force Base (EAFB) and Twentynine Palms Marine Corps Air Ground Combat Center (Twentynine Palms), California, during the course of ongoing headstart programs operating at both sites. We used 20 microsatellite loci to genotype mothers, neonates, and potential fathers encountered in the vicinity. We included nests with ≥3 neonates from which genotypes could be obtained in the paternity analysis. We used both conservative criteria (requiring evidence from 2 or more loci) and less rigid criteria (requiring evidence from only 1 locus) to estimate the incidence of multiple paternities at each site. At EAFB, 50 to 100% of the nests were sired by multiple males, and at Twentynine Palms 58 to 83% of nests showed evidence of multiple paternity. Desert tortoises clearly exhibit multiple paternities, which may have

important implications for their conservation, and raises interesting questions about female choice in this species.

Managing Desert Tortoise on California BLM lands: Can We Chart the Path to Recovery Amidst Renewable Energy Development?

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In 2009, the Bureau of Land Management (BLM) continued to work on projects such as tortoise translocations associated with Fort Irwin Expansion, signing Northern and Eastern Colorado desert routes (especially in the Chuckwalla Bench Desert Wildlife Management Area) as the first step in habitat restoration efforts, the in-depth tortoise study initiated in 2008, acquisitions of private land, and conducting desert tortoise surveys in several areas. We funded an evaluation of the effects of the Hwy 58 fencing on tortoise mortality and densities, 19 years post construction. Additionally, we have coordinated with US Fish and Wildlife Service on data needed for their spatial decision support system, a tool that will assist land mangers in assessing the benefits of different recovery actions for tortoise and help in the prioritization of these actions. However, most of our effort and time was focused on solar and wind energy projects. Industrial renewable energy development projects are of a size and scale that California BLM has not previously contemplated nor envisioned. We face a huge challenge of managing the public trust. With the potential loss of thousands of acres to a single use and the projected mitigation requirements and associated funding, we want to be strategic in how mitigation is applied to get the maximum benefit for the tortoise, and other wildlife species. While many argue that renewable energy will be the demise of the tortoise, we ask, “Could industrial renewable energy provide an unprecedented opportunity to implement suites of targeted recovery actions and actually move the tortoise towards recovery?” In coordination with Fish and Wildlife Service and California Department of Fish and Game, BLM is striving to chart that path.

Health, Behavior, and Survival of 158 Tortoises Translocated from Ft. Irwin: Year 2

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A sample of 158 desert tortoises from Ft. Irwin’s Southern Expansion Area (SEA) was translocated in the spring of 2008 to four study plots located outside the SEA. Prior to translocation, tortoises were grouped into one of four health categories. Tortoises were monitored on a regular basis and have received comprehensive health evaluations during

each spring and fall. We evaluated the development of new diseases, survival, movement patterns, and changes in clinical signs of disease and trauma after translocation. These responses were compared among health categories, sexes, and release plots. Overall, there has been an increase in prevalence of mycoplasmosis (2.8–2.9% tortoises with positive or suspect ELISA tests for *Mycoplasma agassizii* in 2008; 4.9–9.2% in 2009). Deaths of translocated tortoises, primarily from predation, have remained high in 2008 (27.2%) and 2009 (23.5%), and death rates varied among plots. Movement parameters also differed among years, seasons, sexes, and plots. Tortoises have dispersed up to 12.5 km from their release sites, with a mean dispersal distance of 2.5 km. Our results provide evidence that tortoises have begun to settle and that increased activity levels are associated with increased risk of mortality. Future work will entail continued monitoring and health evaluations, analyzing clinical signs of disease and trauma, and quantifying differences in habitat among study plots. We place the preliminary results of this study in context with future translocation projects.

Illegal Collection of Desert Tortoises in the Sonoran Desert

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The expansion of human transportation infrastructure into desert tortoise (*Gopherus agassizii*) habitat in the Sonoran Desert has raised questions concerning the appropriate mitigation strategies to reduce impacts at the population level. While direct impacts (namely road-kill mortality and habitat loss) have been well documented, indirect impacts such as illegal tortoise collection have been insufficiently addressed. From a management perspective, it has become increasingly important to understand the cumulative impacts that roads have on tortoises. We estimated the probability of desert tortoise collection along three road categories to evaluate whether collection probabilities were related to road type. The predicted probability of a motorist detecting a desert tortoise was highest on maintained gravel roads and lowest on non-maintained gravel and paved roads. Given tortoise detection, motorist response varied by road type with the probability of tortoise collection highest on maintained gravel roads. We discuss the implications that these results have for comprehensive road mitigation strategies.

POSTER

Landscape-Level Habitat Models for Desert Tortoises in Southwestern Arizona

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The Arizona Game and Fish Department is developing a landscape-level habitat model to predict desert tortoise (*Gopherus agassizii*) occupancy on three military installations in southwestern Arizona (i.e., U.S. Army Yuma Proving Ground, Barry M. Goldwater Air Force Range, and Marine Corps Air Station, Yuma). These models will assist natural resource managers in identifying potential conflicts between desert tortoise conservation and maintaining the military's mission with the overall goal of reducing conflicts and mitigating the potential impacts of military training activities. We present preliminary results of our first year of research and the anticipated benefits of taking a landscape-level approach to desert tortoise conservation on these installations.

POSTER

Modeling Desert Tortoise Occupancy on the Florence Military Reservation, Pinal County, Arizona

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The Florence Military Reservation (FMR), located in Pinal County, Arizona serves as a desert training complex for the Arizona Army National Guard. The installation also provides habitat for desert tortoises (*Gopherus agassizii*). The goal of this study was to evaluate the distribution of desert tortoises within the FMR training area and develop recommendations to minimize impacts to tortoises while maintaining the National Guard's military readiness mission. We conducted standardized tortoise surveys on 228 3-ha survey plots and calculated occupancy estimates using a likelihood-based approach which allowed us to estimate the proportion of area occupied (PAO) as well as detection probabilities. We also examined the influence of site- and survey-specific covariates on detection probabilities and PAO. Detection probability was best modeled as a function of time, being highest during the early morning surveys (i.e., sunrise to 10am) and declined as the day progressed. The average detection probability across all the survey plots was 0.307 (range: 0.209 to 0.400; *SE* = 0.054). The overall PAO was estimated at 0.216 (*SE* = 0.055). Our results indicate that tortoises were 1.67 times more likely to occupy a plot with each caliche cave present. Desert tortoises were 0.45 and 0.35

times as likely to occupy a plot when roads and cattle sign were present, respectively. We discuss management recommendations for reducing impacts to desert tortoises on the FMR based on the results of this study.

2009 RECIPIENT OF THE DAVID J. MORAFKA MEMORIAL RESEARCH AWARD

The Prevalence and Distribution of *Mycoplasma agassizii* in the Texas Tortoise (*Gopherus berlanderii*)

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Upper respiratory tract disease (URTD) caused by *Mycoplasma agassizii* is characterized by ocular and nasal discharge, conjunctivitis, and decreased appetite and lethargy. Significant morbidity and mortality can be caused by the secondary effects of this disease including generalized malaise and decreased visual and olfactory function. URTD has been associated with major losses of free-ranging desert tortoises (*Gopherus agassizii*) and gopher tortoises (*Gopherus polyphemus*) in the United States. This has prompted investigation into the prevalence and distribution of the disease in the Texas tortoise (*Gopherus berlandieri*). Blood samples were taken from 40 Texas tortoises for detection of anti-mycoplasma antibodies by ELISA. Of the 40 tortoises, 11 were seropositive indicating that they had been exposed to mycoplasma and developed a detectable immune response. Twenty six of the tortoises were seronegative, and three were suspect for antibodies against *M. agassizii* on the ELISA test. Seropositive tortoises were found on both public and private lands in Cameron and Hidalgo counties of south Texas. Nasal lavage samples were collected for culture and detection of *Mycoplasma agassizii* gene sequences by polymerase chain reaction (PCR). Of the 35 tortoises that had nasal lavage performed, only one was positive on culture and PCR for *Mycoplasma* organisms.

Reproductive Nutrition Revisited

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We evaluated whether dietary nitrogen concentration, food consumption, and nitrogen consumption affect the reproductive output of female desert tortoises.

Reproductive output did not vary with the concentration of nitrogen (0.5 to 3.0%), but female size and condition affected reproductive output (e.g., clutch size, fecundity, egg size, clutch mass and clutch nitrogen content). Body reserves probably enabled some females to produce eggs while eating the low nitrogen diets (0.5 and 1.0% N). Neither nitrogen intake nor food intake affected reproductive output of the first (immediate) reproductive season, but reproductive output in the second year was correlated to nitrogen intake, especially nitrogen intake during the first year. These correlations correspond with vitellogenesis of the largest ovarian follicles before winter, although small follicles may also develop at this time. There appears to be a trade-off between current and future reproduction, especially with regards to nitrogen intake in spring. The highest food and nitrogen intakes occurred shortly after females oviposited, suggesting a constraint of current reproductive state on the nutrient intake that influences next year's reproductive output.

QuadState Local Governments Authority: A Partner in Desert Tortoise Recovery

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QuadState LGA continues to speak for and represent local governments in the Mojave and Sonoran Deserts. During the past year it has grown to eight counties, with the addition of La Paz County Arizona. During the past year we have remained engaged with the land management and wildlife agencies regarding both the Mojave and Sonoran Populations of desert tortoise.

Regarding the Mojave Population we await, like many others, the release of the reviewed and revised recovery plan. We look forward to working with the State and Federal agencies on implementation. Counties are actively engaged with the California Desert Managers Group, and have been accorded membership as public agencies in the Management Oversight Group. We participate in the Mojave Desert Initiative which covers the three eastern states, and we provide a conduit of information regarding wildlife and land rehabilitation between the State and Federal agencies and local governments. QuadState grew from a need by the counties for services and advice regarding tortoise, and other natural resources and public lands issues for which many lack staffing to cover. With current budget shortfalls, many may be less likely to directly participate in the future. QuadState and its three member counties from California were granted intervener status in the current litigation regarding the West Mojave, and we are participating with the Federal defendants on the case.

We remain concerned on several elements of the Recovery Plan revision, and hope the Fish and Wildlife Service addresses at least some of them, but will await release before reacting and commenting on what may or may not be in that document.

Regarding the Sonoran Population, Mohave County asked that we become engaged in the review regarding the petition to list, which is under FWS consideration at the present time. We have engaged the wildlife agencies regarding data and information so as to assist Arizona counties in responding to the petition. The addition of La Paz County to our organization is a direct result of the petition process and its desire to engage in the process in advance of decision-making. We have made other counties in Arizona aware of the petition.

We [the counties] look forward to developing partnerships and interface with the Arizona agencies and interagency organizations, and to continuing our relationship with the agencies in California, Nevada and Utah, so as to provide local governments with information; and to provide the agencies with local government's perspective on issues, policies and information.

The Desert Tortoise Conservation Center: A New Story

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In March 2009, the San Diego Zoo's Institute for Conservation Research, as a member of the Conservation Centers for Species Survival (C2S2), entered into a cooperative agreement with the US Fish and Wildlife Service (FWS), the Bureau of Land Management (BLM), and the Nevada Department of Wildlife (NDOW) to take over operations of the Desert Tortoise Conservation Center (DTCC) in Las Vegas, Nevada. Our main goal at the DTCC is to play a role in the conservation of the Mojave Desert ecosystem, including the recovery of the desert tortoise. To that end, the San Diego Zoo and its partners are changing the role of the DTCC from that of a transfer-and-holding facility to one that will support range-wide recovery efforts for the desert tortoise through conservation research, participation in on-the-ground recovery actions, training of biologists, and public education. The DTCC staff will share details of our first year on site. We have made improvements in husbandry and veterinary care, we have conducted a variety of medical tests and performed advanced veterinary procedures, and we have given the facility a face lift. In addition, we have gained community support through a volunteer/intern program, and we have conducted public education to improve the captive care of pet desert tortoises and to discourage people from removing wild desert tortoises from their native habitat. We have also established research protocols for translocation of desert tortoises back to the wild, and we are working with local agencies and organizations to collaborate on projects to improve the lives of desert tortoises everywhere. We are pleased to share the news with the desert tortoise community that the DTCC will soon have a new story to tell; one in which we can ensure that wild desert tortoises beat the odds and win the race to survive.

Tortoises Through the Lens (TTL): A Community-based Approach to Conservation

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Tortoise Through the Lens, TTL, is a community-based conservation action project; empowers high-desert youth by teaching them ecology, biology, and photography and guides them throughout the Mojave to photograph its beauty and species. The project is centered on the desert tortoise, so that the students can gain a deeper understanding of this desert icon and its plight, and can use their art towards conserving this threatened reptile.

The 20-minute presentation will consist of: 1) an introduction to the program, including how and why the program was developed; 2) how education can complement capacity building for youth; 3) what successes and lessons learned can be used to involve and engage non-traditional allies into conservation action; and 4) future efforts for TTL. The format will be a PowerPoint presentation, narrated by David Lamfrom. The presentation will also feature a photo gallery of some of the student's best work. Five minutes will be provided at the end of the program to allow for questions.

Timing is Everything for Renewable Energy

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Work on the 52 solar projects and 54 wind energy projects proposed for public lands is focused on applications seeking federal stimulus funding and on essential transmission line projects. These include nine solar projects, five wind energy projects, three geothermal projects and three transmission lines in the California desert. Most of these are located within desert tortoise habitat. The filing of so many applications in a short period of time created an unanticipated workload for all federal and state permitting agencies, and for the public utilities. Biological consultants, including desert tortoise experts, are stressed.

Conservation of existing habitat for the desert tortoise is a primary issue for nearly all renewable energy projects. An unprecedented amount of detailed information is being received. Many sites have had surprises, ranging from the finding of zero tortoises to the finding of nearly a hundred tortoises to the finding of 3,000 year old tortoise bones.

Relocation or translocation of tortoises from the development sites poses many difficult problems. Given that disease testing, surveys of recipient sites and extensive monitoring may be necessary, how can the tortoises be moved so that the project is "shovel ready" by December 2010? Should tortoises be moved in the fall or in a low rainfall year when little food is available?

The time frame to meet the funding deadline has led to high risk for the energy companies and great uncertainty on how to proceed. Desert tortoise mitigation and compensation issues remain as major obstacles. Substations and transmission capacity may not be available at the time the power plant is ready to start production. The federal bureaucracy is not well equipped to provide timely review. Renewable projects not on the fast track may experience significant delays in review of their plans, even though they may have a superior technology or may be located in places without desert tortoise habitat.

Shifting priorities, infeasible deadlines, lack of experienced staff and mounting opposition from many sources have created a chaotic scenario for biologists attempting to provide a thoughtful and reasoned approach to analysis of the project impacts on the desert tortoise. Regional planning is following, rather than leading, the review of projects. Decisions on the fast track projects will precede the federal Solar Energy Environmental Impact Statement and the California Desert Renewable Energy Conservation Plan. The analysis of cumulative impacts is particularly difficult. For example, preclusion of connectivity linkages between critical habitat units is a possibility.

Despite these challenges, agency biologists have a commitment to "do it right" and to suggest modifications that will conserve essential desert tortoise habitat for the long term. The public interest in conservation of wildlife, including the threatened desert tortoise, is equal to the public interest in achieving energy independence.

PG&E's Renewable Energy Program: Our Approach to Meeting the Challenge

Glen Lubcke, Senior Land Planner, Land and Environmental Management

Pacific Gas and Electric Company

Pacific Gas and Electric Company (PG&E) is the largest investor owned utility in California. There are approximately 20,000 employees who carry out PG&E's primary business—the transmission and delivery of energy. The company provides electricity and natural gas to about 15 million people throughout a 70,000-square-mile service area in northern and central California. Like all utilities in California, PG&E is working towards increasing its renewable energy portfolio and PG&E's portfolio is one of the cleanest in the nation. In our efforts to become an environmental leader, PG&E is actively engaged in many efforts of renewable energy exploration and acquisition in the western Mojave Desert. Examples of our efforts and involvement with renewable energy in the Mojave Desert include:

- The tracking and monitoring of privately-owned renewable energy plants that allow PG&E to sign Power Purchase Agreements (PPAs);
- Participation in regional planning efforts to develop Best Management Practices for the draft Desert Renewable Energy Conservation Plan Best Management Practices & Guidance Manual: Desert Renewable Energy Projects;
- Participation and involvement with the Renewable Energy Action Team (REAT);
- Tracking, monitoring, and participation of the BLM programmatic EIS for renewable energy on public lands;
- PG&E is actively involved with many stakeholder groups that include solar, energy, and environmental groups with a focus on coming up with practical solutions to minimize impacts on the environment;
- Participation with the California Transmission Planning Group to track and monitor the regional planning efforts for transmission lines and renewable energy generation; and
- Participation and involvement with RETI (Renewable Energy Transmission Initiative).

SCE Leading the Way in Renewable Energy

Milissa Marona, Project Manager

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If we equate kilometers to kilowatt-hours, then Southern California Edison (SCE) is the Lance Armstrong of renewable energy buyers. SCE buys more energy from renewable resources than any other utility in the U.S. About a hundred miles separate the Tehachapi wind farms from the Los Angeles basin. That's about two hours on the highway. Well, electricity needs a special super highway to travel on, and SCE is proposing to build it.

STUDENT PAPER: ORAL PRESENTATION AND POSTER

Bolson Tortoise (*Gopherus flavomarginatus*) Headstart in New Mexico, 2009

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Restoration of the endangered bolson tortoise (*Gopherus flavomarginatus*) in the United States is dependant on captive breeding and headstarting of young. Bolson tortoises presently occur in the wild only in a small region of the Chihuahuan Desert in Mexico; an area less than 100 miles across its broadest point (Tennesen 1985, Bury et al. 1988). Three known populations of bolsons now exist in the United States, two on

Turner ranches located in southern New Mexico, and 1 in a zoo setting located at the New Mexico Living Desert Zoo and Garden State Park near Carlsbad. Twenty five live on Turner's Armendaris Ranch and 38 juveniles live on Turner's Ladder Ranch. In 2009, 25 hatchlings were produced; 13 on the Turner ranches and 12 in Carlsbad. Since the transfer of the adults from the Appleton ranch in Arizona in 2006, various techniques have been used to increase the production of neonates, which eventually will be introduced experimentally into the wild to assess their survival. X-rays have proven to be particularly useful because they not only tell us the number of eggs each gravid female has, but also an estimated time of laying. On the Armendaris ranch during the summer of 2009, 10 females were x-rayed 4 times during the nesting season (May-July). Ninety percent were determined gravid for the first clutch and 70% for a second clutch. No females produced a third clutch. Two graduate students surveyed two 8.5 acre enclosures twice daily throughout the nesting season to locate natural nests; success was limited. Nests found were either protected with an 18x16in wooden box and 2x2ft chicken wire apron predator-proof enclosure or eggs were removed for indoor incubation. Three tortoises hatched as laid in one of these enclosures. X-rays determined 84 eggs total from gravid females on the Armendaris. Among these eggs, only 27 (32%) were located in the fenced enclosures. Of the 27 eggs, 19 (70%) were removed for artificial incubation and 8 (30%) were incubated naturally. Time of indoor incubation from eggs hatching ranged between 72–80 days and natural incubating ranged between 100–110 ±5 days. By this and similar field experiments, we will continue to refine techniques to obtain large numbers of hatchlings for future releases in the wild.

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Conservation Challenges of a Desert Tortoise Population at the Edge of its Range

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The Red Cliffs Desert Reserve (Reserve) is located in southwestern Utah at the northeastern extent of the tortoises range. The Division of Wildlife Resources has been monitoring tortoises in the Reserve since 1997. Population monitoring in 2009 indicates a population decline of tortoises throughout the Reserve since 1997. In 2003, an increased number of tortoises with clinical signs of URTD were observed along with an increased number of adult shells. In the summer of 2005, approximately 14,471 acres

burned within the Red Cliffs Desert Reserve. The Reserve is considered a highly threatened population due to its proximity to urban growth, small size, as well as human and stochastic threats (e.g., recreation, fire, disease, drought). We will discuss challenges that land managers face when managing a tortoise population at the edge of its range.

California's Fading Wildflowers: Lost Legacy and Biological Invasions

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Spanish explorers in the late 18th century found springtime coastal California covered with spectacular carpets of wildflowers. Nineteenth century botanists and naturalists describe flower fields across the central valley and interior southern California. Annual newspaper reports of identifiable sites such as Riverside (1885-1905) and the "Alter of San Pasqual" (Pasadena, 1885-1920), and "circle tour" localities (1920-2005) including the Arvin flower festival, Antelope Valley, Coachella Valley and Inland Empire, reveal that interior wildflower fields survived into the mid-20th century. California wildflowers were the basis of floral societies and the foundation of the New Year's Rose Parade in Pasadena. Summer coastal pastures, which were extensively burned by Native Americans, were not "grasslands" as translated from the original Spanish, but "*pasto*" and "*zacate*," interchangeable words that mean forage good for livestock. Spanish, Californio and early American settlers alike describe the California interior in the dry season as "*esteril*" or "barrens," an observation of desiccated and disarticulated native forbs that left little dry biomass.

Invasive annual grasses and forbs from the Mediterranean Basin and Middle East have devastated this nearly forgotten botanical heritage. Franciscan exotics *Brassica nigra* and *Avena fatua* had extensively displaced coastal forbfields by the Gold Rush, but flower fields in inland valleys and plains were displaced a century later by *Bromus madritensis*, *B. diandrus*, and *A. barbata*. Invasives such as *Erodium cicutarium, E. moschatum* and the clovers of *Trifolium and Medicago* coexisted with native forbs, while *Malva parviflora* and *Hordeum murinum* were limited to areas of chronic disturbance. Defenders of the perennial bunch-grassland (*Nassella)* model as the aboriginal vegetation baseline—a hypothesis deduced using space-for-time substitution by Fredrick Clements—built their case on "scientific" evidence that began in the mid-19th century. However the first botanists saw already widespread exotic grasslands, a classic case of the "shifting baseline syndrome"—the story being told is dependent on the baseline of choice. In this story, bunch grassland is assumed to have been replaced by exotic annuals due to overgrazing, but 19th century writings clearly show that bunch grasses were not important to the vegetation and that invasive species spread across California, far ahead of grazing. California wildflower pastures were displaced by invasive species without disturbance. The invasive species—fire feedback hypothesis in coastal California is refuted in view of Crespi's remarkable account (1769) of Native American burning in indigenous fuels, but merits consideration for interior barrens now covered with cured exotic annual grassland. The role of grazing should be viewed in geological time scales because the evolution of the California flora coincided with diverse megafauna that exerted a cattle-like disturbance until the end of the Pleistocene. Packrat middens document that wildflowers have been part of California's heritage as conspecifics since at least the last glacial maximum, perhaps long before.

The wildflower flora was less affected by invasive species in the California deserts. The only widespread introduced species from the Franciscan mission period was *Erodium cicutarium* which likely spread across southeast California in the late 18th century. Descriptions of *Erodium cicutarium* coexistence with wildflowers by John C. Frémont and other mid-19th century naturalists and botanists in the central valley suggests that similar coexistence may have existed in the deserts. Wildflowers were described in the Mojave Desert by Frémont in the 1840s, and the early 20th century in local newspapers including reports of "circle tours" in the Los Angeles *Times* despite the rapid expansion of *Schismus barbatis* across the desert in the 1940s. While *Bromus rubens* first proliferated across coastal California in the 1890s, it was collected extensively in the Mojave Desert only by the 1930s, and did not become abundant until heavy rains fell from 1978 to 1983, the wettest 6-year period in instrumental records in southern California. After wet years vast carpets of red brome from 1978 to 1997 carried extensive fires (ca. 10,000 ha) and suppressed wildflowers. Dry years failed to produce good blooms. Extreme drought in 1989-1991 in the Sonoran Desert, and 1996-1997 in the Mojave Desert resulted in brome "crashes." Mass germination with the first fall rains was followed by mass mortality before reproductive maturity due to poor follow-up rains, destroying both grass cover and the seed bank. Unusually productive *Schismus barbatis* carried fires after wet years in the Coachella Valley in the 1990s. *Bromus rubens* survived best above 1200 m in western Joshua Tree National Park where it contributed to an 18,000 acre burn in 1999, a year after heavy El Niño rains in 1998. Since the 1990s wildflower blooms have again splashed across the desert, where brome has been extirpated at regional scales or greatly diminished. Historically unprecedented extreme drought produced another brome crash in 2002 (no rain fell in many areas of the desert for an entire year) was followed by a "once in a lifetime" spring bloom in 2005, after the wettest winter in instrumental records. Extraordinarily productive wildflowers (1-2 tons ha^{-1}) and native grasses (*Aristida*, *Hilaria*) fueled extensive fires in the NE Mojave Desert, eastern San Bernardino Mountains, and Joshua Tree National Park in 2005 and 2006 (60,000 ha). Fires are seldom fueled by *Brassica tournefortii*, which first proliferated in the lower deserts in the late 1970s, because its flammability is diminished by its coarse stem structure and open arrangement of stems compared to grasses. Once dry, stems also tumble with the first high winds. The future of the California deserts may be one of periodic invasion of brome after wet years and their replacement by native wildflowers after drought. Reconstruction of earthquake history along the Garlock fault near Mojave, using C-14 dates of charate, reveals that fires had infrequently burned creosote bush scrub over the past 7000 years of the Holocene. The desert was not "fire proof" before the arrival of invasive species.

California's wildflower heritage has been overlooked because of a flawed hypothesis that bunch grasses were pervasive in the past. We take for granted the rapidly fading wildflower heritage because the perception of past vegetation among the scientific community and the public has been built upon this erroneous premise. This bunchgrass story has canalized us to perceive California ecosystems in a certain way, preventing us from observing, doubting, and searching for alternative evidence to construct alternative stories. California invasive grasses and forbs are productive and aggressive not because of intrinsic life traits, but because they are New World "goats on islands," without their Old World pathogens. The restoration of California's wildflower flora will require management strategies involving the entire landscape, with a historical perspective. Potential avenues for effective management and conservation include spring burning, seasonal grazing by domesticated livestock, and use of Old World pathogens as biological controls of California's invasive annual species.

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Head-starting Desert Tortoises at the Twentynine Palms Marine Base: 2009 Update

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The Desert Tortoise head-start hatchery-nursery facility at the Twentynine Palms Marine Base was established to research head-start methodology, including vertical transmission (mother to egg) of *Mycoplasma*-based disease (URTD). This question was abandoned following three years of unsuccessful location of wild females having clinical (visible) symptoms of URTD or positive ELISA or PRC tests, but several other questions are being studied. In collaboration with Dr. R. Murphy, we found that the incidence of multiple paternity within egg clutches is high, similar to earlier results from Edwards AFB. Since hatchling sex is determined not by their genes but by incubation temperature, we wondered whether something about the head-start facility may have influenced nest temperatures and thus the sex ratios of hatchlings. Dr G. Kuchling used endoscopy to determine the sex of about 30 juveniles each from 2006, 2007 and 2008 cohorts at TRACRS, and found that from 66% to over 95% of cohorts were females. Results to date are insufficient to test for a significant trend over time. Since 2006, hatching success, survivorship from hatchling to yearling, and survivorship from yearling to three years old have all been between 70 and 90 percent. Analyses of growth rates suggest that most juveniles hatched in the TRACRS facility, which receives supplemental "rain" to prolong growth of food plants, are growing about three or more times faster than do juveniles in "control" enclosures that get only natural rainfall. Projections of these growth rates suggest that these juveniles may reach releasable size (estimated to be about 110 mm MCL) after a minimum of about seven years.

Shell Hardness Index and Rate of Shell Hardening in Desert Tortoises

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Heavy predation on hatchlings and juveniles of the threatened Desert Tortoise is apparently a major impediment to recovery of the species in the Mojave Desert. The shell of hatchlings remains soft and flexible for years, and hardening of the shell, along with increased size, is thought to improve predator resistance greatly. We used a tension-calibrated micrometer to measure shell hardness of 158 young tortoises with ages ranging from one to 17 years, from three desert sites in California. Shell Hardness Index (SHI) values exhibited considerable variation within age cohorts, and adjusting for size (MCL) variation within age cohorts did not reduce this variation in SHI. Shell hardness increased asymptotically with increasing age and increasing size. Juveniles having access to an extended supply of green desert annual plants due to experimental rain supplementation grew faster but exhibited softer shells than control (natural rainfall only) tortoises during their first year (but not in subsequent years) of life.

Conservation Activities to Benefit the Desert Tortoise: Educational Outreach, Land Management, and Habitat Improvement

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For the last 36 years the Desert Tortoise Preserve Committee, Inc. (DTPC) has focused its desert tortoise conservation and recovery efforts through educational outreach, land acquisition, active land management, and more recently, habitat improvement. Success in the campaign for the recovery of the desert tortoise can only result from these types of on-the-ground actions.

Last year approximately 10,000 people were contacted via educational presentations, public outreach events, and through contact with the Interpretive Naturalists staffed at the Desert Tortoise Research Natural Area (DTNA). Each contact helped spread the important message of conservation throughout the range of the imperiled desert tortoise.

The DTPC was awarded $89,000 in grant funding from the Off-Highway Motor Vehicle Recreation (OHMVR) Division for two ground operations projects in 2009. The bulk of the funding ($68,000) will be used to install desert tortoise exclusion fencing along three miles of the DTNA's boundary fence. The dramatic increase in traffic on roads near the DTNA necessitates this protective fencing. The remainder of the funding ($21,000) will be used to replace vandalized and weathered signs, sign newly fenced areas, and provide additional directional signage at major intersections near the DTNA.

The entrance to the DTNA, badly damaged by off-roading activities in recent years, was fenced in 2009. This fencing will prevent future impacts from vehicle trespass and allow the habitat in the area to recover naturally. The fencing also serves to make the entrance of the Natural Area more attractive to visitors.

The long-term goal of completing desert tortoise exclusion fencing along Harper Lake Road was accomplished in December of 2009. The DTPC's Harper Lake Road Fencing Project is the result of a successful multi-agency effort to ensure compliance of mitigation conditions under federal and state permits. The DTPC assumed fencing and monitoring commitments made by Luz Solar Partners Ltd VII and IX whose permits for the protection of the desert tortoise and its habitat were in default. But for the DTPC's role in fencing and monitoring Harper Lake Road, the road and impacts associated with the solar plant built in the 1980s would not have been mitigated.

The DTPC continued to focus heavily on improving the habitat at Camp "C". The five acres of habitat improvements (i.e. vertical mulch, horizontal mulch, and catchments) constructed in 2007 were regularly watered and monitored throughout the year and new practices were conducted on an additional 7.5 acres. The current status of the project and plans for an additional 17.5 acres of habitat improvement will be discussed.

The Pitfalls of Using Test Results for Decision-Making in Conservation Programs.

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The importance of disease risk assessments and disease screening for reintroduction and translocation programs is universally accepted and comprehensive tools are now available to guide the process. However, the traditional approach of developing a list of diseases of concern, testing release candidates for those diseases, and making release decisions based on the test results suffers from several fundamental problems. These problems are best illustrated by looking at two common scenarios where test results are used for decision-making in translocation and reintroduction programs.

The first scenario occurs when a population of apparently healthy animals is being screened to identify disease carriers, or those in the early (asymptomatic) stages of

disease, so they can be *excluded* from a release cohort. It is important to understand that most diagnostic tests are designed to detect an infectious agent (or the host response to an agent) in an animal showing clinical signs of disease. Diagnostic tests that have been validated for the host species in question will generally perform well in this situation, because animals with clinical signs are the ones most likely to have the disease agent. However, when the very same tests are applied to animals without clinical signs, as in our first scenario here, test performance will decline significantly (because animals without clinical signs are the ones least likely to have the agent). Poor test performance will be manifested as a high proportion of false positives in this situation, leading to misclassification errors that not only exclude valuable individuals from translocation programs, but sometimes result in euthanasia of perfectly healthy animals.

The second scenario occurs when a mixed population of healthy and diseased animals is being tested to verify that the apparently healthy individuals are test-negative (truly disease-free), so they can be *included* in a release cohort. Test performance will also be poor in this situation, but will be manifested as a high proportion of false negative results. This leads to misclassification of infected animals as uninfected, and therefore to the unintentional release of diseased individuals into the wild.

Additional problems occur when surveillance is only conducted on the source population. To adequately evaluate the risk posed by the presence of an agent in the source population, one needs to know whether the agent is also present in the destination population. However, it is seldom feasible to sample sufficient numbers of animals in the field to answer this question, and the same interpretive problems with surveillance tests described above would apply.

Using test results for decision-making in conservation programs requires a thorough understanding of these pitfalls and the tailoring of surveillance programs to the specific populations and questions at hand.

Arrival and Spread of *Brassica tournefortii* in Southwestern North America

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Brassica tournefortii ("Sahara mustard") has become an abundant annual weed in open dry areas, especially in sandy soil, through much of southwestern North America. In less than 90 years it is spread from an initial point of establishment in the Coachella Valley in Riverside County, California, to points as far distant as the Central Coast Range of San Benito County, California, El Paso, Texas, and the coast of southern Sonora, Mexico. It has also found its way into southwestern Utah and is continuing to spread north in the Coast Range and San Joaquin Valley of California. So far it is unrecorded from Inyo County, California. It now occupies an area that stretches some 1460 km NW to SE and c. 1300 km east-west. Yet, it has not stopped its spread, though in some areas it may have reached ecological limits.

Natural and Induced Antibodies in Experimentally Immunized Desert Tortoises (*Gopherus agassizii*): The Importance of Season and Gender

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Captive desert tortoises were immunized with ovalbumin (OVA) in Ribi's adjuvant to induce a humoral immune response, both before and after hibernation. We observed a significant mean increase in OVA-specific antibody, and a gender-by-season interaction in the ability of desert tortoises to make an induced immune response. We observed relatively high levels of pre-existing natural antibody to OVA in all tortoises, and levels varied among individuals. There was a significant, negative relationship between an animal's natural antibody titer and the maximum increase in induced antibody titers, and a significant, positive relationship between the magnitude of long-term elevations in OVA-specific antibody titers and the maximum increase in induced titers. Both natural and long-term elevations in induced antibody titers may be important elements of the tortoise immune system, with possible influences on the ecology and evolution of host-pathogen interactions. Reliance upon natural antibodies and the persistence of induced antibodies may be an adaptation in reptiles to defend themselves from pathogens in spite of their slow metabolic rates. In addition, natural and persistent antibodies may impact the interpretation of serological assays.

STUDENT PAPER

Digging Deeper: An Examination of Invasive Species and Nitrogen Deposition Effects on Aboveground Annual Forb Communities and Seed Banks in the California Deserts

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Invasive species pose a threat to natural communities around the globe. In southern California, desert ecosystems are experiencing altered nutrient cycles, increased fire frequency, and competitive effects from invading annual plants. Anthropogenic nitrogen deposition adds to the problem by artificially fertilizing the desert's low nutrient soils and creating a favorable environment for invaders. This degradation of habitat not only affects the vegetative community, but also the animals, such as the desert tortoise, that rely on it. In two related studies, we investigated the effects that invasive annual species and nitrogen deposition have on the aboveground community, as well as how that translates to the soil seed bank. A field study in the Colorado Desert using invasive removal and nitrogen additions demonstrates that both natives and invasives can respond positively to nitrogen additions, however invasive removal is required for natives to

obtain maximum benefits. A seed bank study at Joshua Tree National Park in sites fertilized with nitrogen shows that while nitrogen can have significant effects on the aboveground community, this is not always evident in the soil seed bank. It does, however, elicit important differences between sites, suggesting that factors such as background nitrogen deposition, soil rockiness, and historic levels of invasion may play an important role in seed bank composition. This work has important implications for conservation efforts, as well as emissions legislation. Understanding the combined effects of invasive species and nitrogen deposition on the desert landscape will help to create a more complete picture of how and why natural lands are being altered.

Desert Tortoise Recovery Efforts and Plans at Mojave National Preserve

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Mojave National Preserve encompasses 772,463 acres of designated habitat for desert tortoise (*Gopherus agassizii*) in the Fenner and Ivanpah valleys. In November, 2009 Chevron Inc. began removing the waste water pipeline from the Molycorp Mine site to former evaporation ponds on the Ivanpah dry lake bed. As part of the mitigation effort, Chevron is constructing a facility for research into juvenile headstarting as recommended in the Revised Recovery Plan Implementation Schedule section 3.3. An interagency panel of experts will select one of three highly qualified research groups to undertake this 15 year study. The primary criterion for selecting a research team is the potential to promote recovery of the species. An equally high priority is the ongoing mortality of tortoises along the 140 miles of paved roads through designated habitat. In the spring of 2009 we hired a contractor to conduct transects along Morningstar Mine Road and Essex Road following the methodology of Boarman and Sazaki (1996). Preliminary analyses suggest a population depression extends beyond 1.5 km from the edge of the road. We have requested funding for fencing critical highway sections. Our observations of traffic indicate that the roads connecting Las Vegas with populated areas to the south carry more traffic at a higher speed than other roads. Drivers on these roads have a 4% likelihood of spotting a tortoise in the road and warning signs appear to have no effect. Mojave National Preserve is continuing desert tortoise outreach and education efforts in partnership with the Desert Managers Group.

Desert Managers Group

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The Desert Managers Group (DMG), an organization of federal, state, and county land managing agencies in the California deserts, focuses on coordinating and integrating desert tortoise recovery actions and monitoring efforts among managers and scientists across jurisdictional boundaries. A key to desert tortoise recovery is an informed public that understands and appreciates desert tortoise recovery. Now in its fourth year, the DMG is partnering with non-governmental organizations to continue its desert tortoise education program. Some goals of the program include standards based environmental education, brochures targeting specific audiences or topics, and media releases. The DMG is also coordinating ongoing regional assessments and science with renewable energy permitting plans such as the Desert Renewable Energy Conservation Plan and the Bureau of Land Management's Solar Programmatic Environmental Impact Statement.

Department of Fish and Game and the Desert Tortoise, Our State Reptile

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Since 1939, state laws have been in place in California to protect the desert tortoise. In August of 1989, the tortoise was officially listed by the Fish and Game Commission as threatened under the California Endangered Species Act (CESA). Sections 2080.1 and 2081 of the Fish and Game Code permit take for scientific, educational, management, or incidental take to an otherwise lawful activity provided the take is minimized and fully mitigated. In addition to an Incidental Take Permit, a Memorandum of Understanding (MOU) for Handling Tortoises is needed, and we must review the qualification of each person who applies for the MOU. The Department also issues Scientific Collecting Permits and MOUs for research and studies on desert tortoise; and permits for possession of Captive Tortoises.

The Department, through the CESA permitting process, and by other means, continues to acquire lands within recovery units. Along with the land acquired, the Department has also collected enhancement and endowment fees for management of the lands. Fencing has been installed in some areas to exclude cattle grazing and off-highway vehicle use. In addition to the lands that have been acquired by the Department, mitigation lands have also gone to the Desert Tortoise Preserve Committee.

In 2009, the Department spent significant time and resources on renewal energy projects. Work continued on permitting numerous small projects, which include mining activities, housing and other urban development, and road projects. The Department also spent considerable time again this year working with Department of Defense on the Fort Irwin Expansion, reviewing mitigation lands, working to with the Fish and Wildlife Service to update the Desert Tortoise Handling Guidelines, permitting desert tortoise research projects, improving our methods for dealing with captive tortoises and working on subgroups of the Desert Managers Group on management and protection of the desert tortoise in California.

Fire and Invasive Species Impacts on Native Desert Annuals: Causes for Concern and Opportunities for Recovery

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Exotic annual species, like *Bromus* spp., *Schismus* spp., and *Erodium cicutarium*, have invaded low elevation creosote bush scrub in California and other portions of the American southwest. Exotic grasses, in particular, have exerted a strong influence on this vegetation by increasing the frequency and extent of fire, a disturbance that was historically very infrequent (Brooks and Esque 2002, Brooks et al. 2004). Sites that have been burned show little resiliency as dominant perennial species appear poorly adapted to fire (Brooks and Minnich 2006, Abella 2009). The impact of fire on native desert annuals is less understood (Brooks 2002). We were interested in the following questions pertaining to fire and annual plants; how does fire effect invasive and native annual species composition; how long do these impacts last for; and what is the impact of repeated fire? These questions were addressed by examining a series of burned creosote bush scrub stands from western Coachella Valley that ranged in time since fire from 3 to 29 years ago. In addition, a site containing portions unburned, once-burned, and twice-burned were also investigated. We found that shortly after fire, invasive species like *Erodium cicutarium* and *Schismus* spp. are promoted by fire while *Bromus madritensis* ssp. *rubens* and native annual species decline. Fires decreased native annual species richness, which was detected in burns ranging from 3 to 21 years old. The impact of repeated fire was especially severe, with decreased species richness occurring each time a stand burned. In general, fire promoted invasive annual plants and negatively impacted native annuals.

To tease apart the difference between fire impacts and invasive annual interference on native annual plants, invasive plant removal treatments were implemented in burned and unburned sites. Regardless of fire history, invasive species removal dramatically increased native annual species abundance and richness. Then, when comparing invasive removal plots in a burned site with invasive removal plots in an unburned, relatively "pristine" site with high regional species richness, the burned site exhibited native annual plant abundance and species richness equal to or greater than the "pristine" site. These results imply that native annuals, collectively, are highly resilient to fire if invasive species are not present. In other words, the general decline in native annual species richness that is common in creosote bush scrub after fire is more attributable to invasive species competition rather than from fire itself. Competitive interference from invasive annual species appears to be a great threat to native annuals in both burned and unburned creosote bush scrub. Lastly, our invasive plant removal treatments revealed that a post-emergent herbicide, Fusilade II, is effective at killing both exotic grasses and *Erodium cicutarium* with minimal nontarget effects. If applied with discretion, this product appears to show promise as a valuable tool in the battle to control invasive species in desert landscapes.

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Response of Desert Tortoise Habitat, Populations, and Individuals to the 2005 Southern Nevada Complex Fire in Lincoln County, Nevada

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The Southern Nevada Complex fires of 2005 burned thousands of acres of desert tortoise (*Gopherus agassizii*) habitat in Lincoln County, NV. In 2008 and 2009, we assessed vegetation characteristics at burned and unburned sites by measuring shrub and herbaceous density, species richness, gap intercept, line-point intercept, and herbaceous production. Line Distance Sampling Transects were added in burned and unburned areas as well. Additionally, GPS transmitters were affixed to tortoises near the burned area to efficiently track individual movements. A variety of vegetation characteristics with consequences for desert tortoises differed in burned vs. unburned sites. Overall, species richness of plants palatable to desert tortoises was significantly lower at burned sites. Additionally, an increase in the percent cover and production of all herbaceous plants was observed at burned sites. While this suggests an increase in the quantity of food available to tortoises after fire, much of the increase is likely driven by one exotic forb, *Erodium cicutarium*, which was most prevalent at burned sites. Conversely, species richness and density of native plants, some of which are consumed by desert tortoises, were lower at burned sites. Finally, both species richness and percent cover of shrubs were lower and the spacing of shrubs was higher, at burned sites, which could have impacts on desert tortoise thermoregulation. Line Distance Sampling transects in burned and unburned

areas observed only ~2% of tortoises in burned areas. GPS data indicate tortoises in this study are using burned habitat and ~47% of tortoise home-range areas were burned.

An Introduction to the IUCN Red List of Threatened Species, and its Application to the Desert Tortoise

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This presentation will give a quick overview of the aims of the IUCN Red List of Threatened Species, the criteria determining a species' assessment, the assessment process, and the wider implications of Red List status, using the Desert Tortoise as an example. Much more detail than can be provided in this presentation is available at http://iucnredlist.org, particularly http://iucnredlist.org/technical-documents/categories-and-criteria and http://iucnredlist.org/technical-documents/assessment-process.

The Desert Tortoise (*Gopherus agassizii*) in Mexico, Project Update

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Approximately 40% of the desert tortoise's (*Gopherus agassizii*) geographic range is in northwestern Mexico, yet little is known of the species south of the border. Starting in 2001, we initiated collaborative international efforts involving researchers, agencies, tortoise field biologists, and local citizens to acquire baseline data on tortoise ecology, status, and conservation biology in Mexico. In 2001-2002 we documented a major mortality event on and near Tiburón Island. In 2005-2006 we sampled near Alamos (tropical deciduous forest,TDF), Hermosillo (Sonoran desertscrub), and Obrégon (foothill thornscrub), capturing 63 tortoises, as well as telemetering 19 in the TDF. Disease analysis, which also included 22 captive tortoises, indicated that all but one of the wild tortoises were negative for *Mycoplasma*, whereas 17 of the captives were positive or suspected positive. During 2007-2009, we maintained telemetric monitoring at Alamos. We continued extensive sampling during 2008 and 2009, focusing in Sinaloa where the currently known southern range limit (Topolobampo, Sinaloa) is found, and on the genetic-morphological-ecological transition zone in eastern and southern Sonora. There is concordance of morphology and genetics with the subtropical (desertscrub plus thornscrub) - tropical TDF transition, but these concordances appear imperfect and potentially complex. We found 39 additional tortoises, and still remain to clearly confirm the presence of *Mycoplasma* and related disease in the wild in Mexico. Based on 16 microsatellite loci and ~1200 bp of the mitochondrial ND4 gene, we identified two genotypes in Sonora; one in desertscrub and thornscrub resembling the Arizona type ("Sonoran") and a second notably associated with TDF ("Sinaloan"). Sinaloan samples showed elevated genetic variation. We estimate this Sinaloan type diverged 5-6 mya from a common ancestor with the Sonoran and Mojave lineages. Spatial overlap of several genotypes at the southern boundary of Sonoran Desert scrub may be the result of a natural species friction zone, human translocation or possibly isolation prior to the formation of the Sonoran Desert. Two key conservation problems are likely affecting this tortoise in Mexico—climate-driven mortality episodes and intensified fire regimes associated with type conversion from native vegetation to Africanized buffelgrass pasture. The Tiburón mortality episode was associated with drought, as also observed in southern Arizona Sonoran Desert. Although precise causes of such episodes remain to be rigorously demonstrated, apparent associations with heat and drought foreshadow tortoise declines if current climate change predictions prove correct. We have limited observations of tortoises in buffelgrass-thornscrub landscapes, but plan to expand upon published observations suggesting that type conversion may decimate tortoise populations.

Antigenic Variation in *Mycoplasma agassizii* and Distinct Host Immune Antibody Responses Explain Differences Between ELISA and Western Blot Assays

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Due to the precarious status of desert (*Gopherus agassizii*) and gopher (*G. polyphemus*) tortoises, conservation efforts typically include health assessment as an important component of management decision-making and often may be the determining factor for translocation of animals. Mycoplasmal upper respiratory tract disease (URTD) is one of very few diseases in chelonians for which comprehensive and rigorously validated diagnostic tests exist. Recently, it has been suggested that the ELISA for detection of *M. agassizii* misidentified negative animals as seropositive and that Western blot analysis was a more reliable test. We present data that demonstrates that the failure to detect immunoreactive bands to *M. agassizii* strain PS6 in Western blots from selected ELISA-positive tortoises is most likely a result of the failure to use multiple *M. agassizii* strains as antigens in the Western blot.

In this study, sera and clinical isolates of *M. agassizii* were obtained from eight *Gopherus* tortoises documented at necropsy to be (i) ELISA seropositive, (ii) infected with *M. agassizii* as indicated by direct isolation of the pathogen from the respiratory surfaces, and (iii) to have histological lesions of URTD. We selected four clinical isolates of *M. agassizii* (strains PS6, 723, IR, and 262) for preparation of SDS PAGE and ELISA antigen**.** We also compared the reactivity of tortoise sera in an ELISA in which different strains of *M. agassizii* were used as antigen. Sera from tortoises were tested for the ability to recognize antigens prepared from heterologous as well as homologous strains of *M. agassizii* by both EISA and Western blot.

Serum from all eight tortoises reacted with *M. agassizii* strain PS6 when used as the ELISA antigen, but only 6 of 8 (75%) sera had strong banding patterns against *M. agassizii* strain PS6. All tortoises reacted by Western blot with SDS PAGE antigens prepared with the homologous strain of *M. agassizii,* but unlike the ELISA, reactions with SDS PAGE antigens prepared from heterologous clinical isolates varied markedly. For many mycoplasma species, detection of specific antibodies by ELISA is considered to be relatively strain-independent, whereas other assays such as Western blot, metabolic inhibition, and complement fixation assays are documented to be strain-dependent or best used for confirmation. These differences are likely explained by the location of the antigens (surface exposed, membrane or cytosolic), binding affinity to microtiter plates, degree of surface variation, biofunctional assays, and *in vivo* expression of antigens.

The ability of clinical isolates of most mycoplasma species to express different surface proteins, the variability in host immune recognition of antigenic determinants, and the need for multiple mycoplasma strains as antigens in Western blot analysis of naturally infected animals is well documented in the literature. In our study, individual variation in the immune response among animals, even to the same strain of *M. agassizii,* was common in Western blot. We observed similar heterogeneity in the response of individual animals to *M. agassizzi,* with antigens prepared from both the homologous strain recovered from the individual as well as from heterologous strains. Even in animals documented by the most rigorous methods to have current active URTD, Western blot using a single antigen failed to detect true positive animals in 25% of cases, whereas ELISA reliably detected all animals proven to have URTD.

The American West at Risk:
Science, Myths, and Politics of Land Abuse and Recovery

Howard G. Wilshire and Jane E. Nielson

Email: howardgw@comcast.net

The American West at Risk: Science Myths, and Politics of Land Abuse and Recovery, speaks to rising public concerns over environmental calamities echoed in our national headlines, and offers ways to combat the damages. The text illuminates how the western United States reached a state of resource depletion, along with extensive land, water and air pollution, and species extinctions. Especially in the Western U.S., land misuse and overuse have created a serious crisis.

Southern California suffers from multiple legacies of land abuse, principally misguided grazing and farming practices, military training, reckless urbanization, unbridled mechanized recreation, and exploration for and exploitation of energy and metallic minerals. Massive wastes--the nation's number one product--either created in the desert or disposed of there, include Cold War pollution from both training and weapons tests, both radioactive and not, and the urban garbage overflow. After describing the book's origin, purpose and objectives, we will detail the rapidly accelerating threats and potential consequences of locating utility-scale solar and wind power plants in our deserts, and discuss the best alternatives.

Wilshire, H.G., J. E. Nielson, and R.W. Hazlett. 2008. The American West At Risk: Science, Myths, and Politics of Land Abuse and Recovery. Oxford University Press, Inc. New York, New York. 619 p.

Department of Defense and Desert Tortoise Conservation

Bob Wood[1], Clarence A Everly[2], Manny Joia[3], John O'Gara[4], and Brian T. Henen[5]

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Military installations face many challenges just as other land management agencies. Desert tortoise (*Gopherus agassizii*) populations continue to decline on military bases. Predation by common ravens, coyotes, and domestic dogs has an effect on desert tortoise populations. Military bases must employ ecosystem management principles and manage their lands for multiple uses and military missions. Department of Defense (DoD) installations in the western Mojave Desert initiated and continued many conservation programs for the desert tortoise in 2009. Conservation measures covered a broad spectrum at each installation including education and outreach, research, and other projects to manage the species and habitats. DoD installations also participated in the Desert Managers Group, associated workgroups, and the Desert Tortoise Management Oversight Group, to support recovery planning and action. Projects such as head starting are designed to increase populations and enhance recovery efforts and can be exported to areas beyond installation borders. Some of our research projects have broad applications beyond the boundaries of the military installations. Research projects include disease studies, population monitoring and demographic research, predator research, and head starting. Public outreach and education of base personnel continue to be important programs at military installations. These efforts involve presenting programs in schools, education of military and civilian workforce to supporting public outreach activities in

local communities. Desert tortoise conservation efforts involve a significant commitment of resources within our environmental offices and throughout the installations.

U.S. Geological Survey

The Heat Is On:
Desert Tortoises and Survival

Program Requirements

Purpose:

To highlight USGS scientists' research and build support for the work being done to help with desert tortoise recovery.

To educate people about desert tortoises, their habitat needs, and what people might do to help.

Audience: General public, middle school age to adult.

Target venues:

1. The web.
2. DVDs for distribution and library.
3. Television

Length: 30 minutes

Scientists:

Roy Averill-Murray, (USFW)
Kristin Berry, (USGS)
Kristina Drake (USGS)
Todd Esque , (USGS)
Becky Jones, (Cal F&G)
Larry LaPre, (BLM)
Phil Medica, (USGS)
Ken Nussear, (USGS)
Steve Schwarzbach, (USGS)

Production:

Producer/Director: Steve Wessells, USGS, (702) 564-4626, swess@cox.net

The Heat Is On:
Desert Tortoises and Survival

Fade in:
An amazing sequence of a baby tortoise hatching.
For example:
1. ECU of cracked egg with some reptile-y moving inside. [Hatching video, :52 or :58]

MUSIC: Lively, "welcoming" sound, more world beat than symphonic UP AND UNDER

SFX: if accompanying scene—crunch of shell breaking, possibly tortoise sounds, etc.

2. The baby tortoise's head breaks through the shell [HV 1:12]

NARRATOR: (voiceover)
Hello, newborn desert tortoise!

3. Absolutely marvelous ECU of the tortoise in its shell, looking right at the camera and looking around. At first one foot is out, then it gets the other one out. It looks curious and is pushing at the shell with its leg. [HV 2:05]

Welcome to your world.
Look around.

Break out of your shell
and explore what lies ahead.

Stretch your legs.
Feel the desert soil.

One thing for sure, though—
it won't be easy.

<u>superimpose title:</u>
4. *The Heat Is On: Desert Tortoises and Survival*

MUSIC UP AND OUT
[Music will be incorporated as appropriate throughout the production]

<u>dissolve to:</u>
An intriguing montage of "blips" from the science stories—engaging scenes with voiceovers indicating that the desert tortoise is in trouble. Pick up scientists' dialogue as appropriate and available.
For example:

5-A. Man and woman with tortoise

<u>Man / Woman exchange</u>: (on camera) And this is a male? Yes. Oh yeah look at that tail…yes.

5-B. A woman is walking through scrub all rigged up with transmitter and antenna; see her from behind walking in lovely desert. [Thermoregulation video, 2:33]

<u>Becky Jones:</u> (voiceover)
"...it appears that the desert tortoise is in trouble." [BJ1, 1:13]

6. She slows down and picks up a tortoise, wearing gloves on her hands.

7. Male scientist in red T-shirt is kneeling in the dirt, with his hand deep in a tortoise burrow. [B-roll X-rays, 25:28]

Ken Nussear: (voiceover)
"At, I think, eight or nine study sites we say declines between 30 and 50 percent." [KN, 9:45]

8. CU of scientist rummaging around in the dirt. She or he finds an egg, moves dirt from around it and very gently lifts it up. [B-roll X-rays, 27:37]

Larry LaPre: (voiceover)
"The tortoise has started having severe population declines in about 1989...." [LL1, 1:12]

9. Tilt down from electrical tower to see three small tortoise carcasses with shells with holes pecked in. [DVD3, :05+]

Becky Jones: (voiceover)
"... very few of the small tortoises survive. There's about a 95% mortality rate within the first five years." [BJ1, 15:04]

10. Closeup of drawing blood from a tortoise. [Ft. Irwin blood draw, 11:31]

Ken Nussear: (voiceover)
"We're seeing declining populations due to a variety of factors. Not just disease

not just predation, not just habitat loss but I think a mix of all those things

11. Closeup of vials going into holes in a centrifuge. [Ft. Irwin blood draw, 16:33]

.... are really causing some declines that i hope we can reverse." [KN,4:20]

12. Same scientist from Scene 7, a fellow in red T-shirt. [B-roll X-rays, 5:54+]
He reaches way down into the tortoise burrow.
He pulls the tortoise out of the hole. He lifts her up and blows off the dirt. A female scientist comes over to see. She picks up a clipboard.

Male scientist: voice over
"1-4-7-2-3."

dissolve to:
A sequence of some of the most delightful and fascinating desert tortoise footage. For example:
13. Charming shot of baby tortoise with its feet in front of its face. It moves its feet out of the way and sticks its head out. [DVD 4, 3:45]
14. A scientists is holding a baby tortoise. It moves its feet like it's trying to swim. [DVD 4, 20:06]
15. Collage from standard-def scenes: A great side shot ECU of a tortoise face. [Mojave Desert DVD] A close-up of a tortoise walking. [Mojave Desert DVD]
16. An adult tortoise looks over and up at the camera, comes close and just about puts its nose on the lens. [DVD 4, 22:00]
17. Two tortoises are very close to the camera. One has its nose to the camera, which pans left to the other. This one puts its nose right up there to the camera. [B-roll, X-ray, 5:28]

NARRATOR: (voiceover)

Desert tortoises have lived across this southwest landscape for more than
thousands of years.

Their adaptation to its extreme harsh environment is amazing:

... surviving ground temperatures greater than 130 degrees Fahrenheit.

... and able to live a year, or even two, without water.

But now, the desert tortoise is in danger of extinction.

<u>dissolve to:</u>
An animated mapping sequence that shows the dramatic decline of the tortoise population in the Sonoran and Mojave deserts.
18. Perhaps this sequence begins with a Google Earth zoom from planet-scale to these southwest locales.
19. Animation shows the area with symbols or otherwise representing the thousand tortoises per square mile.

In the 1920s, there were hundreds of desert tortoises per square mile in parts of the Mojave desert.

20. The same area, but with almost no tortoises. Perhaps this can evolve as a sequence, showing the numbers dwindling over time.

Now, in those same areas there may be fewer than a dozen per square mile ...

21. Mapping depicts the Red Cliffs Desert Reserve. This is 62,000 acres. The tortoise population dropped from 3,200 in 2000 to 1,700 in 2008.

Tortoise extinction would have a ripple effect across the desert.

As tortoise numbers drop so too do the numbers of underground burrows that they dig.

A wide host of animals depend upon these burrows from shelter from extreme summer heat and the cold of winter.

Even in a protected Critical Habitat area like the Red Cliffs Desert Reserve, in southern Utah, the tortoise population dropped nearly 50% since 2000.

22. [A graphic element that is a creative transition.]

But perhaps science can yet turn the tide.

<u>dissolve to:</u>
23. Becky Jones on camera. [BJ2, 1:53]
Super title: *Becky Jones, Desert Tortoise Coordinator, California Department of Fish and Game*

<u>Becky Jones</u>: (on camera)
"Science can give us a lot of information on how best to manage populations and areas on which the tortoises live."
[BJ 2, 1:53]

24. Roy-Averill Murray on camera. [RA-M2, 5:27]
Super title: *Roy-Averill Murray, Desert Tortoise Recovery Coordinator, U.S. Fish and Wildlife Service*

<u>Roy-Averill Murray</u>: (on camera)
"... I work with the Desert Tortoise Recovery Office, our job is to facilitate recovery efforts for the species. [RA-M2, 5:27]

<u>cutaway to</u>:
A scene with a lot of scientists. Perhaps:
25. Three people are in a contained area that seems to have dividers; a city is visible in the background. One person has a large tortoise. [B-roll, X-rays, 00:40]

<u>Roy-Averill Murray</u>: (voiceover)
"There's four states, three Fish and Wildlife Service regions, countless agencies and stakeholders and interest groups and researchers..." [RA-M1, :10+]

26. A scientists putting lids on bins that each have two to four tortoises in them. [B-roll blood testing, 5:23]

<u>NARRATOR</u>: (voiceover)
Much of the research guiding the recovery effort is being carried out by ecologists and biologists with the Department of the Interior, U.S. Geological Survey.

27. Todd Esque on camera. [[YouTube 1:10+ tortoise DVD]
Super Title: *Todd Esque, Research Ecologist, U.S.G.S.*

<u>Todd Esque</u>: (on camera)

"USGS researchers are conducting a really great variety of research - including tortoise physiology, general ecology, their responses to fires ...

28. Outside, a long shot with two women carrying three each of these bins, with a fellow at the back of a van, loading the bins inside.[B-roll blood testing, 8:25]

Todd Esque: (voiceover)
"disease and health... hibernation, reproduction, all aspects of their ecology..."

29. A closeup of a tortoise (following from Scene 25) with its neck extended, with almost a haunting look as it looks directly at the camera. [B-roll, X-rays, 2:16+]

Roy-Averill Murray: (voiceover)
"What works? What doesn't work?"
[RA-M2, 6:30+]

30. Closeup of Becky Jones' hand holding a baby desert tortoise in her palm. [BJ1, 11:50]

Becky Jones: (voiceover)
"The more we can learn about the tortoise, the better chance we have to bring it back." [BJ 2, 46:09]

31. ECU of desert tortoise face and shell [Sonoran DVD]

NARRATOR: (voiceover)
Because the Mojave desert tortoise is listed under the Endangered Species Act, there is a federal mandate to restore the populations.

32. A tortoise with a radio collar on top. It moves through rough shrubs toward the camera, moving slowly, and then stops for a bit. [Paula video 10:23]

SFX: beeping sounds (associated with the radio collar)

The tortoise is among the top recipient of federal dollars—because their decline has been quite sudden and wide ranging.

33. A tortoise scratches dirt with its feet, then is digging, digging, digging with the left foot, then digging, digging with its right foot. [Paula video, 12:55+]

... and because they are so long-lived it takes years to know which recovery efforts are working or not.

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dissolve to:

x. Mojave Map

NARRATOR: (voiceover)
The Mojave Desert covers some 25,000 square miles.

It is a part of Utah, Arizona, Nevada and California.

Over 30 years ago, USGS researcher Kristin Berry set up 27 study plots in the Mojave and adjoining Colorado Deserts.

These plots were designed to help understand how tortoise populations and their habitats might be changing over time.

Kristin Berry: (voiceover)
"The long term study plots provide a substantial amount of data on the status and trends in tortoise populations. They are places one can return to year after year, decade after decade and find out how tortoise populations are doing.

I selected for longterm study 15 of the plots that had an adequate sample size of at least 20 to 30 tortoises per square mile.

NARRATOR: (voiceover)

These plots have all experienced declines in tortoise numbers. ..and have helped identify some of the causes behind that decline.

<u>Woman counting:</u>
“..18, 19, 20…..”

<u>Narrator</u>
In this particular plot near Needles, California the scientists are counting the numbers of the invasive plant Saharan Mustard. It is one of several invading plant species causing widespread change to southwest deserts.

<u>Kristin Berry</u>: (voiceover)
... there are 6,000 approximately in this group on the same transect where there was a handful in 1999." [KB2,2:00]

"….the proportion of plants that we have now ten years later is just enormous. It’s been major change" [KB2, 3:05+]

<u>NARRATOR</u>: (voiceover)

Exact impacts of this invasion are being assessed. The invaders take up precious water and nutrients. If the trend continues there’s likely to be a profound effect on native creatures such as the desert tortoise.

Invasive plants pose other dramatic threats as well.

34. A raging desert fire.

SFX: Fire sounds, crackling and sizzling, trees falling over, wind whooshing, etc.

Roy Averill-Murray: (voiceover)
"One of the threats facing the desert tortoise today are increasing wildfires. Because of the invasion of exotic grasses and things which perpetuate a fire cycle that is not historically present in the Mojave Desert. [RAM1, 7:47]

NARRATOR: (voiceover)

The dry stems of spreading invasive grasses fuel devastating backcountry fires.

35. Another raging desert fire scene. [stock footage?]

Tens of thousands of acres of critical tortoise habitat have burned in one year.

36. A fire aftermath scene, showing scorched blackened earth and a dearth of vegetation. [stock footage?]

Native plant foods disappear.
Shrub and shade covers are eliminated.
Some tortoises have been burned to death.

37. Perhaps a scene where invasive grasses are starting to grow again amid the burned land,

Roy Averill-Murray: (voiceover)
"It looks like this is going to be a recurring risk for a long time, at least until we figure out how to deal with invasive grasses." [RAM1, 7:47+]

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45. Pan across sign, "Desert Tortoise Conservation Center." [B-roll, blood and release, 00:10]

Narrator:

The Desert Tortoise Conservation Center was originally established as a way-station for tortoises displaced by Las Vegas development.

46. A wide shot of a person with a tortoise in hand; she turns around and hands the tortoise to another person. The camera moves in to a closeup of the tortoise in the person's hand. [B-roll blood and release, 4:17]

Narrator:

Today, with the expertise of management by the San Diego Zoo and the U.S. Fish and Wildlife Service…it will fill a key role by providing a base for applied research, training and community support.

47. [Inside the Center] a side view of fingers holding a tiny tortoise; its little feet are sticking out. [B-roll, blood and release, 2:32]

Narrator:
One of the U.S.G.S. studies underway at the Center involves a promising Head-starting program.

<u>NARRATOR</u>: (voiceover)
Head starting is taking place at several locations across the Mojave. It is a technique where captive tortoises lay eggs in pens with the young being raised and later released so that researchers can better learn about their survival.

48.

<u>cutaway to:</u>
49. Tortoises are in cement block enclosures. From ground level, see three, then four tortoises moving around over rocks. [B-roll X-rays, 3:50]

NARRATOR: (voiceover)

Since females lay the eggs deep in burrows, how do scientists know when the eggs are laid ... so they can get the eggs to incubate them?

dissolve to:

50. A scientist is next to a female tortoise in the dry-looking and rocky cement block enclosure. [B-roll, X-ray, 1:18]

Scientist: (on camera)
"1-4-7-2-7"

51. Phil Medica on camera. [PM, :30+]
Super title: *Phil Medica, Biologist, , U.S.G.S., Las Vegas Field Station*

Phil Medica (USGS): (on camera)
" ...so we're in the process now of every two weeks we X-ray the female tortoises ... [PM, :30+]

52. A fabulous closeup of the tortoise; it looks at the camera. [B-roll, X-ray, 2:05]

Phil Medica: (voiceover)
"..put the tortoise on the plate…and I'm going to shoot the x-ray now." [X-rays found tape, 3:59]

53. The scientist is wearing gloves holding the tortoise. He or she picks it up and moves it into a plastic bin. [B-roll, X-ray, 1:41]

54. Phil Medica holds the bin, then sets it down, puts on an X-ray apron, walks a little distance away and takes the X-ray. [B-roll, X-ray, 13:13]

Phil Medica: (on camera)
" Okay, stay back. Done."

dissolve to:
55. A woman is seated at a laptop with a round image on the computer screen. [X-rays found tape, 00:10]

Kristina Drake: (on camera)
"So this is one of the X-ray images we shot about
5 minutes ago. And this is tortoise 1-4-9-9-8 ...

56. ECU so that the eggs are visible on the X-ray. [X-rays found tape, 17:19]

... and you can see five visible shelled
eggs on the x-ray here."

57. A different angle of the woman at the laptop. Another woman in a hat is taking notes. [X-rays found tape, 13:44+]

dissolve to:
58. A woman is laying on the ground, feeling deep into a hole. Another person is in the background. [B-roll, X-rays, 25:38]

Phil Medica: (voiceover)
"... and subsequently, if they lay eggs, based on the weight change, we know that at least the 6 eggs that we xrayed last week have been deposited somewhere inside the enclosures.

We will go and find the nest and collect the eggs and then put them in incubators to hatch, hatchlings. [PM, 5:13+]

59. Four people are in the area; one is shoveling dirt. A fellow is scraping dirt. Two other people in the background are moving dirt with their feet. [B-roll, X-rays, 25:49]

Scientist: (voiceover)
"You guys…I found an egg!"

60. A close up of an egg. Hands move dirt from around the egg and very gently lift it out. [B-roll, X-rays, 27:37]

<u>Scientist</u>: (voiceover)
"Got one? Alright! [B-roll, X-rays, 26:29]

61. A person puts the egg gently into a plastic bin and moves dirt around it. [B-roll, X-rays, 28:16]

62. A bin with six eggs is on the ground. A fellow picks it up and carries it. [B-roll, X-rays, 29:50]

63. The fellow is holding the bin, talking to a fellow sitting in a car. [B-roll, X-rays, 30:04]

<u>dissolve to:</u>
64. Inside the conservation center, the fellow writes with magic marker on the bin, then puts it inside an incubator. [B-roll, X-rays, 30:23]
53. Pan around the room that is full of incubators. [B-roll, X-rays, 31:05]

<u>dissolve to</u>:
65. Five eggs with Xs in a plastic bin. [Hatching video, 3:13]

<u>Kristina Drake</u>: (voiceover)
Once the egg's laid in the ground, the temperature in which the eggs are incubated will determine the sex of the offspring. Warmer temperatures are going to produce females, cooler temperatures are going to produce males.

<u>match dissolve to:</u>
66. Five tortoises moving around the plastic bin. [Hatching video, 3:14]

... Once the eggs hatch in the incubators, one of the first things we're going to do is remove them from the incubator. Put them in some sort of out door enclosure, allowing them to get the natural sunlight and hopefully the natural vegetation that they would normally be eating. And then just

monitor these animals and try to ensure survival as best we can.

68. A wider shot of two plastic containers.

69. An engaging tortoise shot. Perhaps: Two tortoises are clambering on rocks; one is looking at the camera. He opens his mouth and yawns. [DVD4, Paul shots, 00:05]

<u>NARRATOR:</u> (voiceover)

For the desert tortoise to be taken off the Endangered Species List, populations must increase or remain stable for 25 years.

70. An engaging tortoise/scientist shot. Perhaps: Scientist at cages for the tortoises. She opens a bin, puts a tortoise in and gives it a little shove. [B-roll blood test and release, 10:34]

Fade to Black then up

71. Marvelous ECU of hatchling tortoise in its shell, looking right at the camera then looking around. [Hatching video, 1:29]

<u>NARRATOR</u>: (voiceover)

Hey, baby tortoise.

You're beginning an amazing life.

<u>"match" dissolve to:</u>

Desert Tortoise Lifecycle animation—For example:

72. The animation begins with an illustration that matches the hatchling in Scene

71. With a desert scene as background, animation shows other reptiles moving in and out of frame, all smaller than a mature desert tortoise. Maybe somewhere here we see its scientific name, *Gopherus agassizii.*

The desert tortoise is the largest reptile in the Mojave Desert.

73. Phil has a graph with data from NTS that can be used here. Perhaps it shows something like age 1-50, with some comparison with humans.

The life span is a bit like humans: Young are soft-shelled and vulnerable.

74. Maybe the animation imitates the footage where one male tortoise is ramming the other. [DVD4, Paula shots, 4:30]

Sexual maturity arrives around age 15.

75. Animation of whatever their courting looks like.

Males and females court...

76. Animation of digging a nest and then the eggs appearing.

... and the female digs a nest for the four to eight eggs, each about the size of a ping-pong ball.

77. Animation that illustrates the two layers. Maybe somewhere in here we can also add on the screen some general statistics that we don't want to take the time to mention, like weight at maturity (8-15 pounds), carapace length (9-15"), height (4-6").

The shell, called a carapace, has two layers:
bone underneath,

…and on top: "scutes"-made of keratin, like fingernails.

78. Animation can show a network of small and long burrows across a landscape.

Desert tortoises spend 90% of their time in underground burrows—which can be shallow, or as long as 30 feet.

79. Animation can illustrate a thermometer with temperature ranges above and below ground.

There they hibernate in winter and stay cool in summer ... when the burrow temperature may be 40 degrees cooler than the searing heat above.

80. Perhaps animation of a wrinkle-faced tortoise match dissolves back into live footage.

Desert tortoises can live to be over 50 years old.

81-A. A close shot of a raven.. It opens its mouth and lets out a caw, then flies off. [DVD3, 7:53+] Or: Looking toward the camera almost inquisitively. It flaps one wing and turns its head. [DVD3, 7:07]

SFX: The raven's low, drawn-out croak

Brian Jacobs: (voiceover)

We're tapping him out with the hopes that when he hears noise he's going to come charging out of the burrow, right on cue.

………..ready?

81-B…..

Narrator:

While deaths from upper respiratory tract disease triggered the endangered species listing…additional threats are multiplying.

Ravens have become an increasingly deadly predator of young tortoises.

82. Larry LePre walks into the scene under two power tower legs; he reaches down. [LLP B-roll, 9:08]
Super title: *Larry LePre, Desert District Biologist, Bureau of Land Management*

Larry LePre: (on camera)
"The easiest place to find Raven nests is underneath power towers.

Yep, they're back for a visit.

Sticks blown off the nest ... "Ooooh, here's a tortoise."

83. A closeup of the pecked tortoise shell. Larry picks it up and holds it in his hand. [LLP B-roll, 10:03]

Larry LePre: (on camera)

"… that's been eaten by a raven. …. its characteristic [sign] ...

84. [Yet to be filmed—ravens pecking at desert tortoise shells and eating what's inside.]

<u>Larry LePre</u>**: (voiceover)**
... that they'll peck a hole in the top to kill it.."
[LLP B-roll, 10:03]

85. Raven flies across a road and lands. [DVD3, 6:09]

"…, in northern forests such as Maine, ravens are still a wilderness bird. In the Mojave Desert, which has had urban sprawl and so many human modifications, ravens have increased up to 1,000% in the last 50 years. [LLP1, 9:09]

86. Raven on the ground eating something. Trucks go by in the distance. More vehicles pass by. [DVD3, 6:16] Wind ruffles its feathers a little bit. It looks at the cars, looks back toward the camera. [DVD3, 7:53]

"and the availability of food has just caused this huge population increase."[LLP1, 7:11]

87. [Some image of a landfill or other human-induced location where ravens are getting food.]

"...they're social birds and they congregate around landfills, around sewage ponds, around fast food restaurants, cattle yards, horse properties, anywhere there's easy food."

88. Looking up to large nest on power tower. [DVD3, 4:37]. Closer shot of nest. [DVD3, 5:12]

"But the ones who have learned to eat juvenile tortoises they can decimate a

generation of tortoises right around the nest. So, those ravens are targeted, and if they find evidence of tortoise predation under a raven nest, then the Bureau of Land Management calls the Wildlife Services of the U.S.D.A and they come out and kill the raven... The power company comes out and knocks down the nest. [LLP2, 1:10+]

89. Larry LePre looks around with binoculars and spots a raven flying above. [LLP B-roll, 00:18]

Larry LePre: (voiceover)
"They're just so adaptable." [LLP1, 8:01]

90. Continuation of Scene 61: [Yet to be filmed—ravens pecking at desert tortoise shells and eating what's inside.]

"and then they teach the young that tortoises are good eatin', and so the next generation becomes a tortoise predator, too."[LLP1, 3:04+]

NARRATOR: (voiceover)
Desert tortoise recovery is enormously complicated because there is so much that scientists need to learn.

91. CU of hand with vials, pouring one thing into another. Pull back to see the vial being put into a tray of vials with blue caps. [B-roll, blood and release, 2:54]

For instance, just with the exotic,
non-native plants:
What happens to tortoises who eat
them?

92. Closer shot of looking down into plastic bins with baby tortoises in them. [B-roll, blood and release, 4:52]

Or, if spraying herbicides is used
to control the invasive plants –
and the tortoises eat them... what
then?

93. Woman at Coyote Springs Desert Management Area being interviewed. [B-roll, blood and release, 11:39+]

Kristina Drake: (on camera)
"We're studying the nutritional ecology of tortoises in relation to wildfires of 2005."

Coyote Springs scientist: (voiceover)
[not fully transcribed]

"..but the pens are so armored to keep the predators from eating them ...
[B-roll, blood and release, 13:01+]

94. A closeup of a hand holding a young tortoise, setting it down a the entrance of a hole. The tortoise is slowly moving into the hole. There is a tiny yellow flower there. [B-roll, blood and release, 17:59+]
[

…about 25 of them are actually progeny from adults that were removed from this property when the housing development started to go in …so we xrayed those adult females, collected the eggs – incubated the eggs and then raised them at the Desert Tortoise Conservation Center throughout the last 6 months... "

95. [Note: I can't tell from my logs where in the sequence of shots the samples are taken, but the vials begin at 2:54, so it would be before then.][B-roll, blood and release, :46-2:54.]

Today we were taking our first blood samples. We have plans to take blood samples 3 times per year for all the animals that went into this project and with the blood we're going to study a variety of parameters…mostly parameters that will help us understand their metabolic fitness that would again to some of the various treatments and their diet. [B-roll, blood and release, 14:42]

96. Roy Averill-Murray on camera. [RAM1, 15:20]

<u>Roy Averill-Murray</u>: (on camera)
"So, the nutrition study is asking primarily—do tortoises on a native diet perform better, grow better, survive better than tortoises on an exotic, unnatural diet?

dissolve to:
97. A close shot of the back of a tortoise at a burrow entrance. Close of tort rear end at hole entrance. It is moving a bit of dirt with its feet. [Ft. Irwin blood draw, 5:31]

NARRATOR: (voiceover)
So much about the life of the
reclusive tortoise is a mystery—
that scientists are beginning to
solve with
21st century technology.

98. Wide shot across expanse of desert landscape. [Sonoran DVD]

For example, a customized GPS
logging system collects
more data, over the vast desert
landscape, than ever would be
possible with field crews.

99. Ken Nussear on camera. [KN 5:05+]

Ken Nussear: (on camera)
"One of the things we've been kind of on the leading edge of for a long time is to get some technology to do a difficult job.

100. A close shot of the front of a tortoise. It blinks. See the radio receiver on its shell. [Ft. Irwin blood draw, 13:41]

Ken Nussear: (voiceover)
"Just the act of putting a radio transmitter on a tortoise, means that we've got to have people out there on a

monthly or sometimes weekly basis monitoring tortoise activity to get data on how they're using habitat and kinds of body temperatures they're achieving.

101. A close shot of one of the GPS logger devices. [have not seen such footage]

Ken Nussear: **(on and off camera)**
"We got a company to help us miniaturize GPS's and actually now we have GPS loggers that are as small as the radio transmitters we were using ten years ago. And now it has a radio transmitter and a GPS and a data logger all in the same package so we're pretty happy about being able to work with technology companies to get the kinds of thins that you have in your cell phone working for us on tortoises to help us understand how they're using habitat.

102. Maybe this is a composite image of a graphic that depicts following one or more tortoises over space and time

NARRATOR: (voiceover)

... the GPS logger can follow and monitor the tortoise all day, every day, and everywhere it moves.

Ken Nussear: **(voiceover)**
"So if I want to know for example are tortoises using burned habitat or not after a wildfire and I only

get one picture of each tortoise a day it takes me a lot longer to achieve the information than if I get detailed information about every day how much time is that animal spending in or out of the burned areas.

So, we’re getting all of this now with people watching tortoises but I think in the future we can get a lot more detailed information and be able to put a better picture together of what they’re doing.

103. Todd Esque on camera. [TE, 3:12]

<u>Todd Esque:</u> (on camera)
"... we've been watching tortoise populations for the desert tortoise for a little over 30 years in the desert, almost 40 years in some areas. And everything indicates to us that there has been a steady decline in populations over that time. Until recently, that was kind of a mystery.

<u>cutaway to</u>:
104. Collage from standard-def scenes: Flying over the landscape of Joshua Tree Forest. [Mojave Desert DVD] Closeup of buckhorn cholla. [Mojave Desert DVD] Beauty shot of Creosote Basin. [Mojave Desert DVD]

<u>Todd Esque:</u> (voiceover)
"... we knew that it was lots of influences but only recently have we had the ability to get on the ground and collect massive amounts of information across the entire Mojave Desert and then put it all into analysis so that we can start to understand the pattern for the Mojave. And we're starting to pin down pieces of that story about why we are having these declines."

105. Catherine Nolte

<u>Catherine Nolte:</u> (on-camera)

"and then did you say that number two is the one without the transmitter? …(mumble)

105. Ken Nussear on camera. [KN 7:59]

<u>Ken Nussear:</u> (on camera)
"Over the last five years we've been working with a team of scientists, including biologists, but also ecologists, plant ecologists, people who do GIS remote sensing hdrologists, geologists and geographers to put together a desert tortoise habitat model.

<u>dissolve to:</u>
106. Animated Mojave Desert Tortoise Habitat model, depicting in 3-D numerous variable layers such as precipitation, vegetation, topography, geology, groundwater, likely predators. Model will expand and contract revealing individual layers and the combined overall habitat model.

[over animation sequence]

<u>Ken Nussear</u>: (voiceover)
“So looking at different elevations, different rock types, vegetation associations, different precipitation and temperature regimens…and how those all come together to influence what we know as the current desert tortoise distribution."
[KN, 7:59+]

<u>NARRATOR</u>: (voiceover)

Shades from yellow to orange then red show good to ideal tortoise habitat…while dark blue is not tortoise habitat.

<u>Ken Nussear</u>: (voiceover)
“So here in the Mojave Preserve you can see we have areas of high tortoise concentration and predicted high suitable habitat and also areas like these blue ones where we predict that it would be low suitable habitat.

Narrator:

The models ability to predict habitat type is proving to have wide applications across the Mojave and into the future.

It’s an invaluable tool for guiding the search for best locations to site new green energy projects.

And the model can project us into the future, helping to clarify possible impacts of climate change. Model components such as rainfall totals and temperature can be adjusted to show how habitats will shift as the climate changes.

The model helps scientists understand the desert tortoise on a range-wide scale over millions of acres.

It has the potential to make a huge difference in desert tortoise recovery ... helping to insure that critical habitats will be suitable into the future.

107. An engaging tortoise shot. Perhaps: A female scientists is holding a baby tortoise. [DVD4, Paula shots, 17:14]

<u>Female scientist</u>: (on camera)
"... a beauty~~, a male,~~ just a little runny nose ..."

<u>NARRATOR:</u> (voiceover)

There's no one thing killing off the desert tortoises; a multitude of threats are interacting. Scientists must prioritize which are the most important and which problems can be solved.

Fade to black then up

Fade in:
109. ECU of hatchling tortoise struggling to get out of its shell.

<u>NARRATOR</u>: (voiceover)

Hey, baby tortoise,
the heat is on.

Not only do you have all the struggles of life in the harsh desert, and dwindling habitat ... now there are new threats on the horizon.

dissolve to:
110. Todd Esque on camera. [TE, 6:25]

Todd Esque: (on camera)
".. I think uh, in pre-Western history of people moving out here, this was a giant wilderness.

cutaway to:
111. Pan across landscape of the Sonoran desert. [Sonoran desert DVD]

Todd Esque: (voiceover)
"It was a very hostile environment to humans.

112. Historic images of people living in the desert in a small shack. [Archival photos]

"And about just a little over a hundred years ago, the West began to be opened up with new trails for immigrants ... Those folks were sort-of eking out a living in the low desert areas.

113. Black/white footage of the new interstate highway from the 1950s. [Archival footage]

... Then, the highway system was put in. That opened up the area so people were moving through ... [TE, 7:35+]

114. Pan across a 1950s housing development in the desert. [Archival footage]

... And widespread availability of lots of electricity and air conditioning made it a less hostile place...

<u>cut back to:</u>
115. Todd Esque on camera. [TE 7:35+]

<u>Todd Esque</u>: (on camera)
"And what this all leads to is going from an area that was just little island of human habitat 80 years ago and 60 years to what is now becoming an area that is dominated by human influence with little tiny islands of open natural habitat left.

116. A medium shot of a tortoise as it walks slowly over rocks. [DVD4, Paula shots, :21]

<u>Todd Esque</u>: (voiceover)
"And that's where we still find the tortoises, in these little islands that are left."

<u>dissolve to:</u>
117. A "time lapse" series of six images that depicts the growth of the Las Vegas area, from 1984 to 2009. [http://earthobservatory.nasa.gov/IOTD/view.php?id=37228]

1984

2009

<u>NARRATOR</u>: (voiceover)

Not only has development encroached into the desert.

Scientists have recently found a pattern that shows human impacts extending beyond where people are living.

118. Animation or graphic that depicts the widening circle of predator range around the developed cities and towns.

There's a shadow that's much larger than the actual footprint of buildings and roadways ...

119. A coyote skulking across the landscape. [Sonoran DVD]

... it's created by predators such as coyotes and ravens, that are subsidized by human food and waste ...

120. Raven pecking in and pulling "food" out of a dead tortoise shell. [Footage to be shot]

... living outside the edge of these areas.

Others have their eye on the

desert, too.

<u>dissolve to</u>:
121. Roy Averill-Murray on camera. [RAM1, 19:16]

<u>Roy Averill-Murray</u>: (on camera)
"There's a lot of sunshine in the Mojave Desert. And there's a lot of open land that energy developers and people who are really interested in getting the country off fossil fuels look at and say, 'Wow! Look at all that sun hitting the ground...

122. Pan across expansive solar panel field in desert/or advertisement for one/or a few examples already in existence.

<u>Roy Averill-Murray</u>: (voiceover)
... We can put solar fields there.' Well, that's also where the desert tortoise lives, and other sensitive species."

123. Larry LePre on camera. [LLP2, 8:42+=]

<u>Larry LePre:</u> (on camera)
"I think it's important that you put these solar projects and the windmill projects over at the edge of the desert, the western edge, or maybe the eastern edge or near major cities, but not in the middle.

124. Solar and the wind towers,

<u>Larry LePre:</u> (voiceover)
"... then you're bringing an industrial park into the middle of tortoise habitat...

"So, siting of the energy projects is crucial, the first priority being to put them on lands already disturbed or where there is no tortoise habitat, and the second being to not fragment large areas that are a uniform block of habitat."

125. A close shot of a tortoise munching, munching on some branches. [DVD4, Paula shots, 14:32]

Roy Averill-Murray: (voiceover)
"The challenge is finding the right balance to be able to achieve our alternative energy goals while not sacrificing the native landscape and our natural heritage at the same time. [RAM1, 19:16+]

SFX: Boom of thunder, sound of hard rainfall

dissolve to:
126. A collage of images

NARRATOR: (voiceover)

One definition of "desert" is a landscape that gets less than 10 inches of rainfall a year.

Todd Esque: (voiceover)
"When the desert gets a good year... maybe one in ten years we'll have a really good winter rain fall and in those years it's just unbelievably spectacular…. [TE, 20:21]

127. A collage of images of the gorgeous life in the desert.

[over sequence]

NARRATOR: (voiceover)
In the Mojave and Sonoran deserts, there live nearly 150 species of mammals... including mountain lions, ground squirrels and desert big horn sheep.

... along with 70 species of amphibians and reptiles, and more than 300 species of flowering trees, shrubs and wildflowers.

Larry LaPre: (voiceover)
"The desert grows on you ...
It's fabulous in the spring. The spring bloom is the most dramatic change of season of any other kind of ecosystem in the U.S. probably, from brown to green to color all within a month."
[LLP**2, 16:02]**

Todd Esque: (voiceover)
"This year was an above average year, it was great. We brought people out on a field trip from all over the world. Everywhere we went in the desert we

found 15 to 20 species of wildflowers growing…it was just a super abundance, just a month ago out here when things were a little bit fresher.... You just think, every time you go around a corner, you're walking up a wash you wonder what's going to be around the next corner. There might be a Gila Monster walking along or a tortoise or some kind of a snake ..you just never know what you're going to find so it makes it really fun to be out here when it's reasonable to walk around in the spring. [TE, 20:21]

128. Open Images: Climate Change

SFX: Natural sounds of these activities if available

<u>NARRATOR</u>: (voiceover)

These desert adapted plants and animals may hold some keys to human survival in a rapidly warming world.

The unique genetic make-up of desert plants and animals - is a sort of "resource for the future"- potentially crucial for developing new crops, livestock and medicines as our climate warms.

Over the next 50 to 100 years temperatures in the Mojave are expected to rise between 5 and 10 degrees Fahrenheit. Rainfall is expected to decrease.

Will temperatures in some places be greater than tortoises or their eggs can tolerate? What will happen to the plants making up their diet? How will tortoise habitat change?

Science is the starting point for addressing these questions. There is already a foundation of scientific knowledge to build on. Tools such as the habitat model can help forecast some effects of climate change while guiding management of habitat and species.

Narrator:

Mounting threats to the tortoise now include: invasive plants, disease, wildfires, roads, ravens, coyotes, off road vehicles, other predators and now climate change.

Narrator:

The question remains can the tortoise population stabilize and thrive?

Ken Nussear: (voiceover)
" people know about the tortoise, they care about the tortoise-- and I think that one thing may be the biggest thing that helps turns it around...

...and so we've gotta have people on our team and people that want to help and people that care and I think that's

coming around and that's a big positive thing.
[KN, 12:25]

<u>Todd Esque:</u> (voiceover)
"But in fact we're dealing with 60 million years of evolution here. Desert tortoises have been around for a very, very long time and people revere them for that reason. The general public wants to know that we have tortoises on the landscape that are not just being put there for their viewing, but they're existing out there in a natural habitat on their own.

129. A tiny tortoise on the edge of a rock. A person's foot walks past.

<u>NARRATOR</u>: (voiceover)

Humans collectively have had a big negative impact on desert tortoise habitat.

130. Tortoise eating the pink cactus flower. [YouTube 6:30 tortoise DVD]

But people individually can make a big positive difference, too.

131. A full shot of a side view of a tortoise walking; he continues over rocks, passes behind some grasses and continues on.

132. ECU of tortoise head as he reaches up and munches on some leaves.

133. A close side view of a tortoise on rocks, with blue sky in the background.

134. Close shot of two tortoises next to each other.

135. Extreme closeup of a baby tortoise.

Larry LaPre: (voiceover)
"If you see a tortoise in the wild, look at it and take its picture, see what it's doing ... Basically, it's something to appreciate but not to mess with. ... take a good look so you really can understand the essence of tortoise, half of which is pulling its head in its shell and stand like that for an hour." [LLP2, 12:00]

transitions to a montage of desert tortoise scientists at work
For example:
136. It is dark outside. A woman is at the back hatch of a white SUV and closes the doors and trunk. [Ft. Irwin blood draw, 6:50]

Narrator:

Before dawn, the scientists' work begins.

137. Continuing from Scene 136: A wide shot on a steep slope with a big tortoise sitting just in front of his burrow at first light with the two women scientists putting on their packs and walking off into the downhill distance. [Ft. Irwin blood draw, 8:21]

Roy Averill-Murray: (voiceover)
" Science is critical to desert tortoise recovery because there are a lot of uncertainties in how all the numerous threats ...

138. Five newly-hatched tortoises are in a plastic bin. One of them is moving around with shell still on its back. It tries to climb out of the bin and falls on its back and gets stuck. [Hatching video, 3:43]

... that face the tortoise interact and affect tortoise populations ... Without science we wouldn't be able to sort any of that out and anything we did on the ground would just be a crap shoot ... " [RAM2, 16:32]

139. Continuing from Scene 136: The woman reaches down into the burrow, brings out a tortoise. The other woman picks it up and blows dirt off it. [Ft. Irwin blood draw, 9:05]

Becky Jones: (voiceover)
"I find the tortoise to be very fascinating because it seems like such a meek species but has been able to survive all these years out in the desert." [BJ1, 17:24]

140. One of the animation sequences of the modeling, from Scene 106.

Ken Nussear: (voiceover)
"I think more and more as we're facing bigger and bigger threats we need to use whatever science we can to understand how these animals are responding ." [KN, 8:22]

141. The scientist in the red T-shirt is holding a tortoise who's looking around, and moving its feet a bit as though it's trying to swim. [X-rays found tape, 5:56]

Scientist: (on camera)
"Got the x-ray plates?
Let's go."

Kristine Berry: (voiceover)
"The tortoise tells us so much about the health of the desert it's a very long lived animal it's a sentinel of the well

being of our environment and for that reason alone I think we should be very concerned about its well being and that it thrive..." [TE, 2:23]

142. Continuing from Scene 136: The scientist puts the tortoise down a little distance away from its burrow. See that it has a radio receiver. [Ft. Irwin blood draw, 13:24]

143. An extreme closeup of a baby tortoise in the scientist's fingers. [B-roll test and release, 3:50]

144. Day's end match to Scene 136. The two women scientists are walking, silhouetted in the dark pink/purple colors of sunset. [Ft. Irwin blood draw, 20:20]

NARRATOR: (voiceover)

Building on our knowledge of the tortoise, it's habitat and threats to its existence remains a key to Mojave Desert Tortoise survival into the future.

Fade out END

STATE OF CALIFORNIA

ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION

In the Matter of: The Application for Certification for the IVANPAH SOLAR ELECTRIC GENERATING SYSTEM	Docket No. 07-AFC-5

Supplemental Testimony of Bill Powers, P.E.
Ivanpah Solar Electric Generating System
Docket 07-AFC-5

March 16, 2010

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I. Introduction

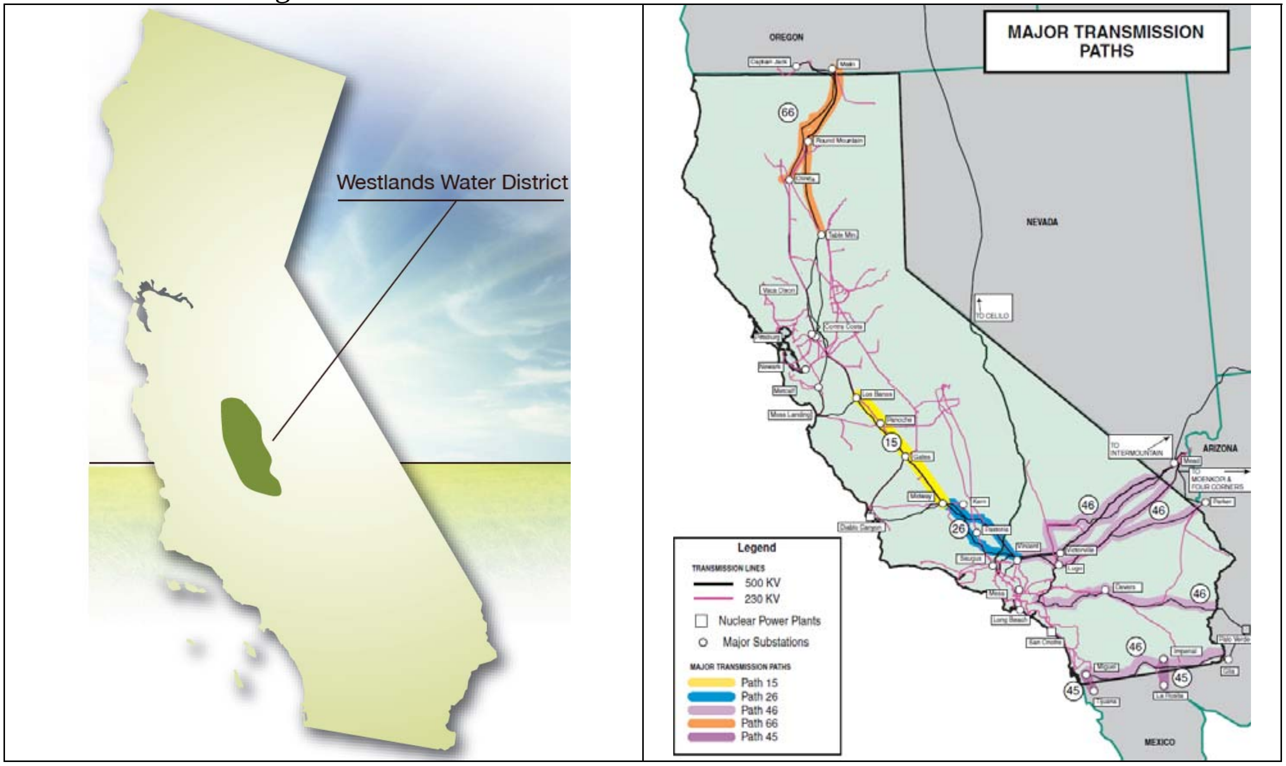
This testimony is offered as a supplement to my December 16, 2009 direct testimony.

II. Solar development in the proposed Westlands Water District CREZ would avoid the environmental problems of Ivanpah site

The Westlands Water District ("Westlands"), on the west side of the Central Valley, is undergoing study by the Renewable Energy Transmission Initiative (RETI) as a Competitive Renewable Energy Zone (CREZ) capable of providing 5,000 MW of utility-scale solar development. Westlands covers over 600,000 acres of farmland in western Fresno and Kings Counties. The proposed "Central California Renewable Master Plan" will utilize permanently retired farmlands in Westlands for solar development. An overview of this master plan is attached. As stated in the master plan overview, "Due to salinity contamination issues, a portion of this disturbed land has been set aside for retirement and will be taken out of production under an agreement between Westlands and the U.S. Department of Interior." Approximately 30,000 acres of disturbed Westlands land, equivalent to 5,000 MW of solar capacity, will be allocated for renewable energy development under the plan.

Transmission Pathway 15 passes through Westlands. Path 15 can transmit 5,400 MW from south-to-north.[1] The transmission capacity from north-to-south is 3,400 MW. The location of Westlands relative to Path 15 is shown in Figure 1.

Figure 1. Location of Westlands Water District and Path 15[2,3]



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[1] Transmission & Distribution World, California bulks up to provide more transmission capacity, June 1, 2004.

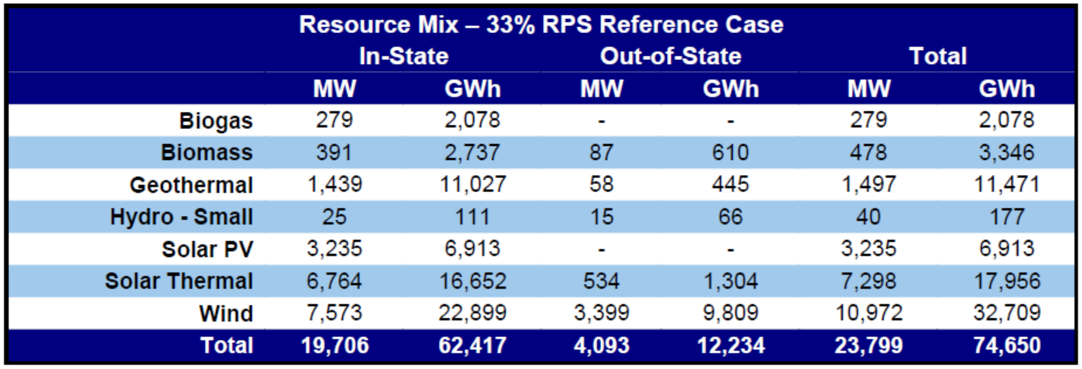
[2] Anthem Group press release, Central California Renewable Master Plan, March 2010.

[3] CEC, Strategic Transmission Investment Plan, November 2005, p. 11.

5,000 MW of solar power can be developed in Westlands with potentially no expansion of the existing Path 15 high voltage transmission capacity that serves Westlands now.

5,000 MW is half of the total remote in-state utility-scale solar currently contemplated in the CPUC 33 percent reference case.[4] The remote in-state solar component of the reference case consists of 3,235 MW PV and 6,764 MW solar thermal.

Figure 2. Resource in CPUC 33 Percent RPS Reference Case



Resource Mix – 33% RPS Reference Case

	In-State		Out-of-State		Total	
	MW	GWh	MW	GWh	MW	GWh
Biogas	279	2,078	-	-	279	2,078
Biomass	391	2,737	87	610	478	3,346
Geothermal	1,439	11,027	58	445	1,497	11,471
Hydro - Small	25	111	15	66	40	177
Solar PV	3,235	6,913	-	-	3,235	6,913
Solar Thermal	6,764	16,652	534	1,304	7,298	17,956
Wind	7,573	22,899	3,399	9,809	10,972	32,709
Total	**19,706**	**62,417**	**4,093**	**12,234**	**23,799**	**74,650**

However, RETI has gradually dropped the amount of new renewable energy resources necessary to reach 33 percent by 2020 from 74,650 gigawatt-hours (GWh) per year as shown in Figure 2 to a current “low load” net short of 36,926 MW.[5] The low load net short is one-half the net short used by the CPUC in June 2009 to estimate the cost of achieving 33 percent by 2020. The CPUC did not include either the 500 MW SCE urban PV project or the 500 MW PG&E distributed PV project in its reference case calculations.

The anticipated energy output of 5,000 MW of fixed PV in Westlands would be about 10,000 GWh/yr.[6] 1,000 MW of urban and distributed PV from the SCE and PG&E projects would contribute another 2,000 GWh/yr. This is a total solar contribution of 12,000 GWh/yr. Substituting this 12,000 GWh/yr of solar for the 23,500 GWh/yr of remote in-state solar in Figure 2 results in the reference case results in a revised reference case production of 63,000 GWh/yr. 63,000 GWh/yr is far more rewable energy production than necessary to reach 33 percent by 2020. The entire in-state wind component could be deleted from the reference case and 40,000 GWh/yr would still be generated. 40,000 GWh/yr is greater than the low load net short of 36,926 MW. Prioritizing utility-scale solar projects like Ivanpah in Westlands, combined with utility-scale urban and distributed PV projects, would allow California to achieve its 33 percent by 2020 target with almost no environmental impacts related to the solar component.

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[4] CPUC, 33% RPS Implementation Analysis Preliminary Results, June 2009, Appendix C, p. 87.

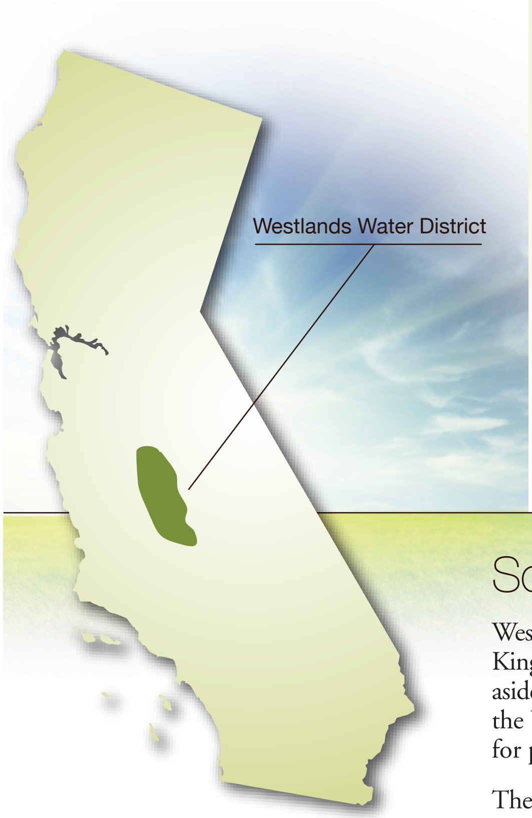
[5] RETI discussion draft, RETI Net Short Update - Evaluating the Need for Expanded Electric Transmission Capacity for Renewable Energy, February 22, 2010. Low load scenario, net short = 36,926 MW.

[6] The reference case assumes 3,235 MW of solar PV will generate 6,913 GWh per year under ideal Southern California desert solar insolation conditions. This is a production ratio of 2,137 GWh per MW(ac). However, solar insolation in the Central Valley and California urban areas will be approximately 10 less than ideal desert sites. See Powers December 16, 2009 Direct Testimony, p. 15. For this reason a production ratio of 2,000 GWh per year per MW(ac) is assumed for the Central Valley and urban areas.

III. Conclusion

The Westlands Water District is a low impact “shovel ready” alternative to the Ivanpah site for utility-scale solar projects. Westlands requires no new high voltage transmission to move up to 5,000 MW of solar power to California load centers. This means solar projects in Westlands will not face project delays due to lack of high voltage transmission capacity. The steadily declining renewable energy net short to achieve the 33 percent by 2020 target, now as low as 36,926 MW, means fewer renewable projects overall are necessary to meet the 33 percent target. The CEC should not approve solar projects with unmitigatable impacts like Ivanpah when 5,000 MW of otherwise unusable disturbed land with no environmental issues and 5,000 MW of high voltage transmission capacity sit idle.

CENTRAL CALIFORNIA RENEWABLE MASTER PLAN



Putting California At The Forefront Of Global Clean Energy Production & Economic Opportunity

- Approximately 30,000 acres of disturbed and contiguous farmland undergoing study as the Westlands Clean Renewable Energy Zone (CREZ) by the Renewable Transmission Initiative (RETI)
- Successful master planning sets the stage for California to meet its near and long term goals for the RPS, while providing certainty to future renewable development
- The broader Westlands area has an estimated potential of accommodating up to 5 GWs or more of renewable power by 2020
- Proximity to existing substations and transmission lines. The Westlands study area is strategically placed near a future planned foundation line corridor that will be designed to connect the different renewable zones in California.
- The Central California Renewable Master Plan is a more environmentally superior alternative to permit for large scale solar than constructing in protected lands in remote desert areas
- Allows large scale solar energy to be produced within California

Solution: The Central California Renewable Master Plan

Westlands Water District (Westlands) covers over 600,000 acres of farmland in western Fresno and Kings Counties. Due to salinity contamination issues, a portion of this disturbed land has been set aside for retirement and will be taken out of production under an agreement between Westlands and the US Department of Interior. This situation positions the Central California Renewable Master Plan for permitting success, solving permitting challenges that are hindering most California projects.

The Central California Renewable Master Plan includes approximately 30,000 acres of disturbed land for renewable development. This acreage is within close proximity to existing transmission corridors and substations, as well as future planned foundation line corridors. The master planning of thousands of acres for utility scale solar generation is a relatively new concept for energy developers but the environmental community and California policymakers are starting to see its benefits. This type of planning better aligns the generation and transmission planning for renewables, resulting in more efficiently developed projects with a better chance for long-term success.

↘ Garnering Major Environmental Support

The Central California Renewable Master Plan is undergoing study as a CREZ in the RETI Phase 2A updates. Westlands and the Anthem Group are working with environmental groups to identify the Westlands study area as a critical renewable energy zone in order to meet California's renewable goals.

↘ A Solution For Today… And Tomorrow

The far-reaching benefits of this project enables California to set up a process for planning transmission system upgrades and new corridors that will create billions in economic development for California. The template laid out in the Central California Renewable Master Plan provides regulatory and permitting confidence for developers and utilities to orderly construct transmission and generation over a 10-year horizon to meet the 33% by 2020 RPS goal.

↘ Linking California To A Greener Future And Economic Vitality

Led by the Anthem Group, the Central California Renewable Master Plan represents the most viable opportunity for California to advance its renewable energy goals. Over a 20-year horizon the potential estimates of total project investment for the 5 GW solar plant could reach well over $10 billion and will provide California with a much-needed economic boost.

CENTRAL CALIFORNIA RENEWABLE MASTER PLAN

Please contact the Anthem Group at (916) 709-9289, dan.anthem@gmail.com or PO Box 582844 Elk Grove, CA 95758-0051 for questions or inquiries on the this project.

Declaration of Bill Powers, P.E.

Re: Supplemental Testimony on Alternatives to the Proposed Ivanpah Solar Electric Generating System

Docket 07-AFC-5

I, Bill Powers, declare as follows:

1) I am a self-employed consulting engineer.

2) My relevant professional qualifications and experience are set forth in the attached resume and the attached testimony and are incorporated herein by reference.

3) I prepared the testimony attached hereto and incorporated herein by reference, relating to the Westlands Water District site alternative to the project.

4) I prepared the testimony attached hereto and incorporated herein by reference relating to the proposed Project in the Ivanpah Valley in San Bernardino County.

5) It is my professional opinion that the attached testimony is true and accurate with respect to the issues that it addresses.

6) I am personally familiar with the facts and conclusions described within the attached testimony and if called as a witness, I could testify competently thereto.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Dated: March 16, 2010 Signed: Bill Powers, P.E.

At: SAN DIEGO, CA

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

1516 NINTH STREET, SACRAMENTO, CA 95814
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APPLICATION FOR CERTIFICATION
FOR THE *IVANPAH SOLAR ELECTRIC GENERATING SYSTEM*

DOCKET NO. 07-AFC-5
PROOF OF SERVICE
(Revised 3/11/10)

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DECLARATION OF SERVICE

I, Lisa Belenky, declare that on March 15, 2010, I served and filed copies of the attached, additional testimony + exhibits for March 22, 2010 hearing. dated, March 12,15, 2010. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at: **[www.energy.ca.gov/sitingcases/ivanpah]**.

The documents have been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(Check all that Apply)

FOR SERVICE TO ALL OTHER PARTIES:

X sent electronically to all email addresses on the Proof of Service list;

____ by personal delivery;

____ by delivering on this date, for mailing with the United States Postal Service with first-class postage thereon fully prepaid, to the name and address of the person served, for mailing that same day in the ordinary course of business; that the envelope was sealed and placed for collection and mailing on that date to those addresses **NOT** marked "email preferred."

AND

FOR FILING WITH THE ENERGY COMMISSION:

X sending ~~an~~ two original paper copy and one electronic copy, mailed and emailed respectively, to the address below (***preferred method***);

OR

____ depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 07-AFC-5
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512
docket@energy.state.ca.us

I declare under penalty of perjury that the foregoing is true and correct, that I am employed in the county where this mailing occurred, and that I am over the age of 18 years and not a party to the proceeding.

Lisa T. Belenky

*indicates change