Exhibit	Brief Description	Offered	Admitted	CEC Use Only
600	Rebuttal Testimony of James M. Andre 7/29/2010			
601	Rebuttal Testimony of Jeff Aardahl 7/29/2010			
602	Revision of Disease Testing Requirements Based on Translocation Distance, Desert Tortoise Recovery Office 7/2010			
603	Spencer, W.D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi, and A. Pettler. 2010. California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California. Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration.			
604	Habitat Use and Food Preferences of the Desert Tortoise, *Gopherus agassizii*, in the Western Mojave Desert and Impacts of Off-Road Vehicles. Proceedings of the New York Turtle and Tortoise Society: Conservation, Restoration, and Management of Tortoises and turtles - An International Conference, pp. 42–45.			
605	Applicant's Responses to Defenders of Wildlife Data Requests Set 1. 12/4/2009			
606	Zitzer, S., King, J., and Etyemezian, V., 2008. *Unveiling the mysterious ecology of a rare relict Mojave Desert forb (Penstemon albomarginatus): Will ecological knowledge put a damper on exponential growth in Southern Nevada?* Report for 93rd Ecological Society of American Annual Meeting.			
607	Mackay, P. White Paper on White-Margined Beardtongue, Penstemon Albomarginatus			
608	CPUC Phase I direct testimony of Dr. Barry Butler, CPUC Application 06-08-010 6/1/2007			
609	T. Mancini, P. Heller, B. Butler, B. Osborn, W. Schiel, V. Goldberg, R. Buck, R. Diver, C. Andraka, J. Moreno, *Dish-Stirling Systems: An Overview of Development and Status,*			

	Journal of Solar Energy Engineering, Vol. 125, pp. 135-151, May 2003.			
610	Schwartz, O.A., V.C. Bleich, and S.A. Holl. 1986. Genetics and the conservation of mountain sheep Ovis canadensis nelsoni. Biol. Conserv**.** 37:179-190 .			
611	Epps, C. W., P. J. Palsbøll, J. D. Wehausen, G. K. Roderick, R. R.Ramey, D. R. McCullough, 2005. Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters, (2005) 8: 1029–1038.			
612	Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon, pages 3-10.			
613	Abstracts, Thirty-fifth Annual Meeting and Symposium, The Desert Tortoise Council, February 25-28, 2010.			
614	Picture of Desert Tortoise observed on site by DOW staff.			
615	Bureau of Land Management, 2005. West Mojave Plan: A Habitat Conservation Plan and California Desert Conservation Area Plan Amendment. California Desert District, Moreno Valley, CA. Page 2-116.			

Exhibit
600

STATE OF CALIFORNIA

Energy Resources Conservation
and Development Commission

In the Matter of:

The Application for Certification for the
Calico Solar Project

Docket No. 08-AFC-13

INTERVENOR DEFENDERS OF WILDLIFE

REBUTTAL TESTIMONY

July 29, 2010

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STATE OF CALIFORNIA

Energy Resources Conservation
and Development Commission

In the Matter of: The Application for Certification for the Calico Solar Project	Docket No. 08-AFC-13

Pursuant to the Committee's scheduling order dated July 13, 2010, Defenders of Wildlife provides the following rebuttal testimony for the Calico Solar Project evidentiary hearings scheduled for August 2010. The foregoing testimony concerns the Biological Resources topic area.

Defenders of Wildlife reserves the right to supplement or revise its testimony at any time up to and including the close of the evidentiary hearings.

REBUTTAL TESTIMONY OF JAMES. M. ANDRE

To the best of my knowledge, all of the facts contained in this testimony (including all referenced documents) are true and correct. I am personally familiar with the facts and conclusions described within this testimony and if called as a witness, I could testify competently thereto.

Qualifications

Serving as Director of the University of California's Granite Mountains Desert Research Center since 1994, I have been instrumental in developing the Center into one of the leading research and teaching facilities in the UC Natural Reserve System. I currently oversee more than 165 arid lands research projects at the Center, which is located in the Granite Mountains, approximately 40 miles east of the Calico Solar Project. I also serve as Curator of the Granite Mountains Herbarium, one of most comprehensive collections of California's desert flora.

My academic training is in plant ecology, conservation biology, and natural areas management. I am a recognized expert on the flora of the Mojave and Southern Great Basin Deserts, with 30 years experience conducting more than 200 focused floristic inventories throughout the desert southwest of California, Nevada, and Arizona. In addition to discovering several new species to science, I am author of several floras, including *A Flora of the Mojave National Preserve*. I am currently working on floras of the Owens Valley and Schell Creek Range, and am editor on the 2nd Edition of the *Flora of the Northern Mojave Desert*. I am a technical reviewer for the forthcoming 2nd Edition of the Jepson Manual: Vascular Plants of California.

My current research focuses on plant taxonomy, population demographics of long-lived desert shrubs, conservation biology of rare plants, and restoration ecology (particularly systems impacted by livestock grazing and invasive species). I am quite familiar with the white-margined beardtongue (Penstemon albomarginatus), having conducted demographic studies (unpublished) of the occurrence at Pisgah since 1994. I addition to my research I have taught more than 20 university-level courses in plant taxonomy, plant ecology, field sampling theory, and natural history courses based out of UC Riverside, UNLV, UC Berkeley, UCLA, and CSU Humboldt. I have taught numerous advanced field workshops and training seminars in botany, including seven UC Jepson Workshops.

I was the program chair, keynote speaker, and session chair of the Mojave Desert Regional Session at the 2009 California Native Plant Society (CNPS) Conservation Conference. I organized the 2nd and 3rd Mojave Desert Science Symposiums held at U. of Redlands (2004) and UNLV (1999) which brought scientists, land managers and consultants together to discuss mutual collaborations. I am co-founder of Mojave Desert Chapter of the California Native Plant Society (CNPS), and have served as the Senior Advisor to the statewide CNPS Rare Plant Program (RPP) and Chair of the RPP Committee since 2008.

Statement

I have reviewed the project applicant's survey reports and the Staff Assessment and find them inadequate in several regards:

1. **The Applicant's Survey Methodology for White-Margined Beardtongue Failed to Capture All Occurrences on the Project Site.**

The white-margined beardtongue is a short-lived perennial herb which maintains a substantial soil seed bank as well surviving underground as a subterranean heterotroph (root/caudex) during dry years. Compared to the other three global occurrences (two in Nevada, one in Arizona), the lone California population that wraps around the north end of the Pisgah Lava Flow occurs in very low densities with approximately 4000 individuals widely scattered across the site. Even during average years of precipitation, such as experienced at the Calico site in 2010, a large percentage of the seed bank will not germinate and many living plants remain dormant underground. Only a subset of plants will put on above ground growth, and an even fewer number flower and set seed. Seed banks can persist in the soil for many decades before germinating.

Zitzer et.al (2008) showed that for Nevada occurrences during any year, a population in full bloom may be less than 10 km distant from another population that is surviving only as underground dormant roots or seeds. Consequently, a difficult to measure fraction of *P. albomarginatus* genetic diversity remains buried for perhaps six or more years, based on 40 % germination of 6-year-old seed stored air-dried at room temperature.[1] Additionally, I have conducted long-term demographic monitoring at the Pisgah occurrence of white-margined beardtongue. Preliminary findings of my work suggest that California plants are not as long-lived as those in Nevada (Zitzer et. al (2008). I have observed and documented frequent localized extinctions of cohorts with rapid establishment of plants in previously unoccupied areas. Thus, plants at the California occurrence behave more like biennials or short-lived perennials, relying upon the maintenance of a viable seed bank, and over time exhibit a shifting distribution within the aeolian sands at the Calico/Pisgah site.

Because the majority of the population occurs underground, only a small portion of the overall viable distribution of the species onsite could be documented during surveys. The Applicant's surveys failed to consider soil seed bank and underground root/caudex dormancy in assessing the potential number and distribution of white-margined beardtongue individuals at the Calico site. The conclusions made in project applicant's survey reports and the Staff Assessment that most if not all of the white-margined beardtongue at the Calico site were documented during surveys are therefore significantly in error.

2. **A Large Portion of the Proposed Site is Potential Habitat for the White-Margined Beardtongue.**

In California, the white-margined beardtongue is limited to the fine alluvial sand (mostly north of Interstate 40) within a sparse creosote bush scrub vegetation community. The sand is deep and stabilized, holding the long taproot in place. A few scattered occurrences can also be found in the pockets of aeolian sands within the Pisgah lava flows to the south of I-40.[2] Both stabilized and more active aeolian sand deposits are common on the proposed Calico Solar project site.

Very few of the population occurrences that I have monitored over the past 15 years at Pisgah were observed during the years of the applicant's field surveys. Therefore, much of the site exhibits potential habitat conditions for white-margined beardtongue, within which above ground distributions are patchy in time and space, and shifting regularly.

BLM has limited incidental take of the white-margined beardtongue to 50 acres of occupied and potential habitat.[3] There is considerable evidence suggesting that there is

[1] Zitzer, S., King, J., and Etyemezian, V., 2008. *Unveiling the mysterious ecology of a rare relict Mojave Desert forb (Penstemon albomarginatus): Will ecological knowledge put a damper on exponential growth in Southern Nevada?* Report for 93rd Ecological Society of American Annual Meeting.
[2] Scogin, R. 1989. Studies of *Penstemon albomarginatus* in California. Report for Rancho Santa Ana Botanic Garden, Claremont, California.
[3] Bureau of Land Management, 2005. West Mojave Plan: A Habitat Conservation Plan and California Desert Conservation Area Plan Amendment. California Desert District, Moreno Valley, CA.

far more than 50 acres of potential habitat for white-margined beardtongue on the project site.

3. The White-Margined Beardtongue in California Could Face Extinction Due to Direct and Cumulative Impacts Within its Limited Range.

In California, a freeway, a powerline, and three pipelines cross the small area in which the white-margined beardtongue occurs. In addition to these existing threats and alterations, the 8,230-acre Calico Solar Project and other renewable energy projects proposed in the Pisgah region would severely limit the white-margined beardtongue's habitat and ability to survive.

The Calico Solar Project will deploy heliostats, power towers, associated building structures, pipelines, and roads across a relatively intact desert ecosystem, where naturally functioning ecological processes still predominate over recent man-made intrusions. The completed project footprint will fragment more than 8,000 acres of desert vegetation community, including the white-margined beardtongue population, into fragments of various size. The biological affects of ecosystem fragmentation are well documented (Saunders et al., 1991). In general, the fragmentation of rare plant habitat on the project site will lead to two fundamental changes to white-margined beardtongue across the landscape; 1) an increasing isolation of remnant populations, and 2) a decrease in the total amount of available habitat for remnant populations. These two phenomena will be repeated throughout the project area under footprints of proposed neighboring energy projects, and throughout tens of thousands of acres of the greater Mojave Desert where hundreds of utility-scale wind and solar project applications are being reviewed in California, Nevada, and Arizona.

To manage for viable rare plant populations, it will be necessary to identify project-related threats to those populations. In general, threats come in three types 1) threats imposed by changes in the environment, either by natural or human causes, 2) threats resulting from disturbance of important interactions with other species, and 3) genetic threats. With so many threats it is difficult to understand how each may ultimately affect the viability of specific plant populations or metapopulations, how to untangle their interaction with other threats, and how to come up with effective methods to alleviate them.

Fragmentation (e.g., roads, heliostat fields, structures) of important habitat for white-margined beardtongue survivability caused by development of the proposed Calico Solar project, and other subsequent energy projects proposed for the Pisgah region, will have serious impacts, but how exactly? Plant conservation biology theory has taught us that if larger populations are broken into smaller ones it leads to restricted exchange of pollen or seed, and this has important genetic and demographic consequences. But fragmentation also creates edge effects and deterioration of habitat quality. It may alter plant-pathogen and plant-herbivore dynamics and disrupt biotic interactions that might include destruction of key pollinator guilds, altered pathogen and herbivore interactions, and hybridization with introduced natives (e.g., revegetation programs).

Due to lack of time, funding or available expertise, the full range of demographic vs. genetic stochasticity parameters are rarely integrated into a population viability analysis. Until such detailed analyses become available, we must strive to maintain natural ecological processes and provide the best natural conditions for populations and metapopulations to persist, while delineating the most likely threats and minimizing or eliminating them where possible.

Current environmental threats to the proposed Calico Project site and surrounding lands are considerable. In order to fully assess impacts to the white-margined beardtongue by the proposed Calico Solar project, it is imperative to fully understand this species distribution onsite (including below ground signatures), its life-history attributes, and identify any threats to the viability of the population. Given the location, scale and the nature of disturbance proposed by the Calico project, it is my professional judgment that the project poses a serious threat of extinction to the lone California occurrence of this species.

4. **The Proposed Minimization 250-foot Buffer Does Not Sufficiently Minimize Impacts to the White-Margined Beardtongue Nor Maintain the Species' Viability.**

California Energy Commission staff has proposed a 250-foot buffer around each plant to minimize the project's impact (*See* DEIS, C.2-55). Enclosing the few above-ground occurrences (the "halo" method) ignores what we know about the biology of the species, as well as the importance of maintaining the population processes over the species' critical habitat. The "halo" plan is fraught with obstacles to the long-term success of self-sustaining plant populations as is detailed in point # 3 above.

The Committee should not consider the 250-foot buffer zone as "avoidance" or as an on-site mitigation measure that will result in long-term, self-sustaining populations of rare plants. Mitigation practices certified on this project will be precedent-setting for subsequent project applications and should be based on sound scientific information. The extent of protection afforded to plants within isolated halos remains speculative at best. Preserving intact habitat and connectivity with surrounding areas are inherent to the most basic principles of conservation biology. To maintain viable populations of white-margined beardtongue it is crucial to preserve the intact nature of the current, pre-project condition with the rest of the undeveloped Calico/Pisgah sand system. The difficulties in deciding if and how to avoid, minimize, and mitigate project impacts become moot when one considers turning to the alternatives of distributed photo-voltaic solar generation and utility-scale projects sited on low-impact lands to provide the MW of electricity that the Calico Solar project would produce.

5. **Rare Plant Surveys Lacked Late Summer/Early Fall-Flowering Taxonomic Inventory**

Each species requires its own unique conditions for growth and reproduction. Surveys, no matter how thorough, performed during seasons and years when specific growth conditions are lacking will miss the presence and/or full range extent of rare plants. I estimate that approximately 25% of the plant taxa at the project site reach their peak reproductive maturity in late summer/early fall. A number of these potentially-occurring taxa are special status plants that flower primarily in summer/fall.

The floristic surveys conducted by the applicant to through 2010 (to date) were reasonably thorough to capture both early and late spring-flowering species. These surveys were also performed by well-qualified field personnel. However, floristic surveys for desert rare plants must be performed over a number of years during both spring and summer/fall flowering seasons in order to maximize the probability of identifying all special status species with the potential to occur on the project site. Without an accurate inventory of plant taxa that occur on site, it is not possible to fully assess project impacts to special status plants and meaningful mitigation cannot be developed.

What is more, the Eastern Mojave is a botanical frontier where in the past few years alone, there have been a number of very significant botanical finds, including new species to science or to California. More discoveries are to be expected. Summer annuals and fall-flowering species represent perhaps the most underdocumented group of plants in the California Deserts. Since summer/fall surveys have yet to be performed at the project site, there is no baseline information on the presence and extent of these taxa. Therefore, summer/fall surveys need to be conducted throughout the entire site (following adequate precipitation) in order to obtain a full account of special status species on site.

Below is a partial list of special status plants that flower primarily in late summer/early fall and that have potential to occur at the Pisgah/Calico site. This list was compiled from CNDDB records, herbarium records, and from my professional experience working with each species.

Amaranthus watsonii
Chamaesyce abramsiana
Chamaesyce parryi
Chamaesyce revoluta
Matelea parvifolia
Muhlenbergia appressa
Munroa squarrosa
Physalis lobata
Portulaca halimoides
Salvia funerea

6. Project Destroys One of the Last Ecologically Functional Examples of Central Mojave Desert Ecosystem.

The proposed Calico Project is located in the heart of California's Mojave Desert, at a place where the western Mojave transitions into the eastern Mojave Desert. Much of the central and western Mojave Desert is impacted by encroaching human activities and development. Encircled by the Kelso Dunes Wilderness and the Bristol Mountains Wilderness on the east, and the Cady Mountains Wilderness Study Area to the north, the Pisgah/Calico region is part of the most expansive and viable examples of pristine central Mojave Desert ecosystem. It represents one the last remaining sanctuaries for hundreds of vascular plant species unique to the central Mojave Desert floristic region. Direct and indirect impacts associated with the proposed Calico Project will further deteriorate the ecological integrity of the larger central Mojave Desert ecosystem.

7. **The Calico Solar Project is Precedent-Setting, Will Irreversibly and Negatively Impact Intact Wildlands, and a Statement of Overriding Considerations Should not be Issued.**

The Calico Solar project has the potential to become one of the first examples of transformative energy generation practices in California, in terms of both scale and technology. Unfortunately, the applicant has chosen an ecologically high-impact location for this project. In good faith, the applicant has responded by developing, at great expense, high quality (though still incomplete) botanical surveys, and special-status plant mitigation plans in addition to extensive animal mitigation, and engineering plans. The challenges associated with reviewing the project's application for certification have been extensively discussed and reported, and should be met with equally transformative decision making.

I endorse the concept of State and Federal governments making an example of this project by calculating the amount the applicant has expended on site planning thus far, and applying those funds as a joint state and federal credit to the applicant toward obtaining a right of way on public lands or the purchase of private lands elsewhere on ecologically low-impact lands. This would thereby provide the means and incentives to relocate the project to a less damaging location, while establishing the precedent for what types of lands are and are not suitable for utility-scale renewable energy generation. This type of solution honors the economic and political expenditures of the applicant and others involved in the certification process, while recognizing that the preservation of ecosystem is paramount to all discretionary actions. The Commissioners must consider and make sustainable management decisions that are firmly grounded on science-based ecological principles and that recognize the inherent value of the landscapes that contain the structures, composition and processes that support and enhance biodiversity, heterogeneity and complexity. As the decision-making body for this and subsequent utility-scale solar energy projects, the Commission becomes our representative to future generations. If the decision is to build the project as proposed by relying on mitigation concepts with no scientific foundation, and on statements of overriding consideration, then we will have set a very low bar for how our generation chooses to transform how we generate energy while cohabiting the planet, and will have hastened the type of ecological destruction for which the Calico Solar project is meant to mitigate.

James M. Andre

Curriculum Vitae

EDUCATION
M.A. Botany, 1989, Humboldt State University, Arcata, CA.
Thesis: *Population Biology and Conservation of Abronia alpina in the Southern Sierra Nevada, Inyo County.*
B.A. Plant Ecology/Geography of Ecosystems, 1982, University of California, Los Angeles

RESEARCH INTERESTS
Rare plant conservation biology and recovery, vascular plant floristics (western U.S.), demographics of long-lived desert shrubs, alpine ecology, vegetation analysis and classification, species distribution ecology, invasive plants, vegetation dynamics of coastal and interior dunes, and impacts and restoration ecology (particularly in systems impacted by livestock grazing).

PROFESSIONAL EXPERIENCE

1993-present	Director, University of California's Sweeney Granite Mountains Desert Research Center
2008-present	Senior Advisor and Chair, California Native Plant Society Rare Plant Program
1995-present	Curator, GMDRC Herbarium
1997-present	Adjunct professor, Lecturer, University of California Riverside
1985-present	Independent Consultant. Clients include Southern Nevada Water Authority, Native American Land Conservancy, Southern California Edison; Bureau of Land Management; Dept. of Defense; Los Angeles Dept. of Water and Power; US Forest Service, USFWS, BLM, National Park Service; The Nature Conservancy; Counties of San Diego, Inyo, Humboldt and Stanislaus; FAA, California Native Plant Society, East Bay Municipal Water District.
1989-1993	Senior Plant Ecologist, BioSystems Analysis, Inc, Tiburon, CA.
1987-1989	Research Associate - Plant Ecologist, Humboldt State University
1983-1989	Forest Botanist, U.S. Forest Service, Inyo National Forest
1986-1987	Teaching Assistant, Humboldt State University
1982-1983	Research Assistant, San Diego State Univ. (vernal pools studies)
1981-1982	Preserve Manager, Ewing Oak Preserve, The Nature Conservancy, San Diego Co.
1979-1980	Botanist/Ornithologist, National Park Service, Santa Monica Mountains National Recreation Area.

BOTANICAL RESEARCH AND INVENTORY

- awarded more than 25 academic research grants (ex. National Science Foundation, Smithsonian) and 40 government agency research contracts, managing grant budgets ranging from $500 to $8,100,000.

- oversee and facilitate 165 current multi-disciplinary research projects affiliated with the UC Granite Mountains Desert Research Center.

- principal investigator on more than 100 academic research projects in the California and Nevada deserts since 1994.

- lead author on numerous published regional floras and annotated vascular plant checklists, including floras for the Owens Valley, Mojave National Preserve, Big Pine Canyon, Dead Mountains, Old Woman Mountains, Ash Meadows Natl. Wildlife Refuge, and Schell Creek Range.

- conducted over 400 floristic inventories in the desert southwest since 1979 (full list available upon request, some examples included below).

- principal investigator conducting comprehensive studies in population ecology, demographics and threats analysis to evaluate conservation status for more than 100 California rare plants (full list available upon request). Examples include *Abronia alpina*, *Erysimum menziesii*, *Pogogyne abramsii*, *Eriogonum thornei*, *Penstemon albomarginatus*, *Plagiobothrys parishii*and *Eriophyllum mohavense*.

- directed (ongoing) the Flora of the Mojave National Preserve Project, a floristic study of the 1,700,000 acre Mojave National Preserve and surrounding 500,000 acres. Included 7000 hours of field surveys, published annotated checklist of plants, compiled database of records submitted to NPSpecies national database; illustrated technical flora (book) is pending.

- conducted numerous large-scale floristic inventories including the 2 million-acre Golden Trout Wilderness, 800,000 acre Joshua Tree National Park (NPS), 900,000 acre Owens Valley survey, and 500,000 acre 20 Palms Marine Corps Base (DOD).

- principal investigator on 3 year project develop rare plant status reviews for 8 federally-listed species at Ash Meadows National Wildlife Refuge, Nye Co. Nevada.

- project manager of the DOD Legacy Program coastal dunes ecological study which included population studies and habitat analyses of four rare plant species on the coastal dunes and bluffs at USMC Camp Pendleton, CA.

- conducted rare plant surveys for 845-mile PG&E-PGT Pipeline from Alberta to Fresno, the 275-mile Tuscarora Pipeline Project from Reno to Malin, Oregon and the 384-mile Mojave Pipeline Project from Needles to Bakersfield. For the later project, developed and implemented rare plant and vegetation restoration, long-term monitoring, and evaluated 10-year post-construction success of restoration measures.

- 15 yrs experience as Curator of the University of California- Granite Mountains Herbarium.

- conducted inventory and mapping of more than 100 seeps and springs (40,000 acres) as part of the Lower Owens River Project, Inyo County, CA. Developed demographic monitoring and impact studies on Inyo County star-tulip (*Calochortus excavatus)* and Owens Valley checkerbloom (*Sidalcea covillei*).

- principal investigator of a 90,000 acre floristic inventory and vegetation analysis of the Old Woman Mountains Preserve, eastern San Bernardino County for the Native American Land Conservancy.

- conducted detailed impacts surveys and population analyses for several federal-listed species in Cushenberry Cyn, San Bernardino Co., including Parish's daisy (*Erigeron parishii*), Cushenberry buckwheat (*Eriogonum ovalifolium vineum*), and Cushenberry milkvetch (*Astragalus albens*).

- conducted complete floristic inventories and rare plant surveys along approximately 110 miles of pipeline corridors in the Virgin River area of eastern Clark County, Nevada (Southern Nevada Water Authority).

- principal investigator for botanical surveys for more than 400-miles of proposed water pipeline corridors in White Pine, Lincoln and Clark Counties of Nevada (Southern Nevada Water Authority).

- consulted for numerous interdisciplinary projects on the design and implementation of optimal field sampling protocol, including riparian vegetation/habitat monitoring on the upper Sacramento River as part of a study of the impacts of the Cantara Bridge chemical spill. Provided expert testimony in federal court on research findings.

- conducted more than 30 quantitative vegetation classifications employing ARCGIS, TWINSPAN, DECORANA, and PCA other multivariate software programs. Examples include:
  - riparian vegetation analysis of tributary streams (Bishop and Mill Creeks) of the Owens River employing multi-stage sampling protocols and vegetation monitoring (using a laser theodolite) to determine the effect of changes in stream flow on riparian systems (SCE);
  - characterization and mapping of vegetation at Tonto Creek, AZ for long-term monitoring of change (BOR);
  - characterization and mapping of riparian and meadow vegetation on the Kern Plateau for purpose of monitoring grazing and erosion impacts (USFS);
  - multi-stage classification and monitoring of riparian forest and woodlands along Sacramento and Stanislaus Rivers to monitor affects of alteration of flow regimes upstream (EBMUD);

- Twinspan and PCA classification of vegetation along Eel and Mad Rivers of Humboldt Co. (USFS);
- classification and mapping of vegetation series and associations of vernal pools and swales in central Sacramento Valley, CA.;
- long-term monitoring and classification of vegetation on desert riparian thicket and tamarisk-invaded streams and seeps in the Mojave Desert.

- designed a vegetation classification scheme and reviewed field protocols and data collections for the Mojave Desert Mapping Project (CDFG and DOD, 1998-1999).

- documented vascular plant composition for vernal pools in seven counties in the Sacramento Valley using relevé sampling; assessed temporal changes in species composition and hydrology in the Kearny Mesa vernals pools of San Diego County; developed conservation management for more 8 rare plant taxa, addressing recovery, enhancement, and long-term viability of the species.

NATURAL AREAS MANAGEMENT

- 20 years of experience as a leader in coordinating academia research and regional natural areas management among scientists and agency managers in the Eastern Mojave Desert.

- served as Principal on Inventory and Monitoring Committee to develop protocols for the National Park Service I & M Program - Desert Southwest Region. Provided data and participated in the writing of the National Park Service's Mojave Inventory and Monitoring Network Biological Inventory Study Plan (2001).

- coordinated the writing of a Cooperative Management Agreement between the University of California and the National Park Service for joint management of lands within the Mojave National Preserve.

- served on numerous academic and land management committees including the Desert Advisory Committee (congressional appointment) Science Data Management Interagency Working Group for the Desert Managers Group, Center For Conservation Biology at UC Riverside, Research Advisory Committee - Mojave National Preserve, and the Advisory Council to the California Wild Heritage Campaign, and California Native Plant Society Rare Plant Committee (Chair).

- developed a comprehensive Coastal Dunes Vegetation Management Plan for the 13-mile coastal beach and dune system at Camp Pendleton, California. Study included the development of vegetation monitoring plan, GIS ARC/INFO quantitative habitat mapping, Least Tern and Snowy Plover habitat enhancement, and implementation of rare a plant and dunes recovery and enhancement program (exotic species removal and establishment of native vegetation).

- designed and implemented long-term monitoring for 12 rare plant species in Inyo and eastern San Bernardino Counties to assess the effects of grazing impacts on population dynamics.

- conducted long-term monitoring of special-status plants and vegetation recovery following disturbance in numerous study sites throughout the East Mojave in collaboration with the California and Nevada Native Plant Societies.

- coordinated numerous exotic species control/removal programs including a 7 year study of tamarisk removal along 16 streams in the east Mojave Desert using repeated physical removal and systemic injection of Garlon.

- drafted a Resource Management Plan with the National Park Service for joint management of the federal lands within the Sweeney Granite Mtns Desert Research Center, including removal of exotic burros and plants, erosion control and habitat restoration and enhancement (ongoing).

- developed long-term vegetation and habitat management plans for the Native American Land Conservancy's Old Woman Mountains Preserve.

- developed an illustrated technical manual detailing techniques for high elevation meadow restoration on the Inyo National Forest.

- drafted vegetation management sections of the Inyo National Forest Plan at USDA Forest Service; prepared seven sensitive plant Species Management Guides;

- supervised 10-15-person backcountry crews to evaluate the success of restoration and revegetation of montane meadows in the southern Sierra Nevada degraded by livestock grazing.

- developed a long-term vegetation management plan for Inyo National Forest and coordinated sensitive plant inventory and monitoring.

- conducted a 3-year programmatic botanical assessment for East Bay Municipal Water District's Water Supply Management Program and EIR/EIS, including impact assessment of for 52 proposed reservoir sites and 14 aqueduct corridors in the Central Valley and western Sierra Nevada foothills.

- prepared a comprehensive Hardwoods Management Plan for County of Contra Costa, California.

TEACHING, PRESENTATIONS, CONFERENCE ORGANIZATION

- session chair for more than 20 major workshops and conferences, including the 2009 CNPS Conservation Conference, 2009 Desert Research Symposium, 2004 and 1999 Mojave Desert Science Symposiums.

- co-architect and lead organizer of the Desert Research Symposium and Mojave Desert Science Symposium series.

- developed curricula and taught over 20 university-level field courses or workshops in botany and plant ecology and desert ecology at the Granite Mountains Desert Research Center; taught 9 accredited college courses (including: Humboldt State Univ., UCLA, UC Berkeley, San Diego St. University) in plant ecology and vegetation sampling theory.

- instructor for more than 15 plant taxonomy field courses for the Jepson Herbarium Workshops, Joshua Tree Foundation, and Rancho Santa Ana Botanical Garden; taught numerous field courses in natural history for the Sierra Institute, California Native Plant Society, and Victor Valley College.

- presented over 150 lectures/presentations at university departmental seminars, agency workshops, and scientific conferences, including the opening speaker at the 2009 Southern California Botanists Symposium.

- published a fully-illustrated Ethnobotanical Guide to the Plants of the Old Woman Mountains, an educational guide book along with other educational materials for the Native American Land Conservancy's Old Woman Mountains Preserve.

- developed public education programs which included docent-led field trips and slide presentations for the Ewing Oak, Lanphere-Christensen Dunes Preserves, and Old Woman Mountains Preserves.

SCIENTIFIC REVIEW AND ACADEMIC COMMITTEES

- reviewed numerous academic books including the forthcoming *The Jepson Manual, Higher Plants of California 2nd Ed* and sections of the *Flora of North America.*

- peer-reviewed more than 30 refereed journal submissions and technical papers for Journal of Arid Environments, J. of Ecology, Ecol. Monographs, J. of Conservation Biology, Crosossoma, Madrono, Novon, Fremontia, and USGS, USDA Forest Service and USDI Park Service publications.

- served three years on UC Natural Reserve System's Mildred E. Mathias grant selection committee to evaluate proposals and award University of California graduate research grants to student researchers.

- initiated the establishment of graduate student research grants, including the California Desert Research Fund (Riverside Community Foundation) and Joshua Tree National Park Graduate Student Research Grant; served on selection committee for both grants over the past decade.

- reviewed or prepared technical sections for EIRs/EISs, Biological and Environmental Assessments, FERC Exhibit E's, agency mitigation plans, and numerous endangered species and resource management plans.

- NRS representative (2 year appointment), UC Office of the President Universitywide Advisory Committee .

- drafted or reviewed more than 20 federal and state and federal listing petitions (for CDFG, USFWS and CNPS) for listing of rare California and Nevada plant species.

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PROFESSIONAL AFFILIATIONS

American Institute of Biological Sciences (AIBS)
Botanical Society of America (BSA)
Society for Ecological Restoration (SER)
Natural Areas Association (NAA)
Society for Conservation Biology (SCB)
Ecological Society of America (ESA)
California Native Plant Society (Mojave and Bristlecone Chapters)
Nevada Native Plant Society (Las Vegas Chapter)
Southern California Botanists Association
Desert Legume Program, University of Arizona
California Exotic Pest Plant Council
Union of Concerned Scientists

Exhibit 601

STATE OF CALIFORNIA

Energy Resources Conservation
and Development Commission

In the Matter of: The Application for Certification for the Calico Solar Project	Docket No. 08-AFC-13

INTERVENOR DEFENDERS OF WILDLIFE

REBUTTAL TESTIMONY

July 29, 2010

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STATE OF CALIFORNIA

Energy Resources Conservation
and Development Commission

In the Matter of: The Application for Certification for the Calico Solar Project	Docket No. 08-AFC-13

Pursuant to the Committee's scheduling order dated July 13, 2010, Defenders of Wildlife provides the following rebuttal testimony for the proposed Calico Solar Project evidentiary hearings scheduled for August 4-6, 2010. The foregoing testimony concerns the Biological Resources topic area.

Defenders of Wildlife reserves the right to supplement or revise its testimony at any time up to and including the close of the evidentiary hearings.

REBUTTAL TESTIMONY OF JEFFREY B. AARDAHL

To the best of my knowledge, all of the facts contained in this testimony (including all referenced documents) are true and correct. I am personally familiar with the facts and conclusions described within this testimony and if called as a witness, I could testify competently thereto.

Qualifications

I have an Associate degree in Forestry from Pasadena City College and a Bachelor of Science degree in Wildlife Management from Humboldt State University, California. From approximately 1974 through 2005 I was employed by the Bureau of Land Management and held several positions including wildlife management biologist, environmental coordinator, and supervisory resources management specialist. During the period from 1989 through 1995, I was the Resources Management Division Chief in Death Valley National Park; and from 1997 through 2000, I was a wildlife biologist in the Washington, D.C. headquarters of the Bureau of Land Management. I retired from the Bureau of Land Management in 2005, and have been employed by Defenders of Wildlife as a California Representative since 2009.

During my career with the Bureau of Land Management (BLM) I was involved in the following activities involving the Desert Tortoise:

- Conducted several dozen relative density survey transects throughout the western and eastern Mojave Desert.
- Assisted in preparing the wildlife element of the California Desert Conservation Area Plan of 1980 (CDCA Plan).
- Prepared and implemented the management plan for the Desert Tortoise Natural Area located in the western Mojave Desert near the Rand Mountains and Fremont Valley.
- Analyzed several hundred multiple land use project proposals and prepared environmental impact assessments and recommended mitigation measures.
- Analyzed proposed amendments to the CDCA Plan and prepared environmental impact assessments and recommended mitigation measures.

I have visited the site of the proposed Calico Solar Project several times during 2009 and 2010 for the purpose of examining the quality of the habitat, searching for Desert Tortoises and their burrow and shelter sites, Bighorn Sheep and their sign, and assessing potential habitat connectivity and movement patterns.

Statement

I have reviewed the project applicant's Application for Certification, supplemental survey reports, the Staff Assessment/Draft Environmental Impact Statement (SA/DEIS), the Supplemental Staff Assessment (SSA) and the BLM's Biological Assessment for the proposed project and have the following concerns:

1. The number of Desert Tortoises that would be directly impacted by the proposed project has not been concisely and accurately reported

The former proposed project would have affected 8230 acres of Desert Tortoise habitat and an estimated 176 Desert Tortoises based on protocol surveys conducted in the spring season of 2010. The Supplemental Staff Assessment published in July 2010 indicates that the revised project proposal now would affect 6215 acres of habitat and 57 Desert Tortoises, based on information provided by the applicant.

The supplemental staff assessment correctly states that the former proposed 8230 acre project would have impacted an estimated 176 Desert Tortoises. This estimate is based on the number actually observed during protocol surveys and modified according to a formula provided by the Fish and Wildlife Service (FWS) that accounts for rate of delectability based on environmental factors. For this project area the number observed was 104 and the total estimated population is 176. Thus, the rate of detection was 0.59 or 59%.

My analysis of the applicant's Supplement to the Application for Certification, and specifically the photo-map of locations of Desert Tortoises and their burrows within the proposed project area, resulted in significantly different direct impact projections. Specifically, the number of individuals occurring within the new avoidance area that were observed is 26, which means that the observed number within the revised project area is 104 - 26 or 78, not 57. Applying the detection rate results in an estimated 44 being avoided and 132 directly impacted. The SSA needs to clearly state the correct number of individuals impacted based on actual number observed and the estimated population.

Based on information contained in the SA/DEIS and SSA, I conclude that the following direct effects to the Desert Tortoise and its habitat would occur:

Project Area	Est. Acres	Desert Tortoises		Percent of Total
		Observed	Est. Total	
Exclusion	1100	25	42	24
Phase I Detention Basins	550	8	14	8
Phase I Suncatcher Area	700	7	12	7
Phase II South of Railroad	2200	2	3	2
Phase II North of Railroad excl. detention basins	1600	62	105	59
Total	6150	104	176	100

2. The significance of the Desert Tortoise Population and its habitat has not been analyzed.

The proposed Calico Solar Project is located within the east-central portion of the Western Mojave Recovery Unit for the threatened Desert Tortoise, and in proximity to the boundaries of the Eastern Mojave and Northern Colorado Recovery Units.[1] The proposed Calico Solar Project would directly impact 6215 acres of Desert Tortoise habitat and an estimated 132 Desert Tortoises based on the applicant's protocol surveys performed in 2010. This is by far the largest number of individuals of this species that would be affected by any of the proposed renewable energy projects currently under permit review. In comparison, the next most-impacting proposed project, the Ivanpah SEGS, would directly impact at least 25 Desert Tortoises.

Individual Desert Tortoises observed and documented on the proposed project site by the applicant's biological consultant visually appeared healthy, and included adults, sub-adults and juveniles of both sexes, an indication that successful reproduction is occurring.

The relationship of this population and its habitat to other known populations to the east, north and south has not been adequately described and analyzed in the environmental analysis. Although the Calico solar project is not located within a recommended Desert Wildlife

[1] Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon. 73 pages plus appendices

Management Area (DWMA) for the recovery of the Desert Tortoise, or a BLM-designated Area of Critical Environmental Concern (ACEC) for Desert Tortoise conservation, Desert Tortoises occurring outside of these administratively designated habitat areas, such as within the proposed Calico project area, may be important in the overall recovery of this species because their habitat may provide corridors for genetic exchange and dispersal of Desert Tortoises among the DWMAs.[2] Specifically, its value in contributing to the genetic health and sustaining populations within designated DWMAs and ACECs has not been addressed.

In addition, Desert Tortoises occurring in suitable habitat outside of DWMAs and ACECs may be much less susceptible to the deleterious effects of shell disease and Upper Respiratory Tract Disease because of their lower density.[3]

3. The nature of the Desert Tortoise population that would be affected by the proposed project has not been adequately analyzed and reported

Age, sex, visual characteristics and behavior of the Desert Tortoises observed and documented during all field surveys need to be analyzed and disclosed in a supplemental report. The applicant submitted field survey data forms containing such information for Desert Tortoises observed, but the SA/DEIS and SSA lacks an analysis of this information that is necessary to characterize the nature and health of the potentially affected population.

Age and sex of observed Desert Tortoises should be analyzed and conclusions made about their reproductive health and potential from a demographic perspective. For example, the proportion of hatchlings and juveniles would indicate reproductive rate over time, and compared with those of other known populations, allow for a determination of the status and trend of the population.

Data collected during the field surveys also included visual assessments of apparent health of individuals and their behavior. The visual health profiles of the encountered individuals are important and should be included in a supplemental report.

Lastly, the photographs taken of each individual Desert Tortoise should be included in the supplemental report because they would may provide additional visual information about the age and health of the individuals to subject matter experts.

4. Habitat connectivity and Desert Tortoise movements have not been adequately analyzed.

The project applicant, FWS and BLM concluded that because Desert Tortoises occupy the northern portions of the project site, in addition to habitat generally extending to the south in the vicinity of railroad, they would be able to move in an east-west and west-east direction over time across the northern portion of the site if the remainder of their habitat to the south was lost due to the solar project, including project perimeter fencing. The staff concludes that north-south movements would be eliminated by the proposed project.

[2] Id, page 45.
[3] Id. Page 45-46, 49.

In response to concerns expressed by the FWS and BLM the applicant has proposed to exclude approximately 1100 acres in the northern portion of the project area from development in order to maintain a Desert Tortoise movement corridor. Studies of Desert Tortoise movements within, to and from the project area have not been studied and the concept of a movement corridor across the northern portion of the project area is hypothetical. Staff of the CEC and BLM concluded, in the absence of documentation from field studies, that the BNSF Railroad and I-40 act as barriers to movement of Desert Tortoises.[4] However, staff also stated that many existing railroad trestles that span drainages provide opportunities for Desert Tortoise movement.[5] Staff concluded that I-40 is a barrier to Desert Tortoise movement without providing any supporting evidence.

In fact, there are numerous bridges and culverts under I-40 and the adjacent Route 66 that are sufficiently large to allow for Desert Tortoise movement south-north and north-south through the proposed project area. If such movements occur, they may provide biological connectivity with known populations to the south within the Ord-Rodman Critical Habitat Unit which is also a designated DWMA and conservation ACEC. Staff also reported that the area located between the BNSF Railroad and I-40 contained Desert Tortoise sign, and that two Desert Tortoises were observed in this area during surveys conducted in the spring of 2010.[6]

The applicant concluded the following with regard to Desert Tortoise movements and preferred habitat:

> "Movement of desert tortoise in the vicinity of the Project, north of the railroad, is expected to be mostly in the east-west directions, and mostly in the northern area near the base of the Cady Mountains where tortoise densities are greater (Figure 2.6-3). Movement corridors are not necessarily areas where animals spend most of their time, but are areas they periodically use to move between areas of preferred habitat. The modifications to the Project boundary would expand the east-west movement corridor by about 2,900 feet and allow for tortoise and other wildlife to move past the steeper topography that may hinder regular movement through this area."[7]

Desert Tortoise densities within the project area are greater north of the railroad, but are not concentrated near the base of the Cady Mountains, which is evident from observations of individual animals plotted on Figure 2.6-3. The greatest concentration occurs within a zone targeted for Phase II of the proposed project where an estimated 105 individual Desert Tortoises comprising 59% of the entire affected population occur over an area of approximately 1600 acres.

Desert Tortoise movement studies within and adjacent to the proposed project have not been conducted, so all the statements in the SA/DEIS and SSA about movement corridors for Desert Tortoises are speculative and based on best professional judgment of the agency staff biologists.

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[4] Staff Assessment/Draft Environmental Impact Statement for the Proposed Calico Solar Energy Project, March 2010, page C.2-4.
[5] Id. Page C.2-27.
[6] Applicant's Supplement to the Application for Certification for the Calico Solar Project, May 2010, Figure 2.6-3.
[7] Id. Page 2-16.

Only locations of observations of Desert Tortoises and their burrows have been documented based on surveys conducted over a brief period of time during the spring of 2010.

In response to data requests concerning wildlife movement impacts from Defenders of Wildlife and others, the applicant on 12/4/09 submitted Figure No. 13: Modeled Potential Desert Tortoise Habitat and Desert Tortoise Movement Corridors. The habitat model is based on a recent USGS publication, but the identified Desert Tortoise movement corridors are speculative and unsupported by any field studies. Interestingly, the depicted movement corridors do not include the proposed project area even though it is located in the middle of the highest quality habitat within the region that provides continuity with habitats and populations to the northwest, south, southeast and east.

It is much more likely that movements of Desert Tortoises on the Calico project site occur in an east-west and west-east direction in the lower half across more flat terrain, and in a south-north and north-south direction in the northern half through the numerous braded washes. Jennings[8] studied Desert Tortoise movements at the Desert Tortoise Natural Area located in the western Mojave Desert. He reported that Desert Tortoises were associated over 90 percent of the time during the spring season with washes which they used for travel, excavation of burrows or dens, and for feeding.

Figure 2.6-3 also reveals that the proposed project construction area would result in narrow constrictions of the hypothetical movement corridor due to terrain features of the toe-slope of the Cady Mountains at the eastern and north central portion of the proposed project. These constrictions have not been analyzed for their potential to limit Desert Tortoise movements. Furthermore, based on terrain features associated with north-south drainages on the bajada of the Cady Mountains, Desert Tortoise movements in an east-west direction would naturally be difficult or sometimes impeded depending on the wash depth and bank slope.

The applicant and the CEC have concluded that Desert Tortoise occur in higher density near the base of the Cady Mountains, but analysis of the information provided by the applicant and analyzed by agency staff indicate otherwise.

5. Bighorn Sheep movements north and south across the proposed project area have been prematurely dismissed as an issue.

Agency staff addressed the potential impacts to Bighorn Sheep movements due to the proposed project, but limited their analysis generally to movements between the Cady Mountains and Bristol Mountains to the east, and access to seasonal foraging habitat on the bajada south of the Cady Mountains. Potential movement south across I-40 was not analyzed, apparently on the assumption that I-40 functioned as a barrier to such movement, and because there is no evidence that such movements occur.

[8] Jennings, W. Bryan. 1997. Habitat Use and Food Preferences of the Desert Tortoise, *Gopherus agassizii*, in the Western Mojave Desert and Impacts of Off-Road Vehicles. Proceedings of the New York Turtle and Tortoise Society: Conservation, Restoration, and Management of Tortoises and turtles - An International Conference, pp. 42–45.

The absence of analysis for the potential movement of Bighorn across I-40 is somewhat puzzling given that staff in the SSA cited a recent habitat connectivity study by Spencer, et.al[9], and concluded that the proposed project "...is located within the essential connectivity area and has the potential to adversely affect wildlife movement. This area acts as an important link between wildlife populations in the eastern and western deserts. Further reading of Spencer, et al. study reveals that the area of essential connectivity links the Cady and Bristol Mountains with the Rodman, Newberry and Ord Mountains south and west of I-40. Staff did not address the Bighorn Sheep within the context of wildlife movements across an essential linkage area spanning I-40. Their analysis was limited to the Desert Tortoise.

Since Desert Bighorn habitat connectivity and movement potential across I-40 was neither addressed nor dismissed as a potential impact, the SSA included only one mitigation measure to address potential impact: Monitoring of animals detected within 2000 feet of the project construction area and possible cessation of construction activities if individuals are detected within 500 feet.

The study by Spencer, et al. contains the following statement regarding essential connectivity areas: "...in the relatively undeveloped forest and desert ecoregions—such as the Sierra Nevada and Mojave Desert—many Essential Connectivity Areas connect highly intact wilderness and park lands across private or federally managed multiple-use lands, which support mostly natural landcovers and are relatively permeable to wildlife movements. In these "low-contrast" situations, managing to sustain wildlife movements between existing protected areas may be the primary conservation approach."

Bighorn Sheep in the Cady Mountains have expanded their population from an estimated 50 to over 300 individuals since approximately 1990 based on aerial surveys performed by the Department of Fish and Game. This population is natural and has not been augmented by transplants from other herds. The Cady Mountain herd movements have not been studied through radio telemetry, so little is known about the movements of individual animals comprising the herd.

Numerous culverts and bridges occur under I-40 in proximity to the proposed project, and many are of sufficient size to allow the movement of Bighorn Sheep and other species. No wildlife movement studies involving these engineered drainages were conducted as part of the environmental review of the proposed project.

Bighorn movement under an elevated bridge on I-8 in Imperial County was noted in the Supplemental Staff Assessment for the Imperial Valley solar project. Movement was detected via radio telemetry from a collared animal. This is one instance where a bighorn was documented moving under a freeway at an elevated bridge. Since no radio telemetry study is available for the Cady Mountains bighorn, bighorn could potentially travel under I-40 without

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[9] Spencer, W.D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi, and A. Pettler. 2010. California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California. Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration.

detection, especially at relatively low levels. In the absence of further study, such movement can't be dismissed.

Wehausen (personal communication 2010) indicated that recent studies to detect movements of Desert Bighorn between permanently occupied habitats based on genetic markers provide insight into herds that are isolated and those that are connected to other herds. Although studies to date did not find genetic evidence of connectivity between herds in the Cady Mountains and the Rodman, Newberry and Ord Mountains, Wehausen cautioned that the "resolution" of the genetic testing is such that a low level of gene flow across I-40 in the vicinity of the proposed project can't be ruled out.

Staff failed to identify the potential for Bighorn Sheep to move from the Cady Mountains into the Rodman, Newberry and Ord Mountains, and also failed to identify the numerous culverts and bridges under I-40 which would accommodate such movement. The proposed Calico Solar Project would be a barrier to movement, which is a significant impact under CEQA. Therefore, staff should develop conditions of certification to mitigate such impact. In my opinion, acquisition of lands with similar value as movement corridors for Bighorn Sheep and connectivity between populations is appropriate compensatory mitigation for such impacts, provided that the benefits from such mitigation enhance opportunities for Bighorn Sheep movements across I-40.

Jeffrey B. Aardahl

Curriculum Vitae

Education:

Associate of Arts in Forestry, Pasadena City College, Pasadena, California, 1968
Bachelor of Science, Biology (Wildlife Management), Humboldt State University, Arcata, California 1970.

Professional History:

2009 – Present: California Representative. Defenders of Wildlife, California Program Office, Sacramento, California.
2005 – 2006: Wildlife Biologist/Conservation Planner. Center for Biological Diversity.
2000 – 2005: Resources Management Branch Chief. Ridgecrest Field Office, Bureau of Land Management, Ridgecrest, California.
1997 – 2000: Wildlife Biologist. Headquarters Office, Bureau of Land Management, Washington, D.C.
1995 – 1997: Resources Management Branch Chief. Barstow Field Office, Bureau of Land

Management, Barstow, California.

1989 – 1995: Resources Management Division Chief. Death Valley National Park, Death Valley, California.

1976 – 1989: Wildlife Biologist. Ridgecrest Resource Area, Bureau of Land Management, Ridgecrest, California.

Professional Training:

1977 – 2002: 960 hours in diverse subjects – remote sensing, visual resources management, air quality management, wilderness management, cultural resources management, Native American relations, wildlife habitat management, deer population management, environmental protection and NEPA compliance, natural resources monitoring and assessment, Endangered Species Act compliance.

General:

1971 – 1972: U.S. Army, active duty, Honorable Discharge

Exhibit 002

Revision of Disease Testing Requirements Based on Translocation Distance
Desert Tortoise Recovery Office
July 2010

This document describes changes made to the distance at which disease testing must accompany physical health evaluations prior to the translocation of desert tortoises. The original distance provided in the translocation guidance, 5 km, was put forth by the Science Advisory Committee (SAC) in 2009 (Hudson *et al.* 2009) and was derived using information available at the time and professional judgment of the scientists. As large projects involving translocations started making their way through the planning process, the California Department of Fish and Game (CDFG) expressed concern that 5 km was too liberal. They stated preference to reduce the distance to 305 m (1000 ft), which is a distance both CDFG and the Fish and Wildlife Service have used for past, smaller-scale projects. CDFG justified continued use of 305 m as a disease-testing distance threshold based on their interpretation of data from repeated locations and home ranges of resident desert tortoises at several study sites. They asserted that an individual desert tortoise is usually found within 300 m of its original point of capture, thus is unlikely to contact and thus share similar pathogens with tortoises more than 300 m away (*i.e.*, outside a 29.2-ha area). This interpretation does not take into account overlap with home ranges of neighbors or the number of tortoises that have home ranges larger than the reported mean sizes, which results in a very small neighborhood of similarity (see description of neighborhood below). For example, CDFG cite data from Harless *et al.* (2009), who report mean home range sizes of 28.9 ha and 34.8 ha in consecutive years, yet further examination of their statistics reveals that home ranges of up to 97.7 ha and 87.3 ha, respectively, must be recognized to include the activity patterns of 95% of those tortoises. Additionally, the choice of 305 m did not incorporate data on known dispersal distances of translocated tortoises.

The Desert Tortoise Recovery Office independently reviewed the SAC's distance recommendation for disease testing. In addition to evaluating existing home range data for individual desert tortoises, we considered the fact that individual tortoises exist in "neighborhoods" of contact with nearby tortoises. We also examined data from recent translocation research to evaluate how post-translocation movements fit within these pre-translocation neighborhoods. Based on this assessment, we conclude that revision to the disease-testing distance threshold is necessary as described below, although the data still lead to a slightly more liberal distance than that preferred by CDFG.

Tortoises proximate to one another are expected to harbor similar pathogens, whereas tortoises from more distant areas may harbor different strains or completely unique pathogens. The SAC suggested that when tortoises are to be moved beyond the area expected to harbor similar pathogens, additional disease screening should accompany the physical health evaluation (Hudson *et al.* 2009). Comprehensive data on pathogen similarity and distribution do not exist, thus existing data on movement patterns of tortoises can be examined to help define a tortoise's surrounding neighborhood of similarity. To quantitatively estimate how large this area might be, the SAC chose to be very conservative and based their calculation on a potential home range size at the small end of the range for a female tortoise (5 ha). To this first 5-ha home range, they added 9 additional 5-ha home ranges linearly to represent potential expanded movements of the single tortoise as well as likely contacts with other nearby tortoises both directly and indirectly. The resulting radius of the neighborhood is approximately 2.5 km, not 5 km as stated in the SAC's disease white paper (Hudson *et al.* 2009; confirmed by M. Reed, personal communication, 22 June 2010).

An important consideration missing from the SAC's recommendation is the movement of translocated tortoises upon release. If translocated tortoises are likely to travel beyond their neighborhood, there is potential for exposure to novel pathogens (to both the translocated tortoise and residents of the new area). We looked at data from several recent translocation studies (Berry *et al.* 2009, Boarman *et al.* 2010, Drake *et al.* 2009, Field *et al.* 2007, Nussear 2004) to estimate how far (straight-line distance) from their release points translocated tortoises are likely to move. Tortoises translocated in spring to points more than 3 km from their points of origin had moved mean maximum straight-line distances of approximately 1484– 2536 m (raw data unavailable) by the end of that year's activity season (late fall/winter). From studies that reported sample size and error, we added 2 standard deviations to the reported means to calculate the maximum straight-line distances from release points that would contain 95% of the dispersal distances from those release points. This distance ranged from approximately 4020 to 6500 m. We also looked at the results of short-distance translocations of ≤500 m (0.5 km). Tortoises translocated these shorter distances moved 73-1473 m in straight-line distance from release through the end of that year's activity season. Data were not immediately available for translocations between 0.5-3 km.

Based on our review of recent translocation data, we are revising the translocation distance at which additional disease screening must accompany health evaluations. We calculated neighborhoods of similarity to be approximately 2.5 km in radius, yet an area with a radius of more than twice that would be needed to contain the first year dispersal movements of 95% of tortoises in most translocations. In addition, the farther a tortoise is translocated from its point of capture, the shorter the distance it can travel before exceeding the boundary of its neighborhood (*e.g.,* a tortoise translocated 2 km could only move an additional 0.5 km). Because significant numbers of translocated tortoises are expected to disperse beyond their neighborhood, disease testing should accompany physical health assessments for all tortoises with the following exception. Tortoises translocated very short distances (≤ 500 m) had ranges of movement well within the 2.5 km radius, thus we will not require disease testing for such tortoises (physical examinations are still required). In summary, disease testing must accompany physical health evaluations for any tortoise to be translocated more than 500 m from its point of capture. Importantly, the 500-m distance is measured from the *point of capture* of each tortoise and does *not* represent a 500-m radius around a project footprint.

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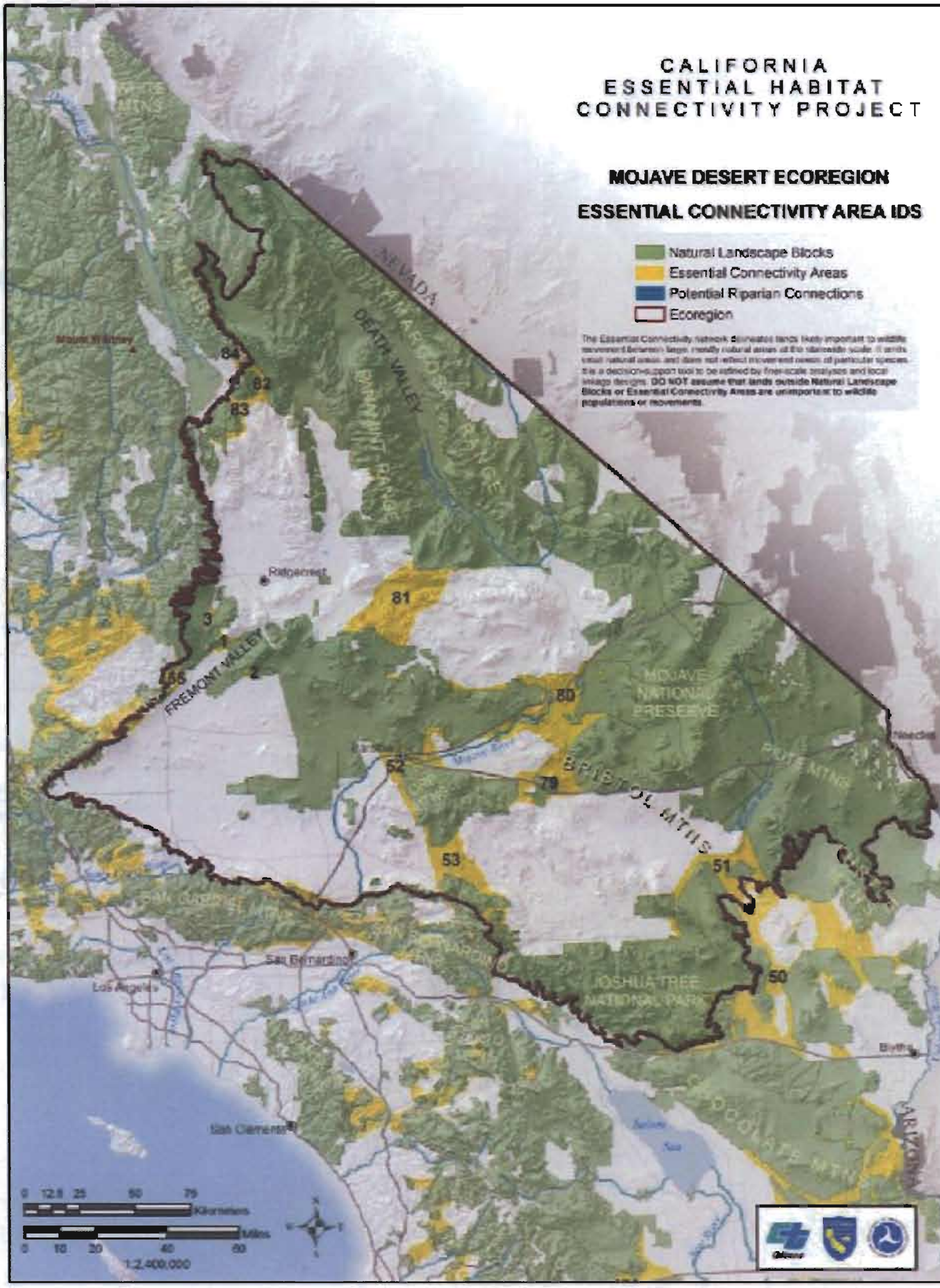
Exhibit 603


CALIFORNIA
ESSENTIAL HABITAT
CONNECTIVITY PROJECT
MOJAVE DESERT ECOREGION
ESSENTIAL CONNECTIVITY AREA IDS
Natural Landscape Blocks
Essential Connectivity Areas
Potential Riparian Connections
Ecoregion
NEVADA
DEATH VALLEY
FREMONT VALLEY
BRISTOL MTNS
MOJAVE NATIONAL PRESERVE
JOSHUA TREE NATIONAL PARK
ARIZONA
Ridgecrest
San Bernardino
Los Angeles
San Clemente
Needles
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84
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Exhibit 604

Proceedings: Conservation, Restoration, and Management of Tortoises and turtles—
An International Conference, pp. 42–45

Habitat Use and Food Preferences of the Desert Tortoise, *Gopherus agassizii*, in the Western Mojave Desert and Impacts of Off-Road Vehicles

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ABSTRACT: The desert tortoise, *Gopherus agassizii*, and its habitats in the western Mojave Desert and elsewhere are negatively affected by off-road vehicles (ORVs). Data from a study conducted at the Desert Tortoise Research Natural Area during 1992 provide insights into why ORVs are likely to affect tortoises. To determine habitat use and food preferences, 18 large immature and adult tortoises were observed. The study site contained four subhabitats or strata: washes (comprising 7.9% of the area), washlets (2.4%), hills (42.3%), and flats (47.4%). The tortoises used the four habitat strata differentially, spending significantly more time (92%) in washes, washlets, and hills throughout spring than in the flats (8%). They were observed to take bites from 2,423 individual plants of at least 43 plant species (37 annual, 6 perennial). They showed preferences for native plants (95.3% of bites) compared to non-native plants. Some of the ten most-preferred food plants were uncommon to rare in the environment. Three of the ten most-preferred food plants occurred largely in the wash strata, and an additional four species were found only in hill strata. Users of recreational vehicles also prefer washes and hills in this region, where they are more likely to encounter tortoises, increasing the possibility of direct mortality, and where they are more likely to have a greater impact upon preferred forage and habitats.

Recreational use of off-road vehicles (ORVs), popular since the late 1960s in the southwestern deserts of the United States, poses significant threats to desert tortoises in some parts of their geographic range (U. S. Fish and Wildlife Service [USFWS], 1994). The threats are both direct and indirect: direct encounters, damage to and loss of habitat, damage to or loss of burrows, and loss or changes in both the composition of the forage and the quality of shrub cover. In this paper, I report findings from research conducted in the western Mojave Desert in and adjacent to the Desert Tortoise Research Natural Area (Jennings, 1993), specifically, desert tortoise use of different habitat types, their preferred forage plants, and the possible impacts of ORVs on these two critical aspects of desert tortoise ecology.

METHODS

The study area was typical of the western Mojave Desert, a topographic and vegetational mosaic of subhabitats or strata that includes washes, sandy flats, low hills, and rocky slopes where the most common vegetation types are saltbush (*Atriplex* spp.) scrub and creosote bush (*Larrea tridentata*) (U.

S. Bureau of Land Management and California Dept. of Fish and Game, 1988; USFWS, 1994). Specifically, the 2.6 km² study area was composed of four strata or subhabitats, each with its unique composition of perennial and ephemeral plants (Jennings, 1993). The four strata were flats (comprising 47.4% of the study area), hills (42.3%), washes (7.9%), and washlets (2.4%). Wash and washlet strata were lumped for a portion of the analyses. In the flats, the dominant species were three shrubs: goldenhead (*Acamptopappus sphaerocephalus*), burro bush (*Ambrosia dumosa*), and creosote bush. In the hills the most diverse of the strata with 11 species, five species of shrubs were dominant: burrobush, California buckwheat (*Eriogonum fasiculatum*), goldenhead, Mojave aster (*Xylorhiza tortifolia*), and creosote bush. Shrubs in wash and washlet strata were burrobush, cheesebush (*Hymenoclea salsola*), goldenhead, bladdersage (*Salazaria mexicana*), creosote bush, and Anderson thornbush (*Lycium andersonii*). Data on absolute and relative densities of plant species were collected once for the perennial shrubs using linear transects and 2 × 5 m quadrats. Similar data were collected using the same method for herbaceous perennial and ephemeral plant species on 17–20 April, 12–15 May, and 12–13 June. Details of methodology are in Jennings (1993). Scientific names of plants are taken from Hickman (1993).

To determine how the tortoises used the four habitat strata, I observed 18 large immature and adult tortoises (8 females and 10 males), which ranged from 179 to approximately 380 mm in carapace length at the midline (Jennings, 1993). Most tortoises had been fitted with radio transmitters as part of other research programs. The tortoises were tracked from the time they emerged from hibernation through the spring (1 March–30 June), and their activities, use of habitat, and forage items were recorded. Because the ephemeral and herbaceous perennial plants on which tortoises feed have different growth, flowering, and fruiting periods during the year, I grouped the species into three phenological periods for analysis: 1 March to 30 April, 1 to 31 May, and 1 to 30 June. The use of phenological periods for data analysis also provided a better understanding of when and where tortoises were foraging, how they were using the habitats, and when the different forage plants were consumed.

RESULTS

The tortoises made differential use of the four habitat strata (Jennings, 1993). Between 1 March and 30 April, they spent a disproportionately longer time within the hill and washlet strata (84%; $X^2 = 1353.01$, d.f. = 2, $P = 0.0001$) and foraged on preferred food plants located exclusively in hill areas (*Mirabilis bigelovii*, *Astragalus didymocarpus*) and washlet margins (*A. layneae*, *Camissonia boothii*). During the second phenological period, the use of hill, wash, and washlet areas continued to be important (100%; $X^2 = 1405.8$, d.f. = 2, $P = 0.0001$). Tortoises foraged on *A. layneae* and *C. boothii* and then moved into the hills to eat the preferred *Lotus humistratus* and *Prenanthella exigua*. (Both *Lotus* and *Prenanthella* were restricted to the hills.) During the third phenological period, tortoise activity declined markedly because of heat and dry weather, and the few tortoises that remained above ground used primarily washes and washlets (68%; $X^2 = 753.83$, d.f. = 2, $P = 0.0001$), drawing on plants confined to those areas (*Euphorbia albomarginata* and *C. boothii*). Overall, tortoises made little use of the more common flat stratum.

The tortoises' diet and preferred foods were determined from observations of a total of 34,657 bites taken from 2,423 individual plants between 24 March and 21 June of 1992 (Jennings, 1993). Tortoises foraged from at least 43 species of plants (37 species of winter-spring annuals and 6 perennial species) as well as a dead leopard lizard (*Gambelia wislizenii*) and tortoise scat. Some important patterns emerged. These tortoises were highly selective foragers and preferred to consume native plants (33,712 bites or 95.3%) over non-native species (1,644 bites, 4.1%). The non-native species were filaree (*Erodium cicutarium*), Mediterranean grass (*Schismus arabicus*, *S. barbatus*), and foxtail chess (*Bromus madritensis* ssp. *rubens*), and were readily available. The tortoises also took more bites from annuals (69.2%) than from perennial plants (30.8%); with the exception of four bites from cheesebush, all bites of perennial plants were from herbaceous or suffrutescent perennial plant species. Tortoises took more bites from legumes (44%) than from any other plant family.

Some of the ten most-preferred food plants consumed during 1992 were uncommon to rare in the environment (Jennings, 1993). For example, during the first phenological period, plants of the suffrutescent perennial *M. bigelovii* constituted 29.7% of the bites taken by tortoises, yet *M. bigelovii* constituted <1% of the perennial plants in the environment and far less of the total biomass of both ephemeral and perennial plants. *A. layneae* was also an important forage plant (3.9% of bites) but was not found on plant transects. During the second phenological period the annual *L. humistratus* constituted 63.9% of bites taken, yet was not found in annual plant samples. During the third phenological period, the herbaceous perennial *Euphorbia albomarginata* constituted 57.4% of bites but did not appear on any plant transects. Overall, >25% of all the plants on which tortoises fed were in the washes and washlets, about twice the number as might be expected considering that washes and washlets comprised only 10.3% of the study area habitats. Three of the ten most-preferred plants, *E. albomarginata*, *A. layneae*, and *C. boothii*, were largely confined to washes.

DISCUSSION

Desert vertebrates and their habitats are vulnerable to and negatively affected by ORVs (Busack and Bury, 1974; Bury et al. 1977; Luckenbach, 1982; Webb and Wilshire 1983). The desert tortoise is not exempt from these effects (Berry et al., 1986). In the western Mojave Desert where the use of ORVs is prevalent, tortoise populations have undergone steep declines, compared to relatively undisturbed desert tortoise populations and in habitat in the eastern parts of their geographic range (USFWS, 1994).

Hills and washes are favored in the western Mojave Desert for use by ORV recreationists (U.S. Bureau of Land Management, 1980). Four major ORV recreation areas with hills, washes, and canyons are adjacent to the Desert Tortoise Research Natural Area (Rand Mountains) or are within 50 km (Jawbone Canyon, Dove Springs, and Spangler Hills). The users of motorcycles, trail bikes, all-terrain vehicles, and other four-wheel vehicles prefer the washes, washlets, canyon bottoms, and hilly country for riding (see Goodlett and Goodlett, 1993 for an example of trail densities in flats, hills, and wash habitats). They gradually widen trails and create more individual tracks and trails, which damages or destroys increasing amounts of habitat. The flats are used primarily for camping, as staging areas for competitive events, and as play areas.

Desert tortoises are vulnerable to negative effects from ORVs because of their habitat preferences. The tortoises in this study spent significantly more time traveling and foraging in hills, washes, and washlets than on the flats, the same areas preferred by ORV users. In other parts of the species' geographic range (the southern, eastern, and northeastern Mojave and the Sonoran deserts), washes are also important in the ecology and behavior (Woodbury and Hardy, 1948; Burge, 1978; Baxter, 1988). The tortoises use the washes for travel, excavation of burrows or dens, and for feeding. Because tortoises spend so much more time in washes and hills, they are also more likely to suffer direct mortality from vehicles than if they used the habitat randomly.

The food preferences and forage locations of the tortoises provide additional insights. A substantial portion of the food bites taken by tortoises were from plants that were infrequent to rare in the environment and occurred in the hill, wash, and washlet strata. Four of the ten most-preferred food plants were found exclusively in the hills, and an additional three were confined largely to washes. At least 25% of the forage plants were in or on the margins of washes or washlets. Vehicles disturb the soil and terrain in washes and other areas, which results in deterioration or denudation of vegetation (Burge, 1983; Woodman, 1983; Goodlett and Goodlett, 1993). They destroy the natural margins of washes and small washlets as the trails are widened over time (Berry et al., 1986). If the preferred forage plants are damaged or destroyed, tortoises will be forced to select other less-preferred and possibly less-nutritious species.

The 18 desert tortoises preferred native to non-native or alien plant species. The Desert Tortoise Reserve Natural Area has been protected from disturbance for almost two decades, and it has a relatively lower biomass of the alien plants than do the adjacent areas outside its protective fence (Brooks, 1995), where sheep grazing and uncontrolled ORV use occur. Most native desert plant species thrive in undisturbed habitats, in contrast to the alien species, which are common in disturbed lands. Some alien species, particularly the grasses, have invaded arid habitats, are fire prone, and have increased fire regimes globally (D'Antonio and Vitousek, 1992). The alien plant/fire cycle is prevalent throughout parts of the Mojave and Great Basin deserts, and wildfires burn thousands of hectares of desert annually (D'Antonio and Vitousek, 1992; USFWS, 1994). In areas disturbed by ORVs, these alien species are likely to constitute increasingly greater portions of the floral biomass, thus increasing the threat of fires.

Recommendations to Protect Desert Tortoises and Their Habitats

1. **Reduce or prohibit vehicle travel off existing roads.** Disturbance to desert soils increases the potential for alien plants to invade and become established, causing significant and deleterious alterations to the flora. And, although washes and washlets constitute only a small portion of desert habitats, they have a disproportionate share of the forage plants favored by tortoises and are frequented by tortoises a significantly greater amount of the time. Therefore, vehicle travel off existing highways and established roads—particularly in desert washes and washlets—in desert tortoise Critical Habitat should be minimized and, where possible, prohibited (see USFWS, 1994).
2. **Investigate food habits of neonates and juveniles.** The tortoises observed in this study were large immature and adult animals. Neonates and juveniles are likely to have different forage requirements and patterns of use because of their small body sizes, limited activity areas, and inability to travel great distances. The food habits of neonate and juvenile tortoises should therefore be determined also by desert region and habitat strata.

ACKNOWLEDGMENTS

Thanks are due to Dr. Michael Klemens and Dr. Kristin Berry for inviting me to participate in this conference and to Dr. Berry and Jim Van Abbema for valuable assistance on the manuscript. The U. S. Bureau of Land Management supported research on the foraging ecology and habitat utilization of the desert tortoise under Contract No. B950-C2-0014.

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Exhibit 605

SES SOLAR ONE

In Response to Defenders of Wildlife Data Requests, Set 1: Data Requests 1-11

In Response to Basin and Range Watch Data Requests, Set 1: Data Requests 1-3

Application for Certification (08-AFC-13)

December 2009

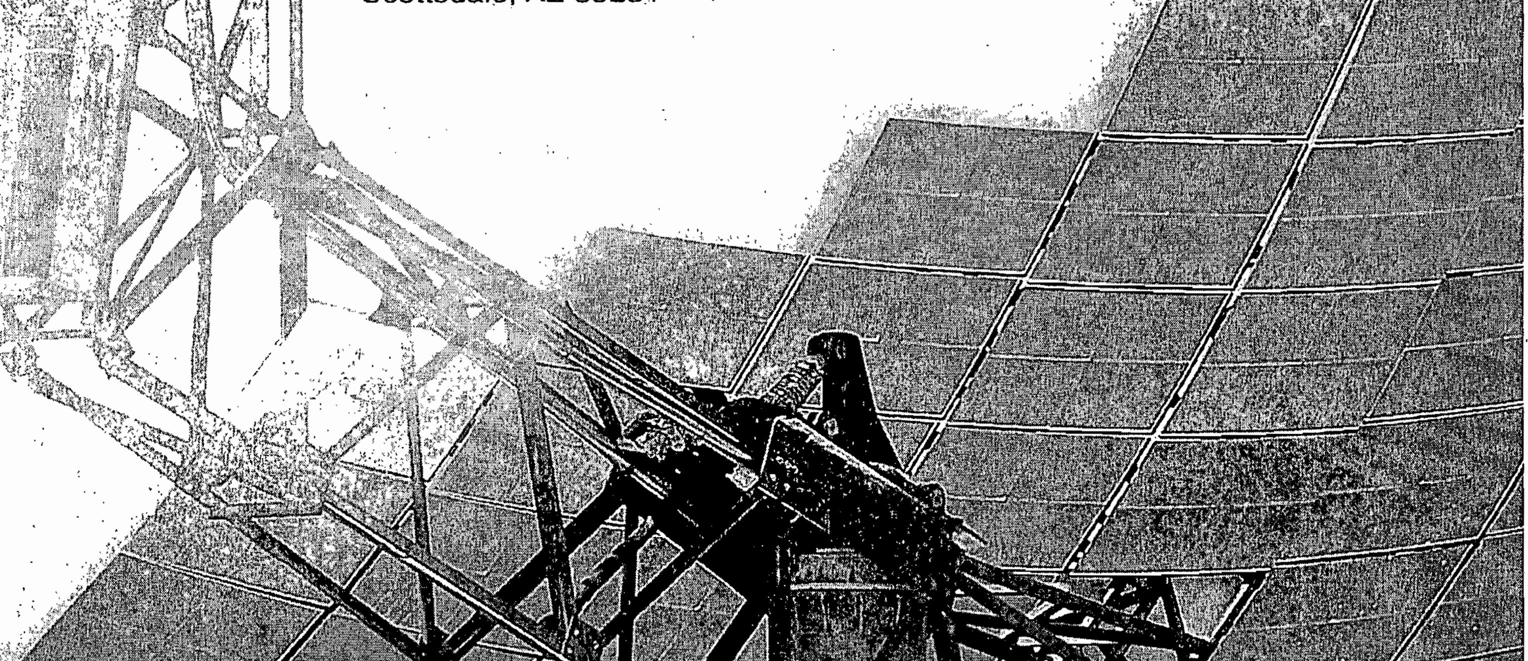
Submitted to:
Bureau of Land Management
2601 Barstow Road
Barstow, CA 92311

Submitted to:
California Energy Commission
1516 9th Street, MS 15
Sacramento, CA 95814-5504

Submitted by:
SES Solar Three, LLC
SES Solar Six, LLC

SES

Stirling Energy Systems
4800 N. Scottsdale Road, Suite 5500
Scottsdale, AZ 85251



Tessera Solar™
power from stirling energy systems

December 4, 2009

Mr. Christopher Meyer
CEC Project Manager
Attn: Docket No. 08-AFC-13
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814-5512

Mr. Jim Stobaugh
BLM Project Manager
Attn: Docket No. 08-AFC-13
Bureau of Land Management
P.O. Box 12000
Reno, NV 89520

RE: SES Solar One Project
Applicant's Responses to Defenders of Wildlife Data Requests Set 1 (Data Requests 1-11)
Applicant's Responses to Basin and Range Watch Data Requests Set 1 (Data Requests 1-3)

Dear Mr. Meyer and Mr. Stobaugh:

Tessera Solar hereby submits the Applicant's responses to Defenders of Wildlife Data Requests Set 1 (Data Requests 1-11) and Basin and Range Watch Data Requests Set 1 (Data Requests 1-3).

20 CCR 1716 (e) specifies that "all requests shall be submitted no later than 180 days from the date the Commission determines an application is complete,. . ." The Commission determined this application to be complete on May 6, 2009, well over 180 days ago. Despite the fact that these requests have been filed out of time, the Applicant voluntarily agrees to respond to these data requests. However, the Applicant will not perform the geologic study which would respond to Basin and Range Watch Data Request 3, as this information is not readily available and would require a detailed study. (20 CCR 1716 (b)).

The Applicant has now agreed to respond to three separate data requests made by Basin Range Watch, Defenders of Wildlife, and CURE, all made after the 180 day limit. Henceforth, the Applicant will not respond to further requests for information without a persuasive showing of need for the information on the part of the requesting party, or an order from the Assigned Committee of Commissioners.

I certify under penalty of perjury that the foregoing is true, correct, and complete to the best of my knowledge.

Sincerely,

Camille Champion
Project Manager

TECHNICAL AREA: BIOLOGICAL RESOURCES

Data Request 1: Please identify all past, present and future foreseeable projects that may have cumulatively significant effects on desert tortoise and bighorn sheep migration corridors.

Response: The need for connectivity between conserved habitats for specific species is dependent on the sustainability of the conserved populations. For example, the 1994 tortoise recovery plan determined that conserved tortoise populations within a 500 – 1000 square-mile area would be sustainable from both demographic and genetic concerns. By establishing eight tortoise conservation areas exceeding this size, the need for connectivity between these conserved populations is reduced. Occasional translocations between these areas would be a benefit, but not a necessity. The potential connectivity routes between tortoise conservation areas in the vicinity of the Solar One Project occur west of the Project area.

Big Horn Sheep (BHS) are distributed among the geographically distinct higher elevation areas located throughout the desert and herds function as semi-independent subpopulations within a larger metapopulation. Adjacent herds occasionally exchange individuals. Herds are isolated by distance from more distant herds. The Cady Mountains herd is connected to herds located east and north of Interstate 40. Exchange with herds south of Interstate 40 appears to be limited (Epps et al. 2007). The cumulative effect on BHS movement would be an issue if future projects were approved within the BHS movement corridor between the Cady Mountains herd and herds east and north of Interstate 40. BLM has designated nearly continuous areas as wilderness areas (Cady Mountains, Kelso Dunes, and Bristol Mountains) that would allow for BHS exchange between herds.

TECHNICAL AREA: BIOLOGICAL RESOURCES

Data Request 2: Please identify the methodology for assessing cumulative effects on desert tortoise and bighorn sheep migration corridors.

Response: Epps et al. 2007 indicate that BHS movement occurs east of the Cady Mountains and north of Interstate 40 (please see the figure provided within this response). Projects proposed in this movement area could potentially impact BHS movement. The winter range of the Cady Mountains herd includes the Pisgah ACEC. Any potential BHS movements south of Interstate 40 would be associated with this BHS use area. Establishment of new herds through translocation between existing herds would enhance metapopulation function through inter-herd exchange of individuals. The Solar One Project is located west of potential BHS movement areas and would not impact BHS movement routes.

No desert tortoise movement corridors have been identified by the wildlife agencies. Potential connectivity areas via tortoise suitable habitat between designated tortoise conservation areas occur west of the Solar One Project site (please see attachment BIO-1, located behind this response).

References Cited:

Epps et al. 2007. *Journal of Applied Ecology* **44**:714–724

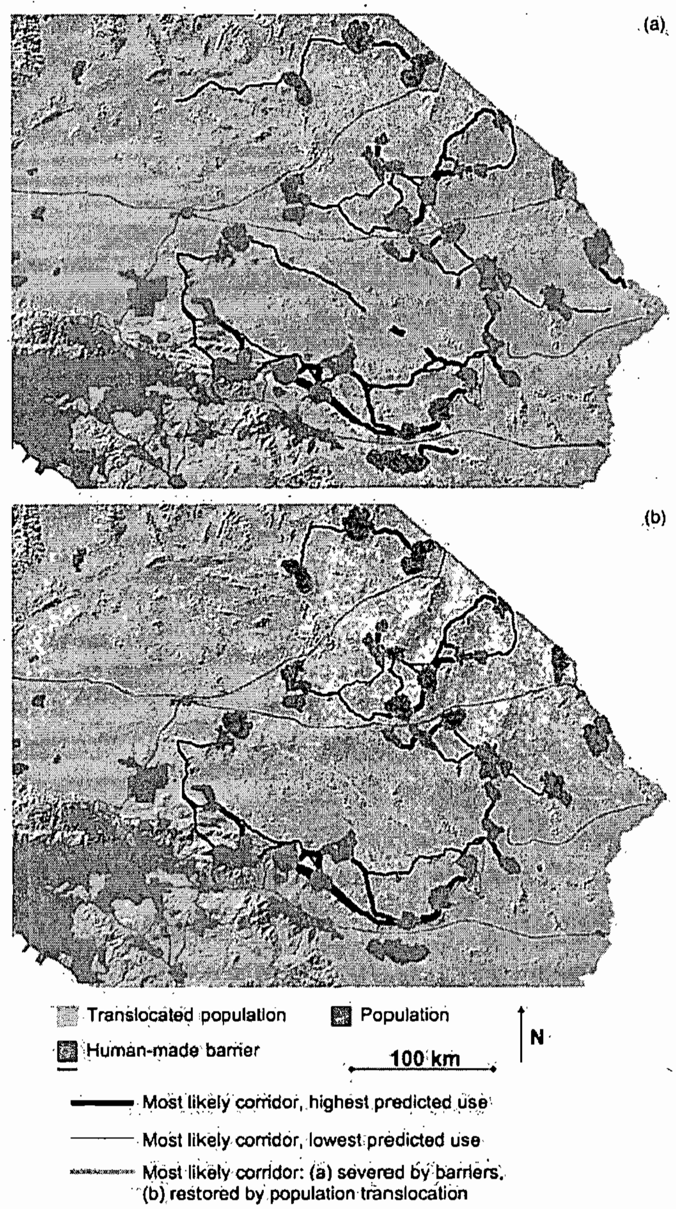
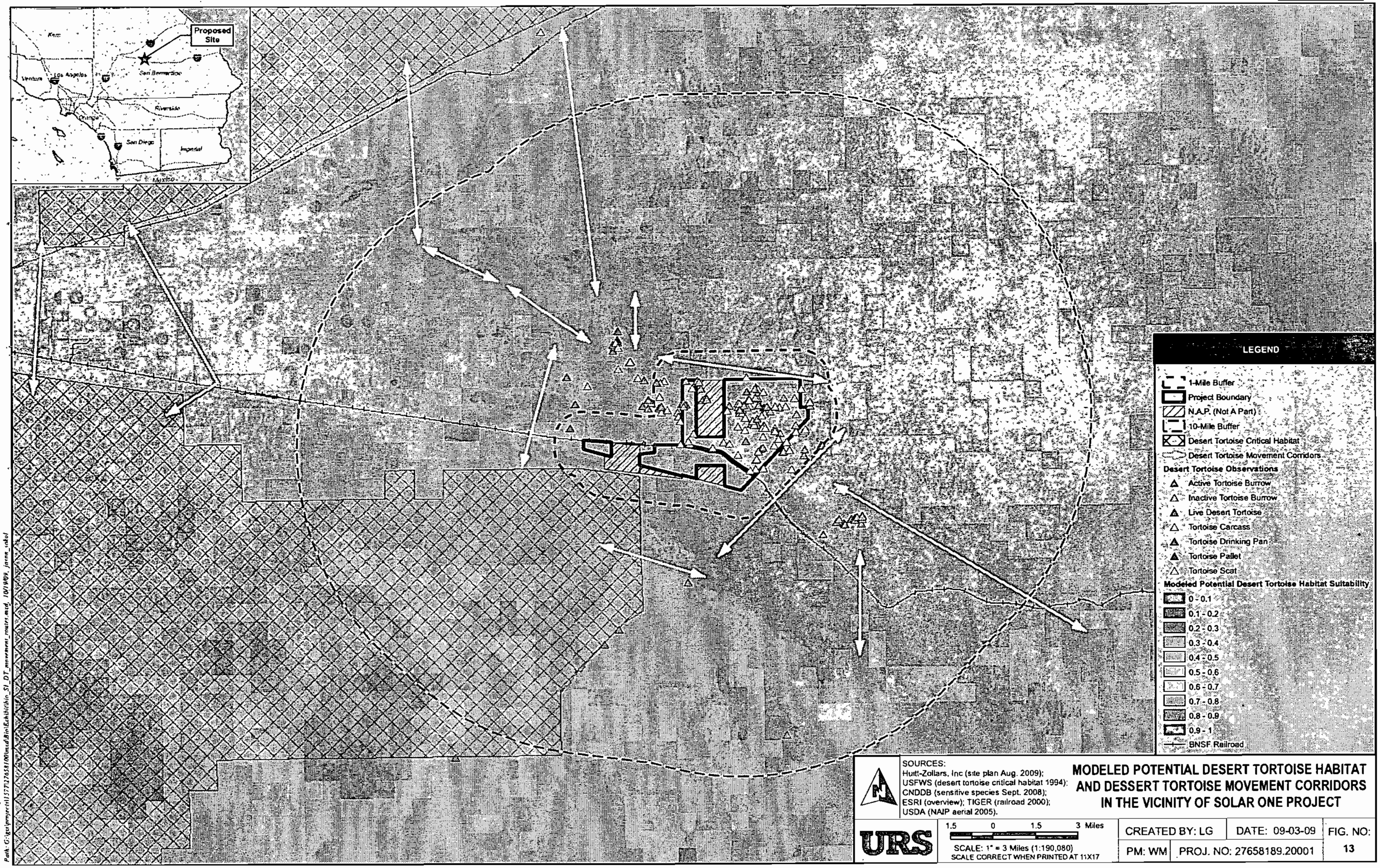


Fig. 4. Dispersal corridors predicted by the best-fitting dispersal model (1.5/0:10) and the HM population model, depicted with hill-shade topography. Black lines indicate least-costly corridor routes for corridors with cost < EGD_{MAX}, yellow lines indicate least-costly corridor routes that (a) were severed by anthropogenic barriers; or (b) were re-established by translocated populations. Corridors are presented based on (a) all extant populations within the study area, with and without current anthropogenic barriers considered; and (b) extant populations with and without those successfully re-established by translocation, with current anthropogenic barriers considered.

From Epps et al. 2007 *Journal of Applied Ecology* **44**:714–724

BIO-1



SOURCES:
Hutt-Zollars, Inc (site plan Aug. 2009);
USFWS (desert tortoise critical habitat 1994);
CNDDB (sensitive species Sept. 2008);
ESRI (overview); TIGER (railroad 2000);
USDA (NAIP aerial 2005).

MODELED POTENTIAL DESERT TORTOISE HABITAT AND DESSERT TORTOISE MOVEMENT CORRIDORS IN THE VICINITY OF SOLAR ONE PROJECT

URS

CREATED BY: LG	DATE: 09-03-09	FIG. NO:
PM: WM	PROJ. NO: 27658189.20001	13

TECHNICAL AREA: BIOLOGICAL RESOURCES

Data Request 3: Based on data in the UCSB Study indicating that development of the Pisgah CREZ results in connectivity being shifted large distances (on the order of >50 km), please provide an assessment of impacts to desert tortoise and bighorn sheep movement corridors from the Project.

Response: Large segments of the Pisgah CREZ are proposed as only Transmission Line or wind energy projects. These linear segments are tens of kilometers long that would allow for wildlife movement past any solar project sited in the vicinity. Large areas are designated as BLM conserved lands (ACECs, DWMA, wilderness areas) and military lands that are managed in a way that would allow for continued wildlife movement. Wildlife connectivity would not be shifted large distances due to solar energy projects so long as future siting takes this issue into account.

Technical concerns about the UCSB assessment are provided below:

- Transmission Lines and Wind Energy projects do not affect wildlife movement. Large segments of solely transmission line development, or proposed wind energy projects will allow for wildlife movement past solar energy projects.
- Siting of solar projects outside of designated conservation areas (ACECs, DWMAs, wilderness areas, and designated Critical Habitat) will allow for regional wildlife movement between conserved habitat areas.
- Tortoise Recovery Plan and West Mojave Plan did not identify the need to connect conserved tortoise habitat areas due to their large size and they support self-sustaining populations.
- Extensive areas of additional tortoise habitat occur on State, military, and National Park Service Lands that are managed with tortoise as a key species of concern. These additional tortoise areas are not considered in the UCSB assessment.
- Cady Mountains BHS herd is connected to herds located east and north of Interstate 40. No existing connection to BHS herds south of Interstate 40 has been identified.
- Climate change effects on BHS habitat will be minimal due to this species' preference for high elevation habitats. BHS metapopulation configuration limits exchange to between nearest neighbor herds (isolation by distance).

TECHNICAL AREA: BIOLOGICAL RESOURCES

Data Request 4: Please identify the incremental contribution of the Project to cumulative impacts, including a total build-out scenario of the Pisgah CREZ.

Response: The Solar One Project would contribute about 8,230 acres of habitat loss, but this impact is being mitigated offsite per the West Mojave Plan and CDFG 2081 requirements. Existing conserved lands east and north of the site provide for continued wildlife movement through the Project vicinity.

TECHNICAL AREA: BIOLOGICAL RESOURCES

Data Request 5: Please identify the mitigation measures that will be implemented for cumulatively significant impacts of the Project on biological resources in a total build-out scenario of the Pisgah CREZ.

Response: The Project site is located in an appropriate area and is consistent with the West Mojave Plan and the Desert Tortoise Recovery Plan. BLM has accounted for cumulative impacts in their West Mojave Plan, and this Project tiers off of that Plan. The Project's contribution to cumulative impacts is incremental and roughly proportional to the Project size. The Project location avoids key areas of biological concern (ACECs, DWMAs, wilderness study areas, and designated critical habitat). Consistent with the West Mojave Plan, additional lands offsite will be conserved to benefit sensitive biological resources.

TECHNICAL AREA: ALTERNATIVES

Data Request 6: Please identify the methodology used in locating alternative sites.

Response: The methodology used in locating suitable alternative sites for this Project was consistent with the evaluation criteria established in the AFC. The Applicant developed the criteria listed below to evaluate the suitability of sites for solar power development. These screening criteria were used to evaluate the potential alternative sites and select the site for the Project.

Solarity: The site needed to be located in an area with long hours of sunlight (low cloudiness). Ideally, insolation, the rate of delivery of direct solar radiation per unit of horizontal surface, levels would be at least seven kilowatt-hours per square meter per day. Solar intensity was the most important screening criteria from a perspective of selecting general regions in California for development of the Project.

Topography: The site needed to be relatively flat; site grade may be up to five percent. Topography, combined with wind speed, represents the second most critical site selection criteria for a Project of this nature.

Wind Speed: The wind speed needed to be less than 35 miles per hour 98 percent of the time.

Land Area: There should be sufficient land area to accommodate a minimum number of acres of solar generation.

Site Control: The land needed to be available for sale or use (e.g., lease or use of an ROW). If private land, the landowner must be willing to negotiate a long-term option agreement so that site control does not require a large capital investment until the license is obtained.

Proximity to Infrastructure: The site needed to be located in close proximity to high-voltage CAISO transmission lines with adequate capacity. Ideally, the site should be located within 10 miles of existing transmission lines and should have an adequate water supply.

Accessibility: The site should have ease of access; close proximity to access roads and railroads is preferred.

Environmental Sensitivity: The site had to be located outside of environmentally excluded areas (such as State and National Parks, areas of critical environmental concern) should have few or no environmentally sensitive resources (particularly biological and cultural resources) and should allow development with minimal environmental impacts.

Jurisdictional Issues: The proposed use should be consistent with existing laws, ordinances, regulations, and standards (LORS).

Land Cost: The site should be located on property currently available at a reasonable cost.

TECHNICAL AREA: ALTERNATIVES

Data Request 7: Please identify the methodology used to assess the environmental impacts of alternative sites.

Response: The Applicant conducted desk-top studies of alternative sites. Data was gathered on the existing conditions of many resource areas, including, but not limited to; biological, cultural, and land use. Results of these studies have been provided in the AFC, Applicant's responses to CEC and BLM Data Requests (most recently as the response to CEC and BLM Data Request 132). Data included CNDDB queries; cultural resources record searches, identification of sensitive land use areas. Additional analysis of each alternative identified will be provided by the Applicant during December, 2009.

TECHNICAL AREA: ALTERNATIVES

Data Request 8: Please identify the methodology used to consider the economic, environmental, social and technological factors involved for each alternative site.

Response: Economic, environmental, social and technological factors were identified that rendered some alternative sites infeasible. These factors were not evaluated for each of the sites, but rather for why each eliminated alternative site was inferior to the selected site. Alternative sites were presented and analyzed for feasibility in comparison with the selected site. Additional analysis of each alternative identified will be provided by the Applicant during December, 2009.

Exhibit 006

Thursday, August 7, 2008 - 2:30 PM

OOS 20-4: Unveiling the mysterious ecology of a rare relict Mojave Desert forb (*Penstemon albomarginatus*): Will ecological knowledge put a damper on exponential growth in Southern Nevada?

Stephen F. Zitzer, Desert Research Institute, James King, Desert Research Institute, and Vic Etyemezian, Desert Research Institute.

Background/Question/Methods

Clark County Nevada has proposed building an airport on a site that may adversely impact a local population of a rare relict perennial Mojave Desert forb, White-margined penstemon (*Penstemon albomarginatus*). Isolated populations of approximately 100,000, 4,000, 26,000 and 42,000 plants occur in NE Arizona, S California and Clark and Nye counties Nevada, respectively. However, many hectares of apparently suitable habitat in Nevada are unoccupied. The objectives of our study are to quantify soil physical and chemical properties, climatic conditions, and plant community structure and determine the influence of these variables on the lifecycle of *P. albomarginatus*. Most *P. albomarginatus* populations occur on aeolian sands, between 800 to 100 m elevation and with winter-dominated annual precipitation of 100 and 400 mm. However, in dry years the below ground portions of the plant remain dormant, consequently as much as 75% of the lifecycle of *P. albomarginatus* is spent as a subterranean heterotroph, including continuous intervals longer > 18 months. We selected penstemon and control sites in Clark County and Nye County in May 2007 and installed sediment transport measuring instruments, a series of soil moisture probes and meteorological data recording instruments and collected soil samples to 70 cm depth in summer 2007. Community structures (canopy heights and areas of all perennial plant species) were measured in 5x50 m transects. Growth, survival, reproduction, and recruitment of all penstemon in these transects are being documented October 2007 through April 2010. Potential root parasitism will also be determined.

Results/Conclusions

Control and penstemon sites had similar community structure, dominated by a deciduous shrub (*Ambrosia dumosa*) and/or a perennial grass (*Pleuraphis rigida*). Precipitation drives timing and amount of aboveground primary productivity and reproductive output, but only site-specific climate data is useful for predicting either. During any year, a population in full bloom may be less than 10 km distant from another population that is surviving only as underground dormant roots or seeds. Consequently, a difficult to measure fraction of *P. albomarginatus* genetic diversity remains buried for perhaps six or more years, based on 40 % germination of 6-year-old seed stored air-dried at room temperature. Soil electrical conductivity, phosphorus, ammonium and nitrate levels were significantly greater in the top 5 cm of control site soils. Understanding heterogeneous deposition patterns of soluble salts and nitrogen may be critical for defining appropriate unoccupied habitat and maintaining the management status of *P. albomarginatus* as rare, instead of threatened or endangered.

See more of OOS 20 - Shake-up in Timing in Ecological Communities: Understanding the Complexity and the Role of Citizen Science
See more of Organized Oral Session

See more of The 93rd ESA Annual Meeting (August 3 -- August 8, 2008)

Exhibit
L607

WHITE-MARGINED BEARDTONGUE
Penstemon albomarginatus M.E. Jones

Author: Pamela J. MacKay, Department of Biology, Victor Valley College, 18422 Bear Valley Road, Victorville, CA 92392-9699

Management Status: Federal: USFWS Species of Concern
California: S1.2, G2 (CDFG, 1998)
CNPS: List 1B, R-E-D code 3-2-2 (Skinner and Pavlik, 1994)

General Distribution:

White-margined beardtongue occurs in southern Nevada, western Arizona, and in the western Mojave Desert in San Bernardino County, California. It distribution in the western Mojave is restricted, occurring in a large four-mile long wash near Pisgah Crater and Lavic Lake, extending southwest from Sleeping Beauty Peak, crossing Interstate 40, and terminating in a flat spreading basin south of the freeway (CDFG, 1997b; Scogin, 1989). Plants are also found in another wash extending south southeast from the same peak for a shorter distance, not all the way to Interstate 40 at Argos, and at Lavic, north of Lavic Lake along Lavic Road (CDFG, 1997b). In western Arizona it is scattered over a plain that extends westward from the Hualapai Mountains, covering an area of approximately 100 square miles between Yucca and Dutch Flat (Button, 1991; Kearney and Peebles, 1964). There are also fifteen populations in southern Nevada, twelve from Clark County and three from Nye County.

Distribution in the West Mojave Planning Area:

All of the California occurrences described above occur within the WMPA.

Natural History:

White-margined beardtongue is an herbaceous perennial plant in the figwort family, (Scrophulariaceae). The stems arise from a 12-48 in (30-120 cm) long taproot that is sunk deep in sandy soil, with the crown just above soil level. Stems reach heights of 6-12 in. (1.5-3 cm), are glaucous and glabrous, and bear entire spatulate leaves that are 0.4-1.2 in. (1-3 cm) long. These petioled, glossy, green leaves have entire margins, which are white and scarious, giving this plant its name of "white-margined" beardtongue. Flower calyces are also white-margined with narrow lance-shaped lobes, and are 0.1-0.2 in. (3-5 mm) long. The corolla is pink to lavender or white, tubular with spreading lobes, and glaucous except the hairy floor. The anthers are spread flat, and the staminode is glabrous (Hickman, 1993; Munz, 1974).

Flowers bloom from March to May (Munz, 1974), and the flowering does not always appear to be dependent on amount of rainfall. It is believed that established plants may bloom even in very dry years by utilizing water and food resources in the large taproot (Scogin, 1989). However, rainfall probably affects seedling germination and survival (Scogin, 1989), and in the California population, seedlings are more numerous south of the Interstate 40 where they most likely receive more accumulated rainfall runoff (Scogin, 1989). The showy flowers are visited by several insects, including small carabid beetles, large flies, and vespid wasps with orange abdomens. Pollen was observed on upper body surfaces of the vespids, making them the most likely pollinator (Scogin, 1989). An attempt was made to determine self-compatibility in this species by exclusion of insect vectors with wire mesh, but the mesh was removed during the study, and no conclusions could be drawn. Observations of very isolated plants that set seed suggests self-compatibility, and the pollen-ovule ratio approaches that of many facultatively out-crossing species (Scogin, 1989). The absence of this species in other drainages nearby might suggest that the seeds are not dispersed long distances, but more likely may be due to the fact that suitable stabilized deep sand habitat is not available at these other sites. The small seeds could possibly be scattered short distances by ants or rodents, or may get transported down the wash by water in very wet years. The tendency for plants to occur in scattered groups of up to 20 individuals, and the fact that young cuttings have been shown to produce adventitious roots in experiments at Rancho Santa Ana Botanic Garden (Scogin, 1989) suggest that vegetative reproduction may occur in this species in its natural habitat, even though attempts to propagate from cuttings at the garden failed (Scogin 1989). Genetic studies of clusters in the field could determine if each group was clonal.

Habitat Requirements:

In California, this plant occurs in fine alluvial sand in a wide canyon within a creosote bush scrub community . The sand is deep and stabilized, holding the long taproot in place. It is also present in wind-blown sand at the head of the canyon. It occurs at elevations from 2000-3000 ft. (700-1000 m.) in alkaline soil (Scogin, 1989). In Nevada, the plants prefer the base of hills and mountains in wind-blown sand dune-like areas, but are also found in deep loose sand in wash bottoms. In Arizona, it occurs in sandy loam uplands and sandy washes in a broad alluvial plain, but gravelly areas alternating with and interspersed with the sandy places do not support this species.

Population Status:

The location in California near Pisgah Crater probably constitutes a single extended population consisting of more than 450 plants spread out along a four mile long wash and sandy basin (Scogin, 1989). Population estimates are not available for the population at Lavic. In 1993, Bransfield and Rutherford found at least 200 plants along benches and terraces adjacent to the easternmost drainage in which plants were previously found. These plants also inhabited wind-blown sand deposits at the base of Sleeping Beauty Peak. It is unclear if Bransfield's and Rutherford's survey extends to the north the range previously recorded for this drainage. Arizona's population of white-margined beardtongue is the largest population known, but no total population estimate is available. It lies within a 100 mi^2 alluvial valley west of the Hualapai Mountains. The upper reaches of this valley with highest white-margined beardtongue densities are being purchased by the Bureau of Land Management. Nevada has twelve recently-discovered population in addition to the three that were previously known. Many of these populations have thousands of plants.

Threats Analysis:

In California, a freeway, a powerline, and three pipelines cross the wash in which the white-margined beardtongue occurs. Numerous utility access roads provide a means by which off highway vehicle (OHV) enthusiasts could get their vehicles into the wash. An established plant may survive occasional damage by tires due to the ability to resprout from the taproot (Scogin 1989). However, churning motions from tires could uproot the taproot (Scogin 1989), and it is possible that frequent damage or crushing of above-ground parts could soon use up the reserves in the taproot. It is also likely that seedlings and young plants in loose sand could be completely destroyed by tires. The remote location of the population and the scattered nature of the plants limits the amount of damage from OHVs at present, so it appears that white-margined beardtongue will not likely be extirpated from this area by recreational human activities in the near future. However, with increasing population growth in urban areas, off-road enthusiasts are traveling farther to find recreational opportunities in less crowded areas, so management steps must be taken to limit access to white-margined beardtongue habitat. The Mannix tank trail is in use as a corridor for the purpose of tank maneuvering between Twentynine Palms and Fort Irwin military bases (K. Waln, pers. comm., 1997). It runs from Mannix to Hector, and currently does not overlap with the range of this species. However, military units have been observed camping in areas where this species occurs, outside of the military base boundary, and military-issue debris has been observed in the area (Lands and Renewable Resources, 1988). There are currently some mining claims within the species' range, so the plant could have localized disruptions from future mining activities. It has been suggested that these plants might have potential for horticultural production (Button, 1991), but attempts to propagate them from cuttings have been unsuccessful, as have attempts at transplantation (Scogin, 1989). The Bureau of Land Management is attempting to acquire white-margined beardtongue habitat in Arizona. Currently the species' range is a checkerboard of BLM managed land, and land owned by a railroad. The land acquisition plan will allow the BLM to control fewer acres of total white-margined beardtongue habitat, but there will be an increase in the total acreage of BLM controlled habitat with high densities of this species. This area will be fenced to discourage vehicular travel and prevent habitat damage. The lower density habitat will then be in private hands, and will be sold as large rural residential lots. Button (1991) notes that white-margined beardtongue in Arizona readily colonizes areas within its habitat that were previously disturbed but where there is now limited vehicular use, such as pipeline routes. Grazing probably does not impact this species much, since it is found growing next to stock tanks in Arizona. The Nevada populations are mostly in Clark County, clustered near Las Vegas. The human population in Las Vegas is increasing dramatically, so there will probably be increased impacts to the white-margined beardtongue from people seeking outdoor recreational opportunities away from the city.

Biological Standards:

The most important management step that must be taken to insure continued survival of the WMPA population is active management of OHV usage. Recreational and military vehicular access to the wash and sandy basin should be severely restricted.

Constant vehicular travel by OHVs and tanks would most certainly uproot and destroy the plants. Scogin (1989) indicates that there is a parking area off the Interstate 40 frontage road that is heavily used by recreationists and possibly military vehicles. This area has the highest density of white-margined beard-tongue, and he suggests that a barrier be erected there to prevent access.

Monitoring of populations, including seed set, seedling counts, and flowering effort by established plants every year or two will help to indicate population health and fluctuation, establish the importance of effects of weather conditions on population size, and may help indicate if management strategies are successful. More propagation studies should be carried out to determine if seedlings, cuttings, or transplanted plants could be used for mitigation efforts.

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Exhibit 608

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA

In the Matter of the Application of San Diego Gas & Electric Company (U 902-E) for a Certificate of Public Convenience and Necessity for the Sunrise Powerlink Transmission Project	Application 06-08-010 (Filed August 4, 2006)

PHASE I DIRECT TESTIMONY
OF DR. BARRY BUTLER
ON BEHALF OF CONSERVATION GROUPS

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Dated: June 1, 2007

Testimony of Dr. Barry Butler on Dish/Stirling Solar Technology

1. INTRODUCTION

My name is Barry L. Butler, PhD. As more fully outlined in my resume, Appendix A, I have a PhD in Materials Science and am the former vice president and manager of SAIC's Solar Energy Products Division. I joined the Solar Energy Research Institute, the predecessor to the National Renewable Energy Laboratory, in 1978, soon after it began operations. Prior to that time I worked at Sandia National Laboratory specializing in solar optical materials. I wrote the chapter on cooperative solar thermal commercialization activities in the book "Implementation of Solar Thermal Technology" published by MIT Press in 1996. I have written or co-authored over 10 technical papers on all aspects of dish/Stirling solar technology development. I was the president of the Concentrating Solar Power Division of the Solar Energy Industries Association from 1998 to 2002, and I am the owner of Butler Sun Solutions, a firm specializing in the design and sales of solar hot water heating systems.

2. BACKGROUND

San Diego Gas and Electric (SDG&E), a company owned by Sempra Energy, has filed an application to the CPUC claiming a 150 mile, 1000 MW transmission line is needed to import energy into San Diego County to ensure the reliability of the regional transmission system on peak demand days, and has further suggested the transmission line is needed to encourage the development of renewable power in Imperial Valley. SDG&E has signed a power purchase agreement (PPA) with Stirling Energy Systems (SES), Phase I of which is for a 300 MW dish/Stirling array, a total of 12,000 of their 25 kW dish/Stirling systems, in Imperial County that must be delivered in increments between 2008 and 2010, as is stated in the CPCN (p. III-11):

> The Agreement with SES contemplates the purchase by SDG&E of up to 900 MW of new solar related energy from SES in three phases. Phase 1 consists of 300 MW scheduled for delivery in the 2008 to 2010 timeframe. While the first phase will provide 300 MW when all construction is completed, the capacity will be added in increments over the 2008 through 2010 period. Phase 2 project consists of an additional 300 MW in the 2011 to 2012 timeframe. SDG&E also has a right of first refusal for a third phase for another 300 MW phase.

According to the SDG&E, commercial production is expected to begin in 2008. The economic terms of the contract, specifically the $/kwh price that SDG&E will pay SES for the power, is unknown.

There are currently six prototype 25 kW Stirling dishes in operation at Sandia National Laboratory. I have been asked to opine on the reliability and cost of SES dish technology and whether it is feasible or realistic to expect that SES can meet the contract schedule defined by SDG&E.

3. DEVELOPMENT HISTORY OF DISH STIRLING TECHNOLOGY

I co-authored a 2003 paper that includes a brief history of the development of dish Stirling technology.[1] I have excerpted the following summary of dish Stirling technology from that paper.

> Over the last 20 years, eight different Dish-Stirling systems ranging in size from 2 to 50 kW have been built by companies in the United States, Germany, Japan, and Russia. The first of the historical systems, the 25-kW Vanguard system built by ADVANCO in Southern California, achieved a reported world record net solar-to-electric conversion efficiency of 29.4%. In 1984, two 50-kW Dish-

[1] T. Mancini, P. Heller, B. Butler, B. Osborn, W. Schiel, V. Goldberg, R. Buck, R. Diver, C. Andraka, J. Moreno, *Dish-Stirling Systems: An Overview of Development and Status*, Journal of Solar Energy Engineering, Vol. 125, pp. 135-151, May 2003.

Stirling systems were built, installed, and operated in Riyadh, Saudi Arabia, by Schlaich-Bergermann und Partner of Stuttgart, Germany.

A third Dish-Stirling system was built by McDonnell Douglas Aerospace Corporation (MDAC) in the mid 1980s and, when MDAC discontinued development of the technology, the rights to the system were acquired by the Southern California Edison Company (SCE). SCE operated the system from 1985 to 1988. Stirling Energy Systems (SES) of Phoenix, Arizona, acquired the technology rights and system hardware in 1996 and have continued development of the system. In 1991, Cummins Power Generation, working under costshared agreements with the U.S. Department of Energy and Sandia National Laboratories, started development of two Dish-Stirling systems: a 7-kW system for remote applications and a 25-kW system for grid-connected power generation. Cummins was innovative in its Dish-Stirling systems, incorporating advanced technologies into the designs. . . The two Cummins programs made progress, but were terminated in 1996 when Cummins' parent company, Cummins Engine Company, realigned business along its core area of diesel engine development.

Dish-Stirling systems have demonstrated that they are capable of producing electricity for the grid and for remote power applications. Technology development needs are for low-cost components and systems that can operate unattended at very high levels of reliability.

SES acquired the intellectual and technology rights to the McDonnell Douglas concentrator and the license to manufacture the USAB (now Kockums) 4-95 Stirling engine based power conversion unit (PCU) in 1996.

The (SES) systems are continuously monitored and repaired whenever a problem occurs. Consequently, they have demonstrated excellent availability, greater than 98%, during the most recent 1,000 hr of operation.

I was the SAIC project manager for a dish/Stirling design that was in competition with the SES design. By 2002, SAIC had also demonstrated relatively high availability of the system for periods of time. However, the "mean time between failure" was approximately 40 hours. Major reliability problems with the SAIC Stirling engine included hydrogen leakage through joints and seals, internal engine seal leakage, swashplate actuator stalls, and heater head braze joint hydrogen leaks. That means that on average once every 40 hours a problem of some type required shut down and maintenance. Nearly continuous maintenance was necessary to keep the system "available" to generate electricity. SES has also demonstrated very high availability, though this has been achieved by a program of continuous maintenance. In 2002, SES and SAIC both had dish/Stirling units operating at the University of Nevada – Las Vegas. Power output was greater for SES than SAIC. Both SAIC and SES conducted maintenance on a nearly continuous basis to keep the units available for electricity production.

Dish/Stirling is not cost-competitive with conventional power generation, or other forms of renewable power generation such as wind and solar, at this time. Wind and geothermal are fully commercial renewable energy technologies with a cost of energy of approximately 5¢ US/kWhr each.[2] As noted in the 2003 Journal of Solar Energy Engineering paper I co-authored:[3]

> In the U.S., niche markets for Dish-Stirling power generation depend on federal or state government subsidies, required to close the gap between the current cost of power from these systems (~30¢ US/kWhr) and the price that the market is willing to pay (~6¢ US/kWhr), a difference of 24¢ US/kWhr.
>
> Even at the relatively low production rate of 50 MW/yr (~2,000 25-kW systems or 5,000 10-kW systems) and at an O&M cost of 1–2¢/kWhr, the cost of electricity from Dish-Stirling systems will be 15–20¢/kWhr enabling entry into some village and remote-power markets. As system costs fall and reliability improves, it is reasonable to expect levelized energy costs of less than 10¢

[2] R. Caputo, B. Butler, *Solar 2007: The Use of "Energy Parks" to Balance Renewable Energy in the San Diego Region*, accepted for publication, American Solar Energy Society, 2007 Annual Conference, Cleveland, July 2007.

[3] T. Mancini, P. Heller, B. Butler, B. Osborn, W. Schiel, V. Goldberg, R. Buck, R. Diver, C. Andraka, J. Moreno, *Dish-Stirling Systems: An Overview of Development and Status*, Journal of Solar Energy Engineering, Vol. 125, pp. 135-151, May 2003., p. 139.

US/kWhr, which will expand the markets to distributed generation and demand-side applications.

A "mean time between failure" between 2,000 and 10,000 hours must be proven before dish/Stirling can be incorporated into utility-scale installations.[4] The current "mean time between failure" is a few hundred hours. This means a great deal of time, effort, and money must be spent on maintenance. This drives up the cost of operating a dish/Stirling unit. The commercial viability of the Stirling system is unproven at this time.

4. PILOT INSTALLATION IS NEXT LOGICAL STEP IN DISH/STIRLING DEVELOPMENTAL PROGRESSION

The 1 MW pilot project being developed by SES for SCE is a good example of a necessary and prudent incremental step to ensure all the technical deficiencies in the first generation production model are worked-out before scaling-up to arrays involving many 1,000s of individual dishes. It is also instructive that SCE, a company with extensive experience with dish/Stirling technology and the company that sold the technology to SES, is requiring the successful deployment of a 1 MW pilot project before scaling-up to a utility-scale installation.

SDG&E has no experience with the operation of dish/Stirling technology, and is proposing to go straight from the prototype to a utility-scale installation. Few or none of the benefits of the 1 MW pilot test will be available to SES as it moves to full commercial scale production to satisfy the SDG&E contract(s), as the 1 MW pilot has not yet begun operation and full commercial production must begin in a matter of months if SES hopes

[4] R. Caputo, B. Butler, *Solar 2007: The Use of "Energy Parks" to Balance Renewable Energy in the San Diego Region*, accepted for publication, American Solar Energy Society, 2007 Annual Conference, Cleveland, July 2007.

to meet the 2010 deadline established in the SDG&E contract. This is neither prudent nor possible unless the technical risks of the operation and maintenance are quantified and then apportioned between the federal government, investors, SES and SDG&E. The SCE 1MW project is the way to quantify the risks, before moving to 10MW then on to 100MW. Without these risks quantified and apportioned, investors who are willing to shoulder all of the risks for a meager reward must be found.

5. DISH/STIRLING IS A PRE-COMMERCIAL TECHNOLOGY

The San Diego Regional Renewable Energy Study Group addressed dish/Stirling in its August 2005 *Potential for Renewable Energy in the San Diego Region*.[5] Several of the co-authors of this report are SDG&E staff. Dish/Stirling is identified as pre-commercial in this study, based primarily on analyses conducted by the National Renewable Energy Laboratory and Black & Veatch.

I concur with this assessment in the *Potential for Renewable Energy in the San Diego Region*. My opinion is that dish/Stirling technology holds much promise. By 2020, the technology could be a significant player on a commercial scale in the concentrated solar power category. However, there is no possible way that dish/Stirling solar can move from high cost prototype models with substantive reliability concerns to large-scale production of high reliability low-cost commercial models by 2008 and full operation of a 12,000 dish, 300 MW array by the end of 2010. An entire step wise development 1MW, 10MW, 100MW with installed cost, reliability and operation & maintenance costs assessed over a year of operation at each step is necessary to move from current prototypes to the large-scale commercial plants contemplated in the power purchase agreements between SDG&E and SES.

I declare under penalty of perjury this testimony and attachment are, to the best of my knowledge, true and correct.

Signed: Barry L. Butler Date: 5/31/2007

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[5] San Diego Regional Renewable Energy Study Group, *Potential for Renewable Energy in the San Diego Region,* August 2005 (www.renewablesg.org).

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Dish-Stirling Systems: An Overview of Development and Status

Dish-Stirling systems have demonstrated the highest efficiency of any solar power generation system by converting nearly 30% of direct-normal incident solar radiation into electricity after accounting for parasitic power losses [1]. These high-performance, solar power systems have been in development for two decades with the primary focus in recent years on reducing the capital and operating costs of systems. Even though the systems currently cost about $10,000 US/kW installed, major cost reduction will occur with mass production and further development of the systems. Substantial progress has been made to improve reliability, thereby reducing the operating and maintenance costs of the systems. As capital costs drop to about $3000 US/kW, promising market opportunities appear to be developing in green power and distributed generation markets in the southwestern United States and in Europe. In this paper, we review the current status of four Dish-Stirling systems that are being developed for commercial markets and present system specifications and review system performance and cost data. We also review the economics, capital cost, operating and maintenance costs, and the emerging markets for Dish-Stirling systems. [DOI: 10.1115/1.1562634]

1 Introduction

With restructuring of utility markets, the emergence of green-power markets, and the increased worldwide demand for distributed generation, the opportunities for small power systems ranging in size from a few kW to several MW are increasing at a rapid rate. This increased demand is largely being met by existing internal combustion and gas-turbine power generators, but it is also the motivation for new technology development such as micro-turbines, fuel cells, and other alternative power generators. One solar power generation system that is targeted for application in these emerging markets is Dish-Stirling technology. In fact, Dish-Stirling systems are being deployed in pre-commercial applications and as demonstration systems at locations in the U.S. and Europe.

Solar thermal power systems, which are also sometimes referred to as concentrating solar power systems, utilize the heat

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†Contributing author.
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generated by concentrating and absorbing the sun's energy to drive a heat engine/generator and produce electric power. Three generic solar thermal systems, power tower, trough, and dish-engine systems, are capable of producing power [2]. Trough systems use linear parabolic concentrators to focus sunlight along the focal lines of the collectors. In a power tower system, a field of two-axis tracking mirrors, called heliostats, reflects the solar energy onto a receiver that is mounted on top of a centrally-located tower. Dish-engine systems, the third type of solar thermal system, comprise a parabolic dish concentrator, a thermal receiver, and a heat engine/generator located at the focus of the dish to generate power.

Of the three solar thermal technologies, trough-electric systems are the most mature, 354 MW are installed in the Mojave Desert of Southern California [3], and the first commercial power towers are currently being designed for installation in Spain [4]. Dish-Stirling Systems, which are the least developed of the three technologies, are being deployed as demonstration units and some pre-commercial plants are in the planning stages [5]. Trough systems produce about 75 suns concentration and operate at temperatures of about 400°C at an annual efficiency of about 10%. Power towers operate at a concentration of about 800 suns, produce temperatures of about 560°C and have annual efficiencies of about 15%. Dish-Stirling systems have demonstrated the highest efficiency of any large solar power technology, producing more than 3000 suns concentration, and operating at temperatures of 750°C at annual efficiencies of 23% [6,7].

Dish-Stirling systems track the sun and focus solar energy into a cavity receiver where it is absorbed and transferred to a heat engine/generator. Figure 1 is a representation of a Dish Stirling System with the major system components, the dish, the power conversion unit (PCU), etc. identified. Although a Brayton engine has been tested on a dish [8] and some companies are considering adapting micro-turbine technology to dish engine systems, kinematic Stirling engines are currently being used in the four Dish-Stirling Systems being developed today. Stirling engines are preferred for these systems because of their high efficiencies (thermal-to-mechanical efficiencies in excess of 40% have been reported), high power density (40–70 kW/liter for solar engines), and potential for long-term, low-maintenance operation. Dish-Stirling systems are modular, i.e., each system is a self-contained power generator, allowing their assembly into plants ranging in size from a few kilowatts to tens of megawatts. The near-term markets identified by the developers of these systems include remote power, water pumping, grid-connected power in developing countries, and end-of-line power conditioning applications.

In the following sections, we describe some of the background of Dish-Stirling Systems and present design and performance details for the four pre-commercial, prototype systems, currently being developed in the U.S. and Germany. We also present some of the details about advanced components under development for dish systems. Last, we present an overview of the current and potential cost of electricity from Dish-Stirling technology and the emerging markets for solar dish power generation systems.

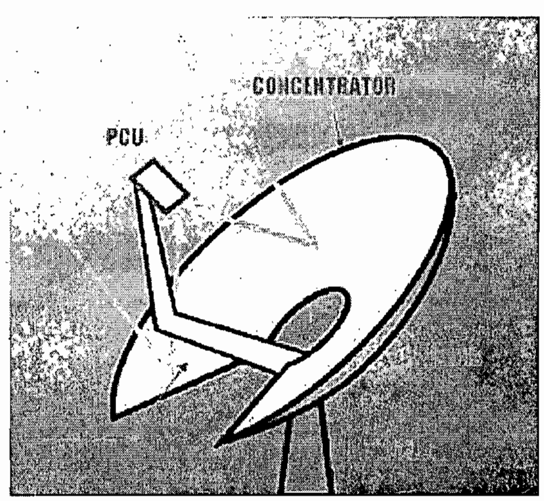

Fig. 1 Dish Stirling system components

II Background of Dish-Stirling Systems

Over the last 20 years, eight different Dish-Stirling systems ranging in size from 2 to 50 kW have been built by companies in the United States, Germany, Japan, and Russia [7]. In this section of the paper, we present detailed background information that directly pertains to the four systems under development today The first of the historical systems, the 25-kW Vanguard system built by ADVANCO in Southern California, achieved a reported world record net solar-to-electric conversion efficiency of 29.4% [1]. The Vanguard Dish-Stirling system utilized a glass-faceted dish 10.5 m in diameter, a direct insolation receiver (DIR), and a United Stirling 4-95 Mark II kinematic Stirling engine. In 1984, two 50-kW Dish-Stirling systems were built, installed, and operated in Riyadh, Saudi Arabia, by Schlaich-Bergermann und Partner (SBP) of Stuttgart, Germany [9]. The dishes were 17-m dia, stretched-membrane concentrators, formed by drawing a vacuum in the plenum space formed by the dish rim and front and back steel membranes. The optical surface of the dish was made by bonding glass tiles to the front membrane. The receivers for the SBP dishes were DIRs and the engines were United Stirling 4-275 kinematic Stirling engines.

A third Dish-Stirling system was built by McDonnell Douglas Aerospace Corporation (MDAC) in the mid 1980s and, when MDAC discontinued development of the technology, the rights to the system were acquired by the Southern California Edison Company (SCE) [10,11]. The parts for eight systems were built, and three systems were tested in the early 1980s. The MDAC/SCE dish was the first Dish-Stirling system designed to be a commercial product. It built on the design of the Vanguard Dish-Stirling system, using the same DIR and the USAB 4-95 Mark II engine. SCE operated the system from 1985 to 1988. Stirling Energy Systems (SES) of Phoenix, Arizona, acquired the technology rights and system hardware in 1996 and have continued development of the system.

In 1989, the Schlaich Bergermann und Partner built their first 7.5-m stretched membrane concentrator equipped with a SOLO V160 Stirling engine. First, in polar tracking configuration and later in an azimuth/elevation tracking configuration, the systems were operated for more than 30,000 hr on sun.

In 1991, Cummins Power Generation, working under cost-shared agreements with the U.S. Department of Energy and Sandia National Laboratories, started development of two Dish-Stirling systems—a 7-kW system for remote applications and a 25-kW system for grid-connected power generation [12,13]. Cummins was innovative in its Dish-Stirling systems, incorporating advanced technologies into the designs, such as: a solar concentrator with a polar-axis drive and polymer, stretched-membrane facets, heat-pipe receivers, and free-piston Stirling engines. The heat-pipe receiver transfers the absorbed solar heat to the engine by evaporating sodium and condensing it on the tubes of the engine heater head. The receiver serves as a thermal buffer between the concentrator and the engine, and because it transfers heat to the engine by condensation, it allows the engine to operate at a high average temperature and efficiency [14,15]. The two Cummins programs made progress, but were terminated in 1996 when Cummins' parent company, Cummins Engine Company, realigned business along its core area of diesel engine development. The assets of the Cummins solar operations were sold to Kombassan, a holding company in Alanya, Turkey.

Dish-Stirling systems have demonstrated that they are capable of producing electricity for the grid and for remote power appli-

Table 1 Definitions of specifications and terms listed in Table 2

Concentrator	The solar concentrator is the system component that tracks the sun, collects the solar energy, and focuses it into the thermal receiver.
Type	All of these concentrators have reflective surfaces made from individual pieces of highly reflective glass. The dishes may comprise many facets arranged in such a manner as to approximate a paraboloidal shape (approximate) or the facets may be laid out and contoured so that the dish shape is intended to be a paraboloid of revolution (paraboloid).
No. of Facets	The total number of distinguishable facets, not the number of glass pieces that comprise the dish.
Glass Area (m^2)	The total glass area on the surface of the dish.
Proj. Area (m^2)	The total glass area projected in the plane of the collector aperture.
Reflectivity	The new, clean reflectivity of the glass as measured in a standard laboratory.
Height (m)	The distance from the ground to the highest point on the collector when it is oriented at its highest profile position, generally when facing the horizon.
Width (m)	The maximum width presented by the collector.
Weight (kg)	The weight of the collector, including the pedestal, support structure, glass, drives, and PCU support.
Tracking Control	The control methodology for the collector. An open-loop control tracks by aiming the collector at the sun's calculated position in the sky. A closed-loop control measures a parameter at the collector or receiver (usually solar energy or temperature) and tracks the collector in response to the measured variable.
Focal Length (m)	The measured focal length of the solar collector.
Intercept Factor	The fraction of the solar energy collected that is reflected through the receiver aperture. This is based on actual, clear day measurements.
Peak Conc (suns)	Measured peak concentration of the collector normalize to DNI of 1000 W/m^2.
Power Conversion Unit	The power conversion unit (PCU) comprises the receiver, the engine, and the generator.
Aperture Dia. (cm)	The receiver aperture diameter.
Engine Manf/Type	Engine manufacturer and type of engine.
No. of Cylinders	Number of cylinders.
Displacement (cc)	Total displacement of the engine.
Op Speed (rpm)	Engine operating speed.
Working Fluid	Engine working fluid.
Power Control	Means by which the engine output is controlled in response to the changing solar input.
Generator	Type of generator used in the system.
System Information	The following system information is actual, measured performance (indicated by bold letters) or system performance estimates (indicated by normal italics type.)
No. Systems Built	The total number of complete systems that have been built and operated.
On-Sun Op (hrs)	The total number of on-sun and hybrid operational hours for the systems listed above.
System Rating (kW)	The system nameplate rating.
Peak Net Output (kW)	Peak, net measured system output for a minimum of 5 minutes of continuous operation and normalized to a DNI of 1000 W/m^2, clean mirrors, and at an ambient temperature of 288°K.
Peak Net Effic (%)	Peak, net measured system efficiency for a minimum of 5 minutes of continuous operation and normalized to a DNI of 1000 W/m^2, clean mirrors, and at an ambient temperature of 288°K.
Ann Net Effic (%)	Annual, net efficiency estimate based on the reported performance curves and reported operating wind speeds calculated using TMY2 data for Albuquerque, NM, USA. Assumes 100% availability.
Annual Energy Production (kWhrs)	Predicted annual performance in Albuquerque, NM, USA, based on TMY2 data, the measured system performance curves, specifications for wind speed, and an assumed availability of 90%.

cations. Technology development needs are for low-cost components and systems that can operate unattended at very high levels of reliability. Current efforts are focused on establishing reliability and, through break-and-repair approaches, identifying the components that require improvement, redesign, and replacement. In a parallel approach, advanced components, such a heat-pipe receivers, controls, and optical surfaces, that promise higher reliability and lower cost are being designed and tested.

III Descriptions of Dish-Stirling Systems

In this section, we present descriptions of the four Dish-Stirling systems that are currently being developed for commercial applications. For each system, we provide a photograph of the system, background information on the system, descriptions of the system components, and a paragraph describing the corporate business development plans. Table 1 lists the parameters and detailed descriptions of the specifications and performance parameters listed in Table 2. The information presented in Table 2 is system information collected through February 2002 that has been documented by test and measurement. In those cases where information is not available, the corresponding table entry has been left blank.

There are a number of parameters that are similar for the four systems including: tracking (all four systems utilize elevation-over-azimuth tracking approaches) all systems use direct-illumination receivers (DIR); cooling systems (the fan/radiator type, similar to automotive cooling systems); lubrication systems (which use motor oil); and the operating temperature range for the receivers (700–750°C).

SAIC/STM SunDish System

Background. Science Applications International Corp. (SAIC) and STM Power, Inc. have been developing a Dish-Stirling power system for utility applications since November 1993. The development of the SunDish system followed many years of separate development of the stretched-membrane solar concentrator by SAIC and the development of the kinematic Stirling engine by STM. After testing an initial prototype system in 1995 [16], a second-generation Dish-Stirling system was designed and four systems were tested starting in 1997. Major features of the second-generation system included the following: face-down stow to protect mirrors and keep them cleaner; staggered facet arrangement to reduce wind loads; increased mirror area to increase power output; upgraded dish control system; non-pressurized engine crank case to reduce cost; gearbox between engine and generator to increase system capacity; and hybrid (fuel) operation capability for electricity dispatchability and enhanced energy pro-

Table 2 Comparative specifications and performance parameters for DS systems

Concentrator	SAIC/STM System	SBP System	SES System	WGA (Mod 1) ADDS System	WGA (Mod 2) Remote System
Type	Approximate	Paraboloid	Approximate	Paraboloid	Paraboloid
No. of Facets	16	12	82	32	24
Glass Area (m^2)	117.2	60	91.0	42.9	42.9
Proj. Area (m^2)	113.5	56.7	87.7	41.2	41.2
Reflectivity	0.95	0.94	0.91	0.94	0.94
Height (m)	15.0	10.1	11.9	8.8	8.8
Width (m)	14.8	10.4	11.3	8.8	8.8
Weight (kg)	8172	3980	6760	2864	2481
Track Control	Open/Closed Loop	Open Loop	Open Loop	Open/Closed Loop	Open/Closed Loop
Focal Length (m)	12.0	4.5	7.45	5.45	5.45
Intercept Factor	0.90	0.93	0.97	0.99+	0.99+
Peak C R (suns)	2500	12,730	7500	>11,000	>13,000
Power Conv. Unit	**SAIC/STM**	**SBP**	**SES**	**WGA ADDS**	**WGA Remote**
Aperture Dia. (cm)	38	15	20	14	14
Engine Manf/Type	STM 4-120 double acting kinematic	SOLO 161 kinematic	Kockums/SES 4-95 kinematic	SOLO 161 kinematic	SOLO 161 kinematic
No. of Cylinders	4	2	4	2	2
Displacement (cc)	480 cc	160 cc	380 cc	160 cc	160 cc
Op Speed (rpm)	2200	1500	1800	1800	800–1890
Working Fluid	hydrogen	helium	hydrogen	hydrogen	hydrogen
Power Control	Variable Stroke	Variable Pressure	Variable Pressure	Variable Pressure	Variable Pressure
Generator	3 φ/480v/Induct	3 φ/480v/Induc	3 φ/480v/Induct	3 φ/480v/Induc	3 φ/480v/synch
System Information	**SAIC/STM**	**SBP**	**SES**	**WGA ADDS**	**WGA Remote**
No. Systems Built	5	11	5	1	1
On-Sun Op (hrs)	6360	40,000	25,050	4000	400
Rated Output (kW)	22	10	25	9.5	8[1]
Peak Output (kW)	22.9	8.5	25.3	11.0	8
Peak Efficiency Net	20%	19%[2]	29.4%	24.5%	22.5%
Ann Efficiency Net	14.5%	15.7%	24.6%	18.9%	N/A[3]
Ann Energy (kWhrs)	36,609	20,252	48,129	17,353	N/A

[1]The Mod 2 ADDS drives a conventional submersible water pump. The test pump is undersized for the output of the system. Therefore, mirror covers are used to limit output to the pump capacity.

[2]The SBP system peak efficiency is calculated at its design point of 800 W/m^2. All other system efficiencies are calculated at their design points of 1000 W/m^2.

[3]The Mod 2 system has not operated for 1000 h.

duction [17]. Figure 2 is a photograph of the SunDish Dish-Stirling system, which is installed at the Salt River Project near Phoenix, Arizona.

Four second-generation systems are operating today. System 1, fielded in April 1998 at the Pentagon in Washington, DC, was moved in January 1999 to the Arizona Public Service Solar Test and Research (APS STAR) site. At the Pentagon, the system operated at half power due to poor optical beam quality resulting from structural deflections. This issue was addressed prior to installing the system at the APS STAR site, where the dish ran on solar energy and in the hybrid mode on natural gas and hydrogen. System 2 was fielded in October 1998 at Golden, Colorado. It is used to evaluate beam optical quality and the changes in beam quality that can occur with time. This dish is in use today as a test bed for engine performance and alternative converter testing. System 3 was fielded in July 1999 at the STAR site and moved to the University of Nevada Las Vegas (UNLV) test site in August 2001 in preparation for a 1-MW Dish-Stirling project in Nevada. System 4 was fielded in September 1999 at the Salt River Project-Pima-Maricopa Indian Community Landfill site and was configured to run on solar energy during the day and landfill gas when solar is not available. The major components of the system are described in the following section. Details of the system design and performance are listed in Table 2.

System Components. There are four major system components: the dish, the thermal receiver, the Stirling engine, and the system controls.

The dish concentrator (Fig. 2) consists of 16 round, stretched-membrane mirror facets, each 3.2 m dia, mounted on a truss structure that attaches to an azimuth/elevation drive on top of a pedestal. The facets are attached in a staggered manner, with some facets on the front and some on the back of the structure, to increase the porosity of the dish and reduce wind loads. The engine support arm articulates at the hub to allow the system to move to a face-down position for stow, keeping the engine near ground level for ease of access for maintenance.

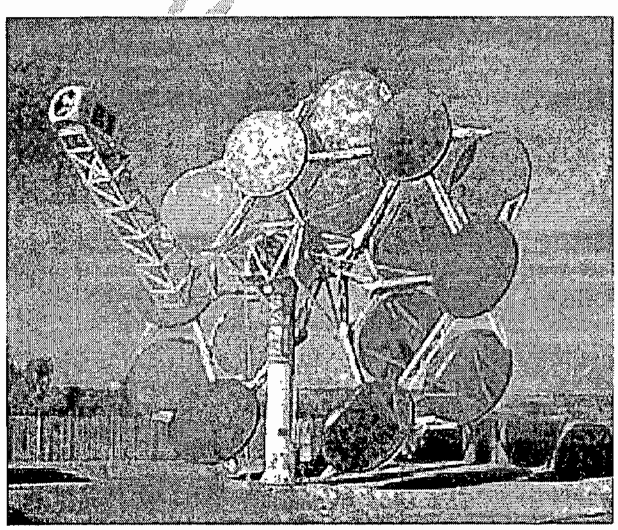

Fig. 2 SAIC system at the Salt River Project near Phoenix, Arizona

The receiver consists of a cavity containing a direct-insolation heater head in the shape of a truncated cone. The heater head is divided into four spiral-shaped quadrants, each feeding one cylinder of the engine and composed of a bank of small, parallel tubes. Burners for hybrid operation are located immediately behind the tube banks; a shutter/plug door closes over the cavity aperture to reduce thermal losses and allow recuperation of the exhaust gases when operating in the hybrid mode.

The engine is the STM 4-120, four-cylinder, kinematic Stirling engine shown in Fig. 3. Each cylinder is attached to one heater-head quadrant that contains a double-acting piston. The four cylinders are arranged in a square pattern with the pistons moving axially. The connecting rods actuate against a swashplate, which both converts the axial motion of the pistons into rotary motion, and by varying the angle of the swashplate, effects engine stroke control output power from the engine. The engine runs nominally at 2,200 rpm and drives a standard induction motor/generator through a gear reduction drive at 1800 rpm. Heat rejection from the engine is provided by a water/glycol cooling system that uses standard radiators and a cooling fan. The engine has a separate controller that communicates with the concentrator controller.

The system is controlled by a micro-processor-based control system. Operator commands are entered through a central control computer that can be located locally or remotely from the system. When enabled by the operator, the system automatically tracks the sun, switches between solar and fuel inputs, stows itself at night and during high winds, and reacts appropriately to fault conditions as required. The control system also includes data logging and heater-head temperature balance for concentrator tracking adjustment.

Performance. The system waterfall chart, which shows the performance of each system component as power flows through the system, is shown in Fig. 4. The first vertical bar in Fig. 4 shows the total amount of solar energy falling on the dish. Each successive bar shows the losses associated with the following sequential transfers of solar energy and heat into electrical power: the reflectivity of the glass, intercept of the reflected solar beam, absorption of solar beam in the receiver, conversion of the heat in the Stirling engine, efficiency of the electrical generator, and last system parasitic power requirements to operate controls, pumps, fans, etc. SAIC and SES currently have two systems operating at UNLV that are demonstrating about the same power output as a function of insolation.

The solar-to-net-electric energy conversion efficiency of the system has been measured at 20% and the peak power output 22.9 kW [17,18]. The estimated system annual performance, which is based on the system performance curve of Fig. 5, TMY2 direct-normal solar radiation data for Albuquerque, New Mexico, is 36,609 kWhrs with an availability of 90% and an annual efficiency of 14.5%. This estimate, which is also made for the other systems reported in this paper, represents an upper bound on the annual performance of the system since it does not include down time due to problems with the system or transients associated with startup and variable weather conditions.

Over the course of the program, SunDish systems logged over 5,800 hr of solar operation, delivering 63,574 kWh of electrical energy to the grid. The systems also accumulated over 600 hr of hybrid operation on natural gas, delivering 6,622 kWh. The system performance curve, shown in Fig. 5, is a plot of the net, measured power output as a function of the direct-normal insolation (DNI) level. The scatter of the data in this figure and others like it presented later in this paper is caused by solar and thermal transients experienced during start up and normal operation, dirty mirrors, etc. The SunDish system is rated at 22 kW at 1000-W/m^2 insolation. A number of system changes aimed at improving performance have been identified, but not yet developed or implemented. These include increasing the area of the dish by about 25%, increasing the temperature of operation of the receiver, and increasing the optical performance of the concentrator by changing the facet design and optical contour.

Systems operation has demonstrated periods of relatively high availability, on the order of 88%. However, annual availabilities are far short of the long-term goals of 95–98%. Current mean time between failure for the SunDish system is about 40 hr. System incidents that require operator intervention include major events associated with the dish and engine, but also include faults due to sensors, controls, computer programming, communication, and wiring. Problems with sensors, such as thermocouples and connectors, caused over 80% of the system faults recorded for these systems. This instrumentation is for detailed monitoring of the system and will not be installed on a commercial system. Major system faults in the engine are due to hydrogen leakage through joints and seals, internal engine seal leakage, swashplate actuator stalls, and heater head braze joint hydrogen leaks. The most significant problems with the dish are due to optical alignment instability, facet focus control, drive wear and tracking, and limit switch and control problems. Improving the dish focal image

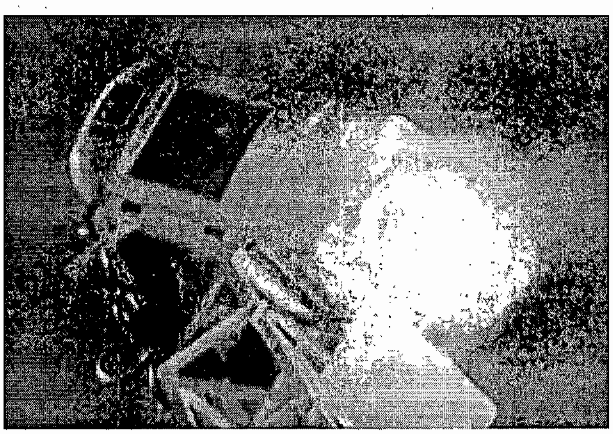

Fig. 3 STM Power engine during on-sun operation

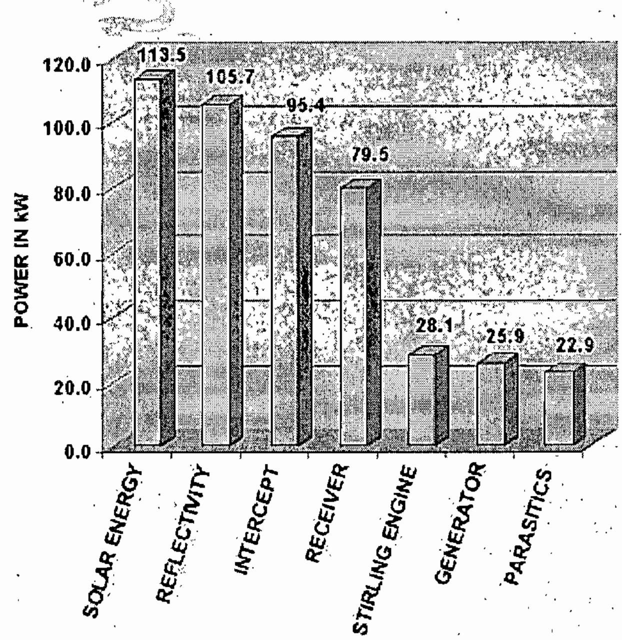

Fig. 4 SAIC system waterfall chart

to smooth and balance the flux on the heater heads is currently being pursued and should dramatically reduce stresses on the engine resulting in improved system availability.

Corporate Business Development Plan. SAIC and STM Power, Inc., and utility team members Arizona Public Service and Salt River Project intend to follow two key strategies to enter the power sales market. First, to support a U.S. National Energy Plan that encourages the use of solar energy and, second, to deploy the systems needed to achieve and verify the system reliability and to address customer-side of the meter power markets.

SAIC and STM Power believe that there is a clear value proposition for Dish-Stirling systems, once systems costs have been lowered to $2000 US/kW. However, they also see market-driven sales at costs as high as $4000 US/kW. The remote market is currently available to photovoltaic systems, which have very high reliability. Markets like these will not be available to Dish-Stirling systems until high levels of reliability are achieved.

In the U.S., niche markets for Dish-Stirling power generation depend on federal or state government subsidies, required to close the gap between the current cost of power from these systems (~30¢ US/kWhr) and the price that the market is willing to pay (6¢ US/kWhr), a difference of 24¢ US/kWhr. State or national Portfolio standards, pollution abatement credits, renewable energy investment tax credits, and/or renewable energy production credits are all needed to help close this gap. The two biggest barriers to the deployment of Dish-Stirling systems are the cost of money and the ability to sell the power through a long-term contract. No-interest or low-interest federally guaranteed loans are an essential part of the strategy to reduce the cost of energy from these systems and take them into the commercial marketplace.

Schlaich-Bergermann und Partner EuroDish.

Background. The EuroDish project is a joint-venture project between the European Community, German/Spanish Industries (SBP, MERO, Klein+Stekl, Inabensa), and research institutions Deutsches Zentrum für Luft- und Raumfahrt (DLR, Germany) and Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT, Spain) [19]. The project, which is headed by Schlaich Bergermann und Partner (SBP), is directed at developing a small series of production prototype systems. EuroDish is the successor to two previous generations of Dish-Stirling systems, the Distal I and II systems [20,21]. The new design replaces the stretched-membrane concentrator used in Distal I and II with a glass-fiber composite shell onto which glass mirrors are bonded with an adhesive. The engine used in the EuroDish is the next-generation SOLO Kleinmotoren 161. Two new 10 kW EuroDish units, shown in Fig. 6, were installed at the Plataforma Solar de Almeria (PSA), Spain, early in 2001 for test and demonstration purposes. Details on the system designs and performance are listed in Table 2.

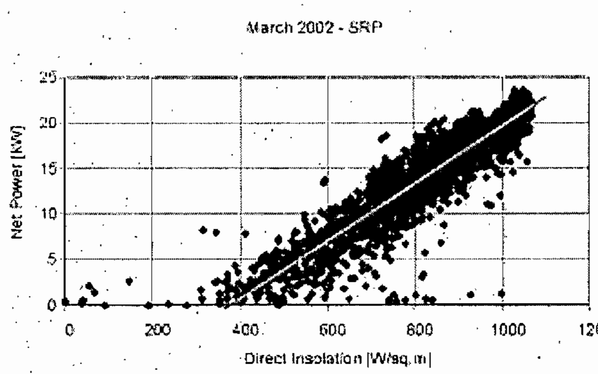

Fig. 5 SAIC system net power output versus direct normal insolation

System Components. The concentrator consists of a thin shell, glass-fiber-reinforced resin sandwich with the mirrors applied to its surface that is supported by a space frame ring truss. Similar to the stretched-membrane designs, the 8.5-m diameter concentrator obtains high stiffness and low deadweight by profiting from the advantageous load bearing behavior of a shell structure. To simplify shipping the concentrator, the shell is divided into 12 identical segments that fit into a standard container for assembly at the site. Based on a detailed structural analysis of the shell and ring truss for both dead weight and wind loads, the resulting sandwich cross section comprises 20 mm of foam and two 1-mm reinforced plastic layers stiffened with a radial rib along the center line. The system is designed to maintain full performance up to wind speeds of 10 m/s with a minor reduction in output power for wind speeds up to 15 m/s. The concentrator is suspended on a space frame turntable rolling on six wheels, similar to previous generation designs. The drive arcs are equipped with simple pre-stressed roller chains. The drive units were redesigned to use standard steel rollers, spur gears and low cost servomotors.

The receiver is at the back of the water cooled cavity and is directly attached to the cylinder heads of the Stirling engine. Its 78 tubes are made from high-temperature steel, 3-mm outer diameter, and their ends are vacuum brazed to manifolds attached to the engine heater head. The receiver tubes absorb the concentrated solar radiation, heating the helium working gas to approximately 650°C. The full load on the receiver is reached at insolation levels of approximately 800 W/m^2. At higher insolation levels, a speed-controlled cooling fan maintains the upper temperature limit at the absorber to avoid overheating the receiver and overpowering engine. Even though this results in increased heat losses from the system at high solar radiation conditions, this is a strategy to increase the annual full-load hours on the system.

The Stirling engine used in this system is the SOLO 161, based on the V-160 engine originally developed by USAB, Sweden, and further developed by SOLO Kleinmotoren GmbH, Sindelfingen. The engine, shown in Fig. 7, is a 90-deg V-type power unit with a swept volume of 160 cm^3 in which helium is the working fluid. The maximum engine working pressure is 150 bars, and the operating gas temperature is 650°C. The engine is mechanically coupled to an induction generator that provides an electrical output of 10 kW at 1500 rpm. The advantages of this engine are its advanced technology and simple, robust construction. The SOLO 161 Stirling engine performance was proved in the DISTAL II units and in the ADDS system at Sandia; and it has demonstrated mature, reliable performance. Consequently, in the EuroDish, only elementary improvements and/or redesign were conducted. These include: joining of the tubes to the manifolds and manifold parts together by vacuum brazing; a new receiver cavity design of a water-cooled aluminum cylinder to address failures due to vibration; and a simplified cooling circuit that uses a single radiator instead of four as in the previous engine design.

The EuroDish control concept allows for fully automatic system operation. Its kernel is a control PC running under Windows NT, located in the operations room or locally in a cabinet at the

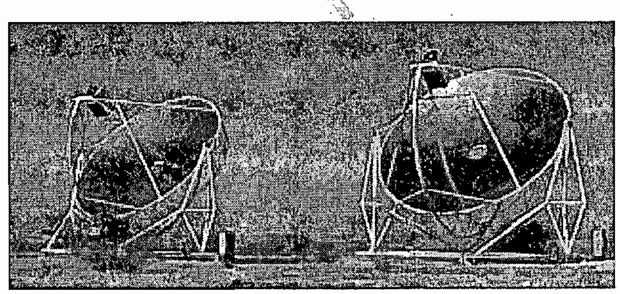

Fig. 6 Two 10-kW SBP Eurodish prototypes at Plataforma Solar de Almeria, Spain

dish, which communicates with up to 16 Dish-Stirling systems through a rugged industrial field bus. The sun position is calculated by the PC control software, obtaining exact time from a GPS receiver or an internet time server. Positioning commands are then sent to the drive control in the local cabinet at each dish. To reduce the number of discrete components in the control cabinet, a so-called motion controller was developed. The motion controller is a microprocessor board located in the cabinet at each dish whose main function is to carry out the positioning commands from the control PC. It is equipped with a field-bus interface to the control PC, to the servo motor controllers for dish the azimuth and elevation drives, and to a manual terminal. Additionally, several other functions were implemented in the upgraded EuroDish controller, including a hardware watchdog and safety de-track functions, manual drive operation, and weather data acquisition.

A new feature, implemented in the EuroDish control system, is the capability for remote access through a web server that will be integrated directly into the control PC in the future. Through the worldwide web, it is now possible to access system status information and online data as well as stored operational data and state and error logs. This enables continuous, operational supervision and preventive maintenance. As a side effect, runtime statistics and selected online data can also be made available to the public online.

Performance. The EuroDish prototypes at PSA were built in 2001 and are still being optimized for performance. The peak solar-to-net-electric energy conversion efficiency of the system is expected to be 21–22%, based on the experiences of former projects with the same engine. The first measurements of peak system efficiency resulted in 20%. The estimated annual performance of a EuroDish system operating in Albuquerque, New Mexico, is the production of 20,252 kWhr of electric energy with an availability of 90% and an annual efficiency of 15.7%.

Additional measurements of one EuroDish system showed improved concentrator performance, that is increased power input to the receiver [19]. The waterfall diagram of Fig. 8 includes this improvement in the receiver efficiency. Because this system is smaller than the SAIC/STM Power and SES systems, its efficiency is slightly lower. The DNI versus net power output of the EuroDish system during a typical operating day is shown in Fig. 9. The plot in Fig. 9 is nonlinear because the system was designed for optimal performance at a DNI level of 800 W/m^2. When the insolation exceeds this level, a fan in the receiver cavity is activated to reject additional heat and maintain the receiver at a fixed temperature. This strategy results in a slight increase in losses at higher insolation levels, but also produces higher annual output from the system. While this may seem counterintuitive, it occurs because the number of operating hours at 800 W/m^2 insolation and below (i.e., at higher efficiency because of the design point) is much greater than the number of hours above 800 W/m^2. In theory, the annual performance from a system could be optimized for a single location, at least in the statistical sense. Pragmatically, this is more a function of how much DNI will be available at the expected locations for which the systems are being designed.

Since the Eurodish prototypes have not been operated for a long time, no reliable number for system availability can be calculated. The systems were operated close to 1000 hr without severe outages, most caused by errors in the control code, electronics or sensor failures. During the last 150 hr, the system operated without intervention except for two restarts after grid power failure and a discharge valve replacement.

SBP and the associated EuroDish industry have performed cost estimates for a yearly production rate of 500 units per year (5 MW/yr) and 5000 units per year, which corresponds to 50 MW/yr. The actual cost of the 10-kW unit without transportation and installation cost and excluding foundation is approximately $10,000 US/kW. The cost projections at production rates of 500 and 5000 units per year are $2,500 US/kW and $1,500 US/kW, respectively.

Corporate Business Development Plan. The two most important issues for commercializing Dish-Stirling systems are cost reduction and system reliability. In addition to ongoing efforts to reduce overall system cost by combining system components, the SBP Team is focused on developing reliable pre-assembled systems, preparing the first pre-production tools, and continuously operating systems under different meteorological and site conditions. Lessons learned and continuous evaluation of system down times will form a sound and reliable data base which is needed to improve system reliability and enable entry into markets.

The European Dish-Stirling Consortium intends to erect as many units as possible at specially selected places in the southern Europe, for example at universities, interested electric utilities, renewable institutes, and local electric authorities within the next two years. With this first step, market showcases and reference systems will help to develop the on-sun operating database needed to provide for further market introductions. In a next step, clustered 0.3–1 MW demonstration plants (30–100 units at one location) are anticipated. This step will help to extend operational experiences and to start the first small series production. These

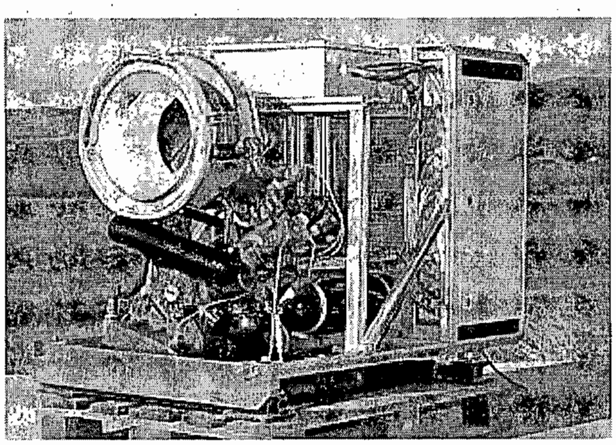

Fig. 7 The 10-kW SOLO 161 engine and receiver

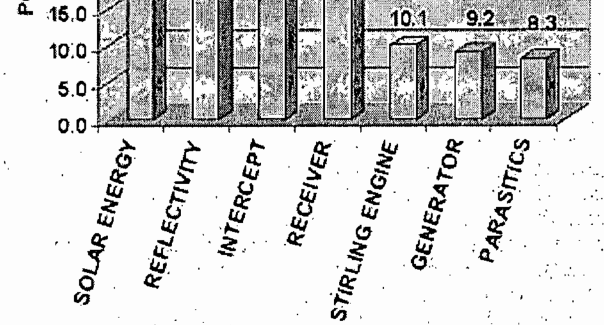

Fig. 8 SBP system waterfall chart

activities will be encouraged by special premiums for solar-electric power, some currently in place and others anticipated in southern Europe.

Stirling Energy Systems' Dish-Stirling System

Background. SES acquired the intellectual and technology rights to the McDonnell Douglas [11] concentrator and the license to manufacture the USAB (now Kockums) 4-95 Stirling engine-based PCU in 1996. At that time, SES initiated a commercialization program to build on the existing solar dish design by improving its manufacturability while continuing to operate the systems and improve the technology. In March 1998, the Dish Engine Critical Components (DECC) Project started with the objective of developing a commercial dish Stirling system. The DECC is a DOE-industry cost-shared project to commercialize the Dish-Stirling system for emerging markets. During Phase 1 of the project, completed in October 1999, its focus was on operating and evaluating the performance of the Stirling engine, the *critical* system component. The main activities were to demonstrate performance and reliability of the engine with primary focus on the internal *hot* parts. DECC Phase II, which started in October 2000 and continues through 2002, is directed at building and testing two complete next-generation systems. As for the two systems previously discussed, the design and performance parameters for the SES system are listed in Table 2.

System Components. Figure 10 is a photograph of two SES systems in operation at the test site at Boeing in Huntington Beach, CA. The SES Dish-Stirling system generates approximately 25 kW of electrical power at a solar insolation of

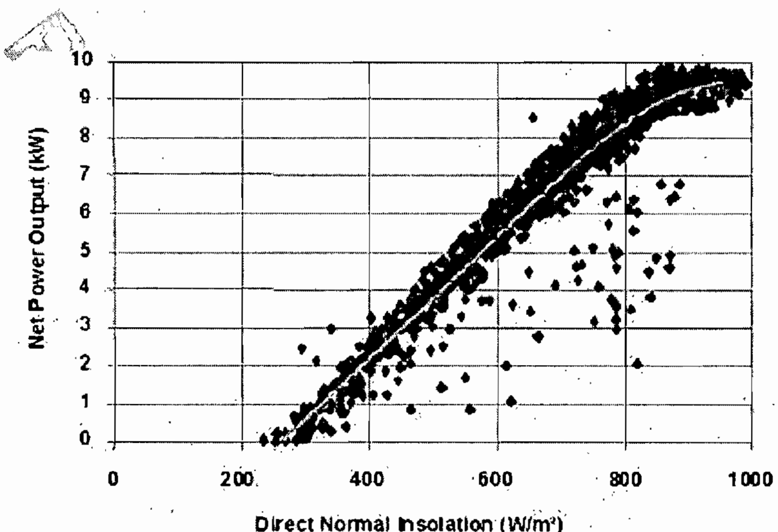

Fig. 9 SBP system net power output versus direct normal insolation

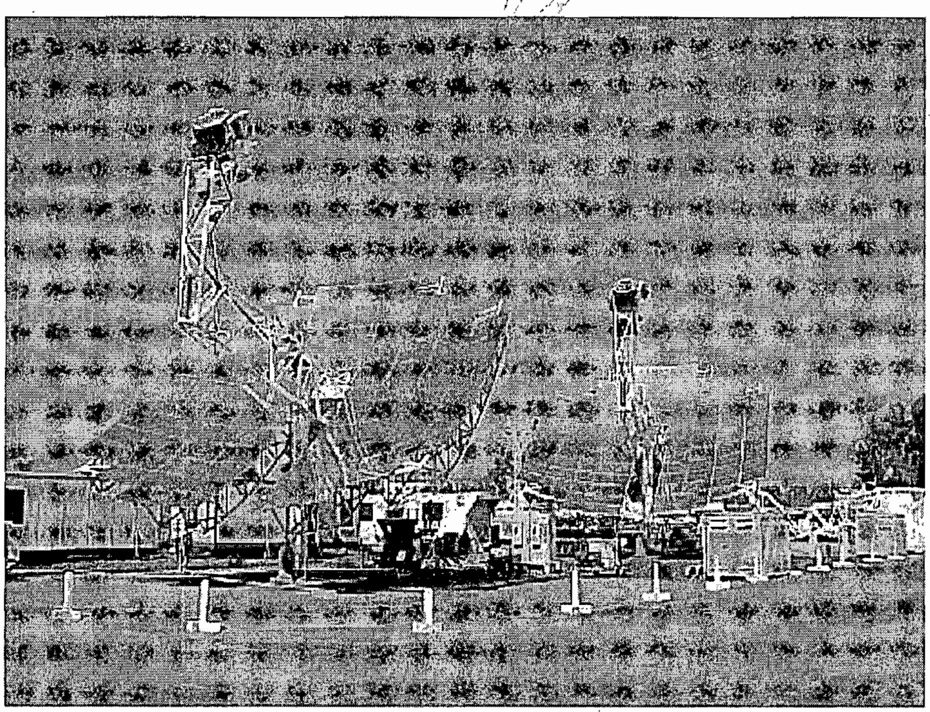

Fig. 10 SES systems on test at Huntington Beach, California

1000 W/m^2. The Kockums 4-95 engine is shown in Fig. 11. The subsystems of the Kockums 4-95 Stirling Power Conversion Unit are: the receiver that transfers the concentrated solar energy to the engine working fluid; the Stirling engine that converts heat into rotational motion of the engine; the electrical generator; a cooling system that rejects waste heat to the ambient air; and the control system that controls and monitors system operation. The basic characteristics of the SES concentrator are listed in Table 2. The main features of the design are a patented balanced design in which the weight of the mirrors offsets the weight of the PCU at the focal point; a slot in the reflective surface that allows the PCU to be lowered to ground level for easy maintenance; and design modularity which allows it to be manufactured in major subassemblies and quickly installed in the field.

Currently, there are four 4-95 Power Conversion Units (PCUs), one in bench testing at Kockums in Malmo, Sweden, and three used on a rotating basis for on-sun operation on two concentrators. Two complete systems are on-sun at the SES/Boeing Solar Test Site in Huntington Beach, CA, one is operating at a test site in Nevada, and components for five more systems are in storage. The first Dish-Stirling module began power generation operation for the DECC Project on June 28, 1998, three different 4-95 Stirling engines have been used with Concentrator No. 1. System Module No. 2 began producing power on February 20, 2000, and testing will continue through DECC Phase II, December 2002.

Performance. The SES Dish-Stirling Systems continue to accumulate both bench and on-sun operating time throughout the DECC Phase II program. Table 2 lists the on-sun operating time for all systems since the start of the DECC program in 1998. An additional 95,101 hr of bench testing of the Kockums 4-95 engine has also been accumulated over this time [22,23]. A peak, on-sun performance of 24.9 kW was achieved on September 6, 2000 with a corresponding 28.8% net system efficiency at direct-normal insolation of 986 W/m^2. This performance is consistent with the net peak electrical power efficiency of 29–30% (at 1000 W/m^2 solar insolation) [10] achieved during the on-sun testing period of 1984-88 at Barstow, California. The estimated annual production for a system operating in Albuquerque, New Mexico, is 48,129 kWhrs of electrical energy at an availability of 90% and an annual efficiency of 24.6%.

The systems are continuously monitored and repaired whenever a problem occurs. Consequently, they have demonstrated excellent availability, greater than 98%, during the most recent 1000 hr of operation. The system waterfall chart from solar energy to net power out is shown in Fig. 12. The numbers shown in the figure are from power measurement data records, system measurements performed at Huntington Beach, California, and from manufacturer's performance specifications for components.

The direct-normal insolation is plotted versus the net power output from the systems for the time period between March and April 2000 in Fig. 13. The results show that at 1000 W/m^2 the Power output is 24.3 kW. The outlying data in Fig. 13 result from dirty mirrors on the concentrating and low pcu performance, which result in reduced system performance and a dirty normal-incidence pyranometer, which results in a lower than actual DNI measurement.

System Cost. Current production costs for the SES Dish-Stirling system are at prototype-scale, a few, hand-built units. Therefore, installed costs are high at about \$10,000 US/kW or \$250,000 US per dish system. These costs are distributed with 40% in the concentrator and controls, 33% in the PCU, and the remaining 27% of the costs in the balance of plant and installation of the system. The SES system is made up of a number of basic components, such as mirrors (glass), mirror backings (stamped steel), structural steel supports (primarily extruded steel tubing), electronic controls (small computer chips), and an engine system with many components that are similar to automotive engines (pistons, crankshafts, engine block, radiator system, fan, water and oil pumps, etc.). Consequently, SES believes that there is substantial potential to reduce the cost of their Dish-Stirling system.

Corporate Business Development Plan. SES is transitioning from a development and test phase to a pre-commercialization phase of operation for its Dish-Stirling technology. Early market efforts have concentrated on developing solar farms (10–100 MW) in the Southwestern U.S. desert areas (particularly in Arizona, Nevada, and southeastern California), and in selected solar-rich international markets. SES is teaming with major companies in Spain, Italy, and South Africa to find ways to enter these markets. SES is also in discussions with major utilities serving the Southwest U.S. to obtain power purchase agreements for peaking power to supplement the power production from conventional power plants. The company's solar products will also help the utilities of Arizona and Nevada to meet renewable energy portfolio standard requirements in effect in these states.

SES projects the majority of its sales will be of equipment to utility companies or independent power producers. They are working with customers to develop projects and to provide on-

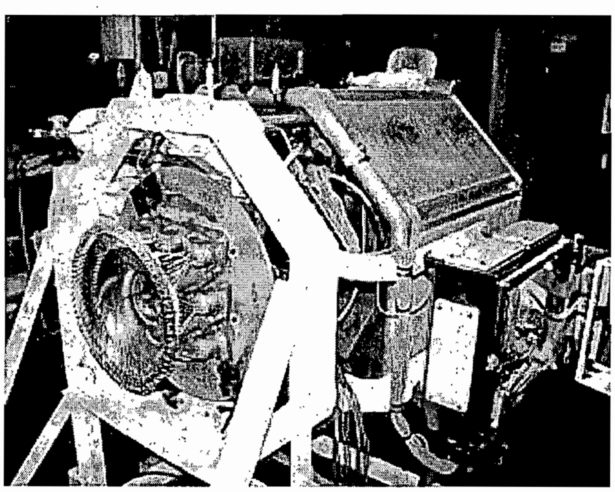

Fig. 11 Kockums 4-95 kinematic Stirling engine

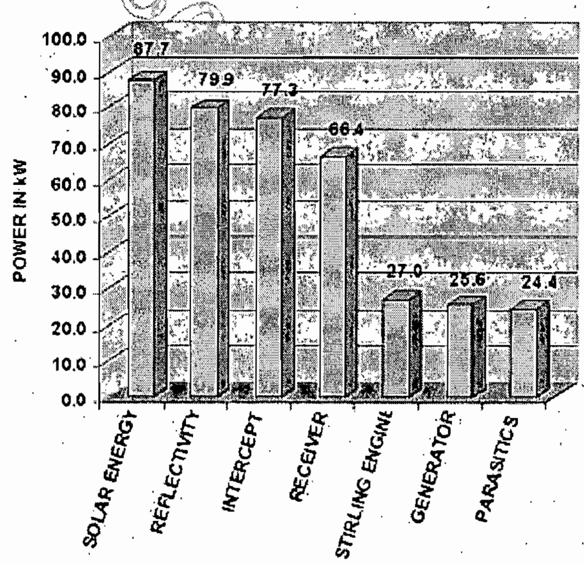

Fig. 12 SES system waterfall chart

going support services to the solar power plants. In foreign countries, SES is considering the licensing of Dish-Stirling marketing rights.

WGAssociates' Advanced Dish Development System

Background. The Advanced Dish Development System (ADDS) project is a direct result of the technology development activities in the Cummins Dish-Stirling Joint Venture Program and the successful experience with the SOLO 161 Stirling engine on a Cummins CPG-460 Concentrator at Ft. Huachuca, Arizona [24]. The project started in October 1998 as a test bed for advanced components and systems-level testing to address the issues of the remote power market. Development activities have focused on extending the application of Dish-Stirling systems to water pumping, reliability improvement, and incorporating advanced components such as structural facets, heat pipe receivers, and advanced controls and communications. Testing includes long-term unattended, automated operation of stand-alone 9.5-kW Dish-Stirling solar power generation systems in both on- and off-grid modes at the National Solar Thermal Test Facility (NSTTF) in Albuquerque. In 1999, the first-generation, grid-connected (Mod 1) system was fielded at the NSTTF and unattended operation initiated. In 2000, an upgraded, second-generation (Mod 2) system design, which includes stand-alone water-pumping capability, was developed. Figure 14 is a photograph of the Mod 1 and Mod 2 systems on test at the test Facility.

System Components. The ADDS design features the WGAssociates (WGA) WGA-500 solar concentrator and controls and the SOLO 161 Stirling power conversion unit (PCU). To address remote power markets, the systems were designed to operate autonomously, for low capital and installation costs, and field-level maintainability. The details for the system specifications and performance of the two ADDS systems are listed in Table 2. Even though they are similar, both sets of parameters are included here because the Mod 2 system is a stand-alone water pumping unit that has some unique features. The waterfall efficiency chart for the Mod 1 is shown in Fig. 15.

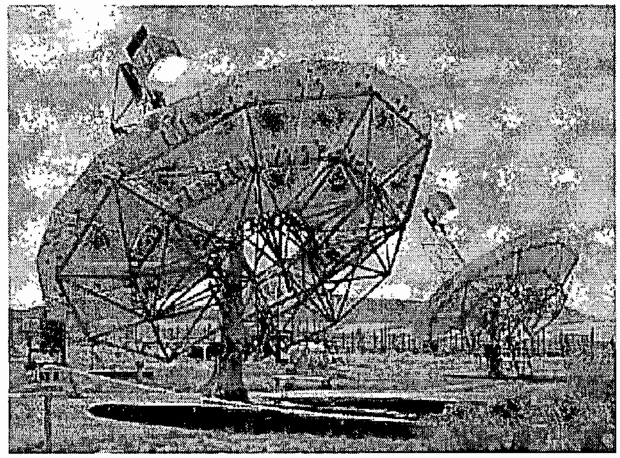

Fig. 14 WGA ADD systems, Mod 1 and Mod2, on test at Sandia's National Solar Thermal Test Facility

The concentrator uses an elevation-over-azimuth tracking space frame dish structure fitted with paraboloidal contoured, trapezoidal shaped, glass-metal mirror facets. The tracking structure is constructed primarily of structurally efficient, thin-wall tubing. The azimuth drive is the field proven, Winsmith planocentric reducer. The Mod 1 elevation drive employs a 10-ton commercial ball screw. To facilitate maintenance of the PCU, it is configured to bring the SOLO 161 PCU below the horizon for access from ladders or from the back of a pick-up truck. The elevation ball screw is powered by a 1750-rpm, $\frac{1}{2}$-hp (373-W) gear-motor through a secondary worm gear reducer, resulting in an average elevation slew speed of about 40 deg/min. Because the system must operate off grid, the Mod 2 Dish-Stirling system is designed with DC drive motors.

The mirror facets are glass/metal structural facets [25]. They

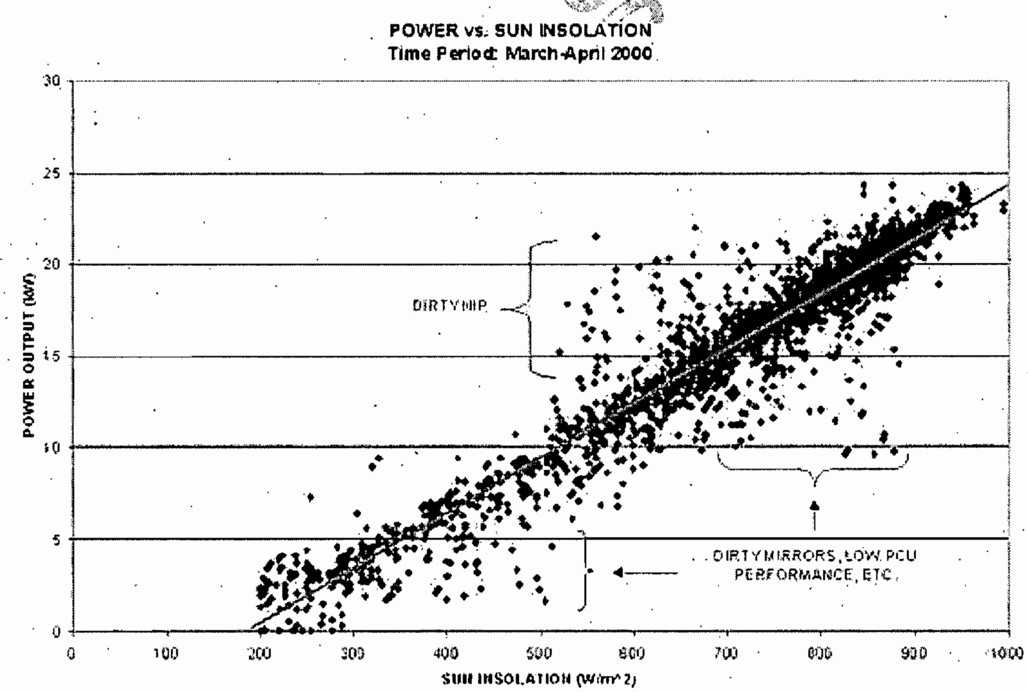

Fig. 13 SES system net power output versus direct normal insolation

utilize a sandwich construction consisting of thin-glass mirrors bonded to a sheet-metal membrane. An aluminum honeycomb is bonded with epoxy between the back of the sheet-metal membrane and a second sheet-metal membrane. The Mod 1 system uses two concentric rows of mirrors, each row consisting of 16 panels. The Mod 2 concentrator utilizes a single row of 24 facets. Facet mounting to the structure is accomplished by the use of three-point mounting studs that facilitate alignment.

The Collector Control System (CCS) used on both ADD systems is an adaptation of one developed by Cummins Power Generation for their two Dish-Stirling systems. This basic control system has over 40,000 hr on-sun tracking and has shown itself to be flexible, robust, and reliable. The CCS provides both control and monitoring of the concentrator and the PCU and provides for autonomous system operation. Sun tracking uses a hybrid approach consisting of both open- and closed-loop tracking. Closed-loop tracking employs four differential-thermocouple sensors equally spaced around the receiver aperture. After a day of closed-loop tracking, algorithms in the tracking program automatically derive seven concentrator misalignment parameters. Once the misalignment parameters are *learned* and applied to the open-loop tracking algorithm, open-loop tracking is close enough to *capture* the focused image.

The control system is configured so that, if the computer *locks up* or otherwise does not respond, the concentrator is driven to stow in elevation to the vertical limit. On the Mod 1 system, the fail-safe system includes a 12-VDC battery and inverter in the event of loss of grid power. The operator has three ways to interface with the CCS: for routine day-to-day operation, a push button control panel is used; when additional system diagnostics are needed, a hand-held terminal can be plugged into the control panel; and, for detailed diagnostics, a computer interface is available. This interface also provides for monitoring and the remote control of the system though an internet connection.

The ADDS system uses a SOLO 161 Power Conversion Unit, which is the same engine used by Schlaich for their Distal and Eurodish systems, shown in Fig. 7. The SOLO 161 engine is being developed by SOLO Kleinmotoren primarily for cogeneration applications. The SOLO 161 utilizes a direct-illumination solar receiver and pressure control of the working fluid to vary

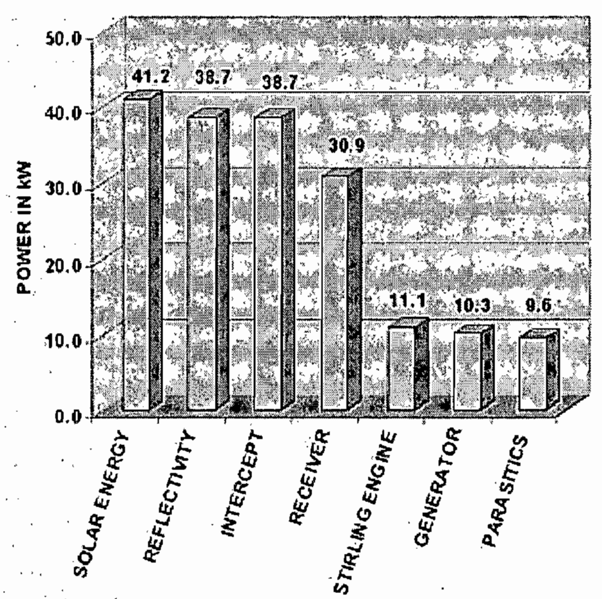

Fig. 15 Waterfall chart for the Mod 1 ADD system. Power and efficiency for the SOLO 161 engine and solar receiver are estimates.

power output. Small working fluid leaks are automatically made up through an external bottle located on the concentrator tracking structure. The Mod 1 PCU uses a 3-phase induction motor/generator to supply 3-phase, 480-V power to the utility grid. This approach provides power for starting the engine and automatically synchronizes voltage and frequency with the utility grid. In the Mod 2 stand-alone system, a synchronous generator is used. In this approach, the generator output varies both in voltage and frequency and directly drives an induction motor and water pump. Because water pumping is a common remote-power need, the Mod 2 design drives a conventional 3-phase 480-V, 7.5 or 10-hp (5.6 or 7.5-kW) submersible water pump. A standard 12-VDC automotive starter is used to start the Mod 2 version of the PCU.

Performance. Testing of the ADDS systems has evolved from concentrator testing early in the project to ongoing system operational, reliability, and performance testing. The Mod 1 system operates automatically and unattended, including weekends and holidays. After the system detects that DNI is within specifications, it tracks to acquire the sun, starts the PCU, and supplies power to the grid. If the anemometer detects high winds, the system automatically drives to stow where it remains until wind speed returns to a safe level for a specified period of time. When clouds are detected (low DNI), the system drives off sun and continues to offset track. When DNI returns to specified levels the system reacquires the sun and starts the PCU. If the sun does not return within a specified time or if the sun elevation falls below a defined angle, typically 2 deg, the concentrator stows. When a fault is detected, the system automatically sends the system to stow and notifies the operator through a pager. In many cases, the operator is able to resolve the problem and resume operation remotely.

Because the SOLO 161 is intended for indoor co-generation applications, helium was initially used as the working fluid. To increase performance, the gas system was converted to accept hydrogen as the working fluid, increasing the system power output from 9 kW to 9.5 kW at 1000 W/m^2, the system rating, even though the concentrator area was reduced by 11% (by covering mirror area) to avoid overpowering the engine. Although system output could have been increased to over 10 kW using the original mirror area, the current specification results in lower engine pressure and longer expected life on the critical Pumping Leningrader (PL) seals. Figure 16 is a scatter plot showing net system power as a function of direct normal solar insolation taken at 1-min intervals on February 6, 2002. The Mod 1 system has demonstrated a peak efficiency of 24.5%. The estimated annual performance for a system operating in Albuquerque is energy production of 17,353 kWhrs at an availability of 90% and an annual efficiency of 18.9%. The Mod 2 ADDS system drives a conventional submersible water pump. The test pump, which is currently being utilized, is undersized for the output of the system, resulting in the peak net output for Mod 2 being less than rated.

Availability and reliability of the ADDS has steadily improved since automated system operation was initiated in November 1999. During the period between January 6, 2000 and October 24, 2000, the Mod 1 system accumulated 1711 on-sun, power-producing hours at times when the insolation was within the system operational specifications, a total of 2369 hr, yielding a gross availability of 72.2%. This availability does not account for periods when the wind exceeded operational limits, and down time for tours, training, and development. [26] In 2001, the data acquisition system was enhanced to accurately record system availability by allowing operators to take "time out" to install and evaluate new features or to take the system off line for tours or other non-operational interruptions. The system also now accounts for low-insolation and high-wind conditions. Since August 1, 2001, availability, which is defined as the time the system produces net positive power divided by the time insolation and wind are within operational specifications, has been about 90%. This availability definition accounts for lost time while the system is slewing to go on sun and while warming up. On days in which the system operates perfectly, availabilities range from the upper 90s% on clear-sky days to less than 50% on mostly cloudy days. Frost and snow significantly impact availability on some days. An availability definition based on lost time from maintenance and faults has been about 94% during the same time period. System mean time between failure (MTBF) has improved along with availability. Data currently indicates a system MTBF of about 250 hr for the Mod 1 ADDS. Most of the down-time incidents are related to controls and are minor in severity.

The WGA ADD system produces up to 11 kW at optimum DNI conditions. It has been field tested for three years and proved to meet present day reliability, availability, and efficiency targets. The system design employs commercially available components, including the PCU. This unit can be deployed in large-scale, on-grid applications. Moreover, it is particularly well suited to cost effective, modular installations in remote areas as an unattended, off-grid power source, or for distributed generation applications. In either case, additional units may be incrementally installed to meet increased power needs.

A Mod 3 design, which will incorporate improvements resulting from the Mod 2 operation, is being developed. The Mod 3 design will represent the next phase of production readiness, reflecting a significant reduction in the manufacturing costs.

Corporate Business Development Plan. WGA continues to work with Sandia on the refinement of the Mod 1 and Mod 2 system designs and is developing a Mod 3 design on its own. WGA is also working with independent power producers towards the development of a project for a multiple-unit build. A large number of operational systems are needed to improve and demonstrate system reliability to the point required by the market.

IV Advanced Dish Receivers

The receiver is a *key* component in a Dish-Stirling system because it must convert the concentrated solar energy to heat and transfer it to the engine working fluid at high-flux conditions of from 75 to 100 W/cm^2 and temperatures of 700–800°C. In this section of the paper, we review some of the advanced receiver concepts that are currently being developed including heat-pipe receivers, hybrid receivers, and a volumetric receiver that could be used for a future Dish-Brayton system.

Heat-Pipe Receivers. Heat-pipe receivers use sodium or a mixture of sodium and potassium to transfer heat from the surface of the receiver to the engine heater head [15,16]. Heat pipes utilize a capillary wick to distribute the liquid metal over the back surface of the absorber. The liquid metal evaporates, vapor is transported to the engine heater head where it condenses, and the liquid metal refluxes to the absorber. In these receivers, the liquid metal condenses at a constant temperature thereby providing uniform heating to the Stirling engine, unlike DIR receivers that can experience large temperature differences between quadrants or along tubes of the receiver. Since the receiver materials typically limit the peak receiver temperature and thus the performance, in a heat pipe receiver the peak temperature is the average temperature, which raises the achievable working gas temperature considerably. The increased working gas temperature, improved receiver efficiency, improved temperature balance among the four cylinders of the engine, and overall simplicity resulted in a 20% increase in system efficiency [27].

The sodium heat pipe receiver for a 25-kW system stretches the traditional sizes and shapes of heat pipes. Most developmental research at Sandia has concentrated on wick improvements to increase the operating margin of the heat pipe. The most promising wick design has been a stainless steel felt, with over 95% porosity provided by 4-μm fibers. This felt provides a large pumping capability with low flow losses. The fine fibers present new manufacturing challenges, requiring extremely clean sodium environments in order to prevent corrosion. Cleaning techniques and processes that virtually eliminate corrosion issues seen in early felt-wick heat pipes, while not significantly impacting the cost, have been developed at Sandia. Bench-test heat pipes have demonstrated over 5000 hr of operation without degradation, whereas prior tests failed at less than 2000 hr. Some smaller capsule heat pipes have been tested for over 30,000 hr without degradation [28,29,30].

Sandia has also developed wick modeling techniques and tools [31] that are critical to the successful design of the heat pipe receivers. Distributed pore size wicks, like the felt metal, rely on vapor generation in the wick, rather than at the heated surface. This provides sufficient heat transfer through the wick while also providing liquid transport along the wick. This approach, which was pioneered by Thermacore Inc., is contrary to conventional heat-pipe technology approaches. Sandia has demonstrated the ap-

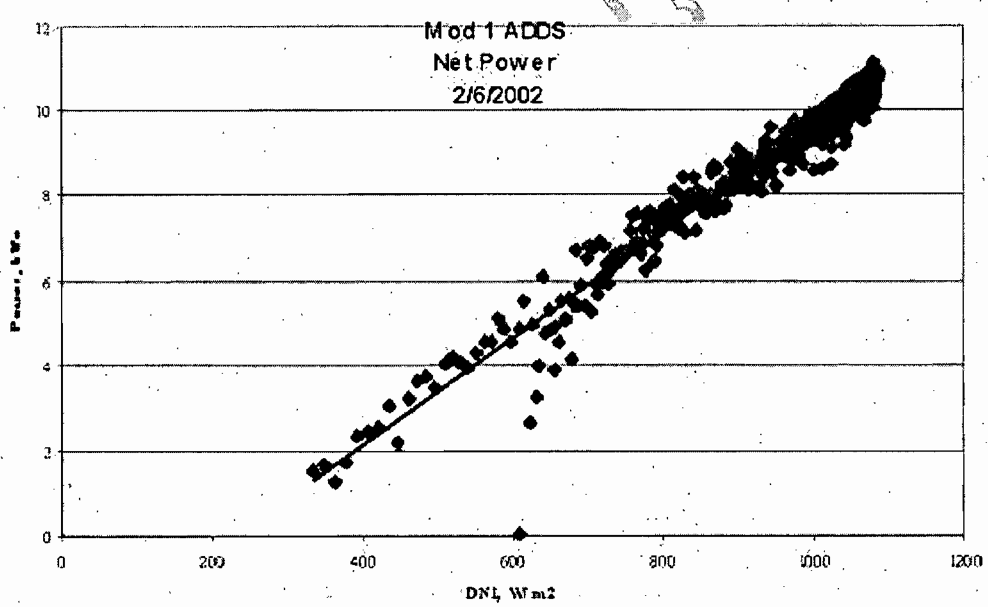

Fig. 16 Mod 1 ADD system net power output versus direct normal insolation

plicability of these modeling approaches on powdered-metal sintered wicks, operating one heat pipe receiver to 116-kW thermal throughput and closely matching the predicted results of the models.

The felt wick heat pipe needs additional development in several areas [32]. The fine fibers of the wick tend to crush over time under the weight of the sodium column. This effect and/or other non-uniformities in the wick structure are thought to have caused the occurrence of hot spots in a few cases. In addition, the integration of the heat pipe chamber with the engine heater heads is a second area that needs to be addressed. While efforts have begun in these two areas, further development is limited by the availability of resources.

Sandia has tested two engines with heat pipe receivers, and a number of additional receivers have been tested on-sun with gas-gap calorimeters for proof-of-concept. In 1996, an STM Power 4-cylinder engine was tested with a felt-wick heat pipe receiver [27]. This was followed by more extensive testing of the engine with a Thermacore, powder-metal-wick heat pipe receiver. This engine demonstrated more than a 20% improvement in efficiency and throughput compared with a DIR receiver on a highly accurate dish. The results would be more dramatic on a less accurate dish, because the temperature distribution on the receiver follows the flux distribution capabilities of the dish. In 2000, Sandia integrated the latest felt-wick receiver with the SOLO Kleinmotoren engine on the ADDS at Sandia. The design took advantage of flexibility in the SOLO cooler, allowing for thermal expansion of the receiver shell. Unfortunately, the receiver failed in initial testing. The failure was traced to an improper clearance in a braze joint where the heater head tubing passed through the heat pipe wall. This resulted in a breach of the heat-pipe containment. Additional work on this receiver has not been possible due to limited resources.

Hybrid Heat-Pipe Receivers. Hybridization is one way to improve the value of electricity from Dish-Stirling systems by making it available on demand. Combining a heat-pipe receiver with a hybrid receiver has the potential to improve the receiver performance, reduce the cost of the receiver, and provide dispatchable electric power.

Two prototype hybrid, heat-pipe receivers have been developed and tested for the SOLO V160/161 by the DLR in Germany [33]. The most recent design has an outer diameter of 36 cm, a cylindrical inner-wall diameter of 21 cm, and is 24 cm deep. It was designed to transfer 45 kW of thermal power to the engine at a maximum temperature of 850°C. The heat pipe structure comprises spot-welded mesh screens with arterial webs to enhance sodium flow. For hybrid or fossil-only operation, a lean, pre-vaporize combustor, which uses combustion gas re-circulation, was developed to lower the combustion temperature. The receiver was tested for almost 400 hr in the laboratory and field, resulting in Dish-Stirling system efficiencies of 16% solar and 15 % in hybrid operation. As part of the same project, a new type of capillary wick structure for the heat pipe was manufactured using radio-frequency, plasma spraying. During preliminary testing, it demonstrated promising performance but has not been fully tested.

Sandia is also developing a 75-kWt hybrid heat-pipe receiver for Dish-Stirling applications. This receiver is a 6-X scaleup of an earlier bench-scale concept that was successfully tested [34]. The design is a compact package comprising a fully-integrated solar absorber, sodium heat pipe, metal-matrix combustor, and folded-membrane recuperator. During the design of this package, special attention was also paid to developing a design that is manufacturable and low cost. Towards this end, Sandia worked closely with commercial fabricators, whose estimates indicate that the hybrid incremental cost will be competitive with the cost of power from its diesel competition. So far, the receiver has been tested in gas-only mode at throughput power levels from 18 to 75 kWt, at output temperatures up to 750°C, and orientations corresponding to sun elevations of 12, 22, 45, and 80 deg. The tests established several landmarks at 75 kWt, including: 1) preheat of fuel/air mixtures above 600°C without preignition, 2) internal wall temperatures over 800°C with minimal warping, particularly at critical internal seals, and 3) 68% thermal efficiency including parasitics. An efficiency of 75% should be achievable with the addition of an external insulation package. The tests also verified that smooth ignition is easily attainable and that buoyancy effects are not a problem. During testing, some non-fatal problems occurred including brief periods of leakage at an internal seal and warping of the burner matrix. Late in the scheduled tests, a hot spot, believed to be the result of a wick flaw, developed on the gas-fired surface. This behavior has been seen in other heat pipe receivers and is the subject of an ongoing investigation, which is on hold due to budget limitations. A comprehensive report on the hybrid receiver is currently in preparation.

BioDish Hybrid Receiver. The BioDish hybrid receiver is a ceramic receiver being developed to absorb solar radiation on one side and to burn a biogas on the backside of the receiver. The project, which involves a number of participants, is co-funded by the European Community. An advanced, fiber-reinforced, SiC-ceramic material, which is already used in non-solar applications, is being developed to withstand an inner pressure of 150 bars of helium in the small channels. The largest design challenge is the manufacture of the complex receiver geometry. The project participants are also performing an economic analysis for a Bio-Solar power plant. The typical plant size would be a farm of 50–100 Dish-Stirling systems with a biomass gasification providing biogas to augment solar operation and to operate the plant at night.

A schematic of the BioDish receiver design is shown in Fig. 17. The absorbing part of the receiver is designed as a ceramic half bowl with internal channels. The concentrated solar radiation illuminates and is absorbed on the inner surface of the bowl. Through the rotationally symmetric design, the flux distribution and the heat transfer to the working gas of the Stirling engine are optimized. The heater heads, which are also made of ceramic, connect the receiver to the engine and allow for higher temperatures and higher cycle efficiencies than current metallic heads. The biogas combustion system consists of a combustor, located on the center axis and surrounded by a cylindrical air pre-heater and a ceramic shell for ducting the combustion gases. Combustion occurs between the receiver and the shell while combustion gases flow through the pre-heater heating incoming combustion air. To meet the requirements of hybrid operation, the power output of the combustor has to be quickly adjustable. This is accomplished by controlling the combustion air flow. To limit emissions from the combustion system, the maximum temperature of combustion is limited to 1400°C.

The design is compact and easy to install in an existing Dish-Stirling system. Preliminary cost estimates for the hybrid receiver are about $15,000 US at modest production levels of 100/yr. The additional cost of adding a biomass gasifier is estimated to be about $3,000 US.

Volumetric Receiver. Because they have the potential to be low cost, reliable, and readily hybridized, micro turbines are being considered as possible converters for some advanced dish-engine systems. The expected conversion efficiency of small, recuperated gas turbines is somewhat lower than of comparable Stirling engines by about 10 percentage points, ranging from 27 to 33%. Solarization of a gas turbine is achieved by installing the solar receiver between the recuperator and the combustor of the gas turbine. Air is heated in the receiver before it is introduced into the gas turbine, thereby replacing all or part of the fuel with solar energy.

One option for the solar receiver is the pressurized volumetric receiver shown schematically in Fig. 18. The concentrated solar radiation enters the receiver through a domed quartz window, which closes the opening of the pressure vessel. Inside the vessel, the volumetric absorber, made with highly porous ceramic foams or similar materials, is heated by the incident radiation. The air passes through the porous absorber where it is heated by forced convection before going to the gas turbine. The hot air from the receiver is ducted to the gas turbine combustor where, if necessary, it is further heated by combustion of fossil fuel. DLR has been developing this receiver technology for several years and has successfully demonstrated operation of several units under conditions similar to those required for a recuperated gas turbine cycle [35]. Tests of this receiver have been conducted up to absorbed power levels of 95 kW, air inlet and outlet temperatures of 580°C and 940°C, and air pressure of 3 bar. The pressure drop through the receiver is less than 20 mbar, which is important for application to gas turbines. A similar receiver for power tower applications has been operated at a power level of 400 kW, air outlet temperatures of 800°C, and pressures of 15 bar.

V Cost of Energy from Dish-Stirling Systems

To be successful, Dish-Stirling systems must meet the needs of the markets; that is, they must be capable of producing electricity at costs that are acceptable to a range of power markets. To do this, the combined costs resulting from the capital costs of the systems; the cost of money, taxes, insurance, inflation; and the cost of operating and maintaining the systems all have to be factored into the cost of electricity from Dish Stirling. This type of cost analysis is a standard financial calculation that is well-documented in the literature [36]. It results in a quantity called the levelized energy cost (LEC), which is the annualized cost of energy from a power plant taking into consideration all of the previously mentioned variables divided by the total, annual kilowatt hours produced by the plant.

Before proceeding to the LEC cost analysis, it is important to emphasize several points. The predicted variable is the *cost* of electricity per kWhr not its *price*. Its price includes adders for distribution costs, other services provided by the local utility, and profit. These are not included in the analysis. Second, solar Dish-Stirling systems, as other renewable energy power systems, are nonpolluting. They emit no hydrocarbons, particulates, CO, CO_2, or other green house gases. Some Independent Power Producers provide a premium for power produced from *green* (or nonpolluting) sources. Some U.S. states and foreign governments have renewable portfolio standards (RPS) or system benefits charges (SBC) to encourage the use of renewable energy for power generation. RPSs mandate that companies providing power in the state provide a portion of that power from renewable sources; while SBCs collect a surtax from the consumer and put it into a pool for developing solar energy and/or other energy resources. The U.S. Federal government currently gives a production tax credit of 1.7¢ US/kWhr for power produced from wind and closed-loop biomass power. This provision is being considered for expansion this year to include power produced from "swine and bovine waste nutrients, geothermal power, solar power, and open-loop biomass" [37]. Solar energy includes Dish-Stirling, power towers and troughs, and photovoltaic power generation. By the time this paper is in print, the decision on the extension of the production tax credit should be resolved. Last, Dish-Stirling systems are capable of operating on the customer- or demand-side of the power meter. In this sense, they can operate as distributed generation offering all of the advantages of any other distributed generator, i.e., line conditioning, limited freedom from the grid, and sale of power back to the grid.

None of the methods for providing additional *value* to power produced from Dish-Stirling systems are included in this analysis. Many believe that it is the approach for assigning additional value to green power sources, in the form of tax credits or through the legislation of pollution penalties and issuance of pollution-offset certificates for green power, that will enable electricity from Dish-Stirling systems and other renewable power sources to bridge the cost gap and enter the competitive marketplace, much like wind power has been able to do over the last three years. Unfortunately, in the current regulatory landscape in the U.S. and many countries, the process of *valuing of green power* is caught up in and secondary to the continuously changing debate over restructuring of the electric utility sector. In the U.S., it is likely to be 3–5 years before this debate plays out. Once restructuring legislation is in place, as much as a decade may be required to resolve court challenges and establish sustainable sets of conditions that the financial community will accept for providing financing for renewable technologies.

Achieving a competitive LEC depends on low O&M and capital costs. Reliability of operation is important for Dish-Stirling systems because poor reliability results in increased O&M costs. A reasonable long-term target for O&M costs for a Dish-Stirling system is in the range of 1–1.5¢ US/kWhr. Precisely what constitutes a competitive LEC from Dish-Stirling systems is an entirely different matter and depends, to a large extent, on the market. It is entirely too easy to say that these systems must compete in base-load markets with coal or with peaking, gas-turbine power plants at LECs of 3–5¢ US/kWhr. This statement ignores the *value* of clean, distributed power described above. Also, as a distributed generation system, Dish Stirling can also compete in demand-side applications with the "price" of power not the cost. It is not unreasonable to expect Dish Stirling power generation to become a significant player in a number of markets if the LEC from the technology is reduced to 8–10¢ US/kWhr.

The LEC analysis presented below demonstrates the sensitivity of the LEC to capital and O&M costs and, to a lesser extent, to the *risk* of investing in a new technology, represented by the rate at

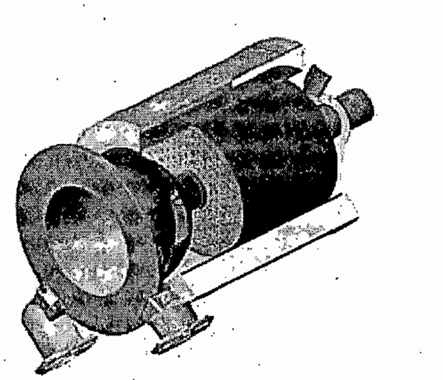

Fig. 17 BioDish hybrid receiver

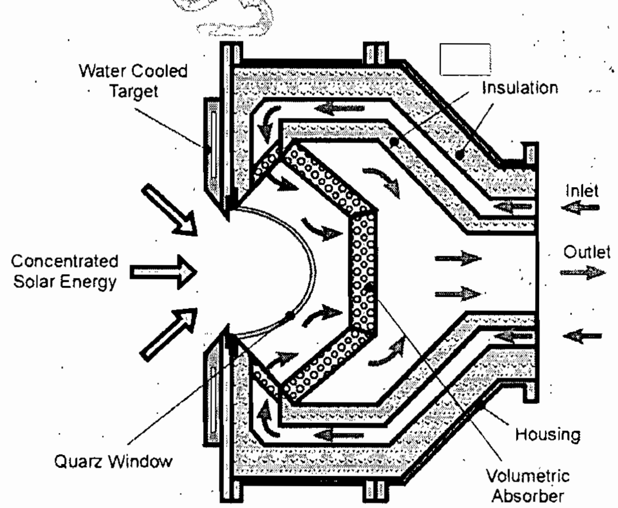

Fig. 18 DLR pressurized volumetric air receiver

Table 3 Parameters for the LEC analysis

Parameter	Case 1	Case 2	Case 3	Case 4
System Rating (kW)	25			
Location	Albuquerque, NM (TMY2 Data Model)			
Combined Tax Rate (%)	40%			
Debt to Cap Ratio (%)	50	50	50	50
Blended Cost of Capital (%)	20	15	10	6
Term of the Loan (yrs)	10	15	20	25
Fixed Charge Rate (%)	24.9	18.1	12.8	8.8
System Capital Cost ($US/kW)	10,000	5,000	2500	1500
Annual Availability (%)	88	92	97	98
Annual Performance (kWhrs)	46,277	50,504	52,831	60,735

which money can be borrowed. This analysis is a generic one and does not represent a specific Dish-Stirling system. The variables for the four *cases* evaluated are presented in Table 3. Figure 19 is a plot of the LEC as a function of system operating and maintenance costs for the four cases.

Case 1. This case represents the current state of the art of Dish-Stirling systems. The systems are expensive prototypes that are hand built and demonstrate modest reliability and system availability. If they will invest in the technology at all, the venture capital community requires a large return on their investment in a relatively short period of time. At this point in the development cycle, the venture capital is more likely to look for a quick return on their investment, realized within 3–5 yr by the sale of the company or their share therein. The cost of energy is more than $1 US/kWhr, so sales of systems are low and supported by those interested in *getting in on the ground floor* or for whom the cost of energy is not the motivating factor for purchase.

Case 2. Case 2 is a modest improvement on Case 1. The system cost is half of what it was for Case 1 and the performance reflects a modest improvement. Reductions of half over prototype costs could be supported by relatively low levels of production. The perceived investment risk remains high, however; the motivation for investment is probably the same as for Case 1. Even though reliability and availability are not yet at the required levels, at LECs below 50¢ US/kWhr the remote power community and some export markets may be interested in the potential of Dish Stirling power generation.

Case 3. In the scenario represented by Case 3, there is significant mass production of Dish-Stirling systems and the reliability and performance have been demonstrated sufficiently to establish for the investment community that the technology is not high risk. This could be similar to the current status of trough-electric technology where more than 350 MW have been in continuous operation in the California desert for a decade or more [3]. The LEC for reasonable O&M costs ranges from 15 to 20¢ US/kWhr. In this cost range and given a stable, restructured, utility environment, Dish Stirling should start to be introduced into some green power opportunities in the U.S. and Europe and may find application in some remote markets, if they can meet reliability requirements.

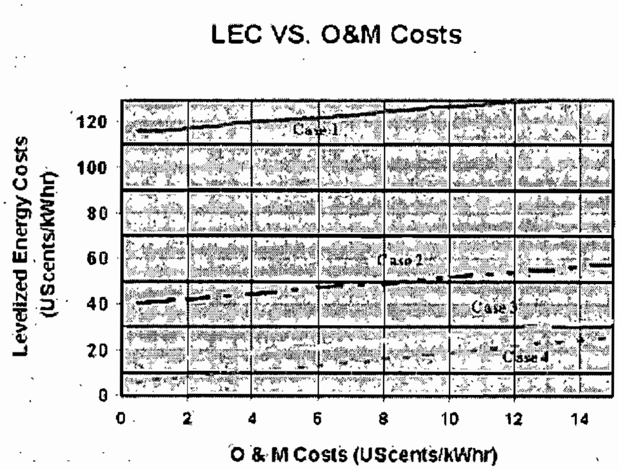

Fig. 19 Levelized energy cost versus O&M costs

Case 4. Case 4 represents what the cost of energy and O&M might look like for a mature Dish-Stirling technology. The investment community treats the risk of investment at the same level as for any mature rankine, Brayton, or combined-cycle system. At modest O&M costs, on the order of 2¢ US/kWhr or less, the LEC will be less than 8¢ US/kWhr. This case is not intended to represent the ultimate potential of Dish-Stirling technology but, at a cost $1500 US/kW, it represents an aggressive target. Further reductions in the cost of energy and improvements in O&M will require major technology changes.

As mentioned earlier, this analysis has not included the *value* of distributed generation or of reducing greenhouse gas emissions, associated with Dish-Stirling technology. It has also not included any of the cost offsets provided by existing or pending legislation on premiums, portfolio standards, or for green energy, available in parts of the U.S. and Europe. Even without these additional cost incentives, green power and remote power markets should be available to systems if costs, representative of Case 3, can be achieved. The potential markets and a market-entry path for Dish-Stirling technology are discussed in the next section of this paper.

VI Markets for Dish-Stirling Systems

A potential path for Dish-Stirling technology, as well as other renewable energy technologies, into the commercial marketplace is shown in Fig. 20. Initial sales are for so-called *opportunity* markets to parties for whom the cost of energy is not the issue. As the costs are reduced and the system reliability increases, the systems will be sold into higher-value green power and distributed generation markets. One of the advantages of Dish-Stirling systems in these markets is their modularity, which allows for the incremental addition of capacity as required. Modularity also allows for the potential consumer to *experiment* with the technology without having to invest in a large-scale power plant. As the reliability increases further to meet even more stringent requirements, Dish Stirling systems will be sold for remote power applications. Last, if costs decline sufficiently, they may also be sold for bulk power generation. These markets are briefly described below.

Opportunity Power Markets. At an initial cost of $8,000–$10,000 US/kW and a cost of energy more than $1 US/kWhr, not many systems will be sold and the buyers are those motivated by having the newest form of power generation equipment or by the future potential of Dish Stirling technology. These markets represent the chance to demonstrate Dish-Stirling technology and educate policy makers and power producers while, at the same time, adding to the operational database and improving the system performance. This is also the time to start introducing the technology to financial institutions.

Green Power Markets. Green power is electricity generated from solar, wind, and other renewable energy sources, including Dish-Stirling systems. The primary reason for the emergence of green power markets is to replace part of the conventional, fossil-fuel-fired generation and the associated production of greenhouse gases. The general approach is to offer a green power product to the customer at a premium price that, when distributed over the customer base, will cover the incremental cost of generation and a modest profit. Generally, the green product is *blended* with conventional fossil electricity or represents a fixed purchase of kilowatt hours of green electricity per month.

More than 100 MW of new renewable energy resources have been brought on line due to green power market development. Estimates of market growth in the U.S. through 2010 range from 1931 to 6971 MW under low- and high-growth scenarios [38], respectively. The four barriers that determine whether the green power markets grow quickly or slowly are the progress or degree of *pull back* of utility restructuring plans; the establishment of favorable *rules* for restructured markets; the level of consumer acceptance of green power markets; and the continued decline in premiums for green power purchases. Even a relatively modest level of Dish Stirling penetration into growing green power markets could result in the deployment of hundreds of MW of Dish-Stirling systems.

Distributed Generation. Distributed generation is electrical power generation that is located near to the load and it may be located on either side of the meter. On the supply side of the meter, the cost of the power must compete with the cost of base load power plus any additional benefits. These benefits could include improvement in power quality, higher efficiency of transmission due to reduced transmissions distances, avoided fuel costs, and offsetting the need to build new base-load plants and transmission [39]. These are additional to the clean energy benefits of renewable energy technologies such as Dish Stirling and may add further value to these systems. One study [39] shows that distributed benefits enable entry of Dish-Stirling systems into the market when costs reach the level represented by Case 3 of the previous section and that the market size increases to 1.5 GW/yr in the Southwest U.S. as costs drop to a LEC of 5.3¢ US/kWhr. This is a low LEC for electricity from Dish-Stirling systems and will be achieved only at very high production levels for very mature system configurations.

On the demand side of the meter, distributed generation competes with the retail price, not the cost, of electricity, which averaged 8.8¢ US/kWhr in the U.S. in 2001, ranging from a low of 5.7¢ US/kWhr in Washington State to a high of 14.6¢ US/kWhr in New York [40]. The increased value of distributed generation may result in it being attractive to the consumer. However, it also requires that someone, probably an independent power producer, purchase or lease equipment, and provide for the operating and maintenance costs. It requires open access to the grid and rules that allow excess power when it is generated to be sold back to the utility, called net metering. These added complications may make demand-side generation unattractive to all but green-power providers and the most aggressive or larger users.

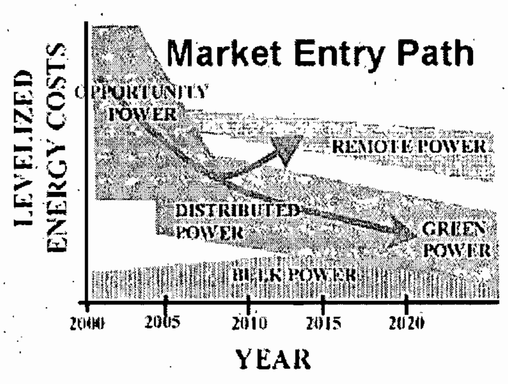

Fig. 20 Market Entry Path for Dish-Stirling systems

Remote Markets. Remote power is installed at locations far from the grid. This could be for limited applications in developed countries or for village power in developing countries where national electrical power grids are not developed. The requirements for remote power vary with the application, but include some combination of reliability and ease of maintenance and repair. Consequently, even though these potential markets represent a high value, they will be open to Dish-Stirling systems only when the system reliability exceeds a minimum threshold, probably on the order of one-year mean time between failure. Several proprietary studies of remote and village power markets suggest that the market size is in excess of tens of gigawatts with the potential to be much larger if the reliability of the systems is high and cost is low. Applications for these systems include power for villages, water pumping and, in some desert areas, desalination of brackish water. This market segment may represent the highest value and, ultimately, may be the largest segment available to Dish-Stirling systems.

Bulk Power Markets. To compete in bulk power markets, which are the lowest-cost, highest-volume energy markets, the LEC from Dish-Stirling systems will have to compete with gas turbine power generation and/or combined-cycle plants where the current costs are typically quoted as 3–4.5¢ US/kWhr. Bulk power will become a market for Dish-Stirling as production costs drop even further and when base load energy costs increase due to carbon taxes and the cost of implementing emission controls.

Near-Term Opportunities. There are two near-term opportunities for deployment of Dish-Stirling systems one in the U.S. and one in Spain. The U.S. deployment is being sponsored by the U.S. Department of Energy's Concentrating Solar Power Program. It has an anticipated release date of May–June 2002 and will be for 1 MW of Dish-Stirling systems in Southern Nevada [5]. There is not much information available on this project at this time. The project is expected to require three years to complete and cost between $12–14 million US. The plant is to be operated like a conventional power plant with the operating and maintenance costs paid by the power purchase agreement.

In 1998, the Spanish Ministry of Industry and Energy developed legislation to promote energy production from renewables, waste, and cogeneration. Since then there have been discussions regarding the size of the subsidy and the eligible technologies. A royal law finalizing the legislation is expected to be enacted during the summer of 2002. The pending legislation is for a subsidy of 0.12 ■■ resulting in an electricity price of 0.156 ■■/kWhr (11 and 14¢ US/kWhr, respectively) for solar-only electricity generating systems at power levels of 5 kW up to a maximum of 50 MW. The solar power producer will deliver electricity to the local utility and be reimbursed according to the actual price of electricity plus the subsidy. The amount of the subsidy will be reevaluated every four years. Several companies and consortia are ready to start erecting solar power plants, once the final amount of subsidy is determined.

For reliable Dish-Stirling systems that have *reasonable* production costs, the Spanish subsidy should be very attractive. Even though Spain has a well developed electricity grid, there are some niche opportunities for power production on the Balearic and Canary Islands where small systems could help to increase the capacity of the grids, offsetting the need to build new fossil-fired power plants.

While the current cost of Dish-Stirling systems is about $10,000 US/kW installed, this reflects the one-of-a-kind, hand-built nature of the current design. Even at relatively modest rates of production these costs will easily be 1/3 current costs. Table 4 shows the cost projections of the four manufacturers whose sys-

Table 4 Cost Projections for Dish-Stirling Systems

Build Rate and O&M	Costs ($US/kW)
5 MW/yr	3000–5000
50 MW/yr	2000–3000
O & M Cost @50 MW/yr	0.01–0.02/kWhr

tems are featured in this paper. Even at the relatively low production rate of 50 MW/yr (2,000 25-kW systems or 5,000 10-kW systems) and at an O&M cost of 1–2¢/kWhr, the cost of electricity from Dish-Stirling systems will be 15–20¢/kWhr enabling entry into some village and remote-power markets. As system costs fall and reliability improves, it is reasonable to expect LECs less than 10¢ US/kWhr, which will expand the markets to distributed generation and demand-side applications. The consideration of SBCs, RPS, and other tax incentives serves to reduce the effective LEC even further thereby making power generation from Dish-Stirling even more attractive. As performance increases and costs fall, the cost of power from Dish-Stirling could eventually compete with conventional bulk power generation.

VII Summary and Conclusions

Dish-Stirling systems have successfully demonstrated that they can produce electrical power for extended periods of time. The major technical issue is establishing high levels of system reliability, thereby reducing the operating and maintenance costs. The second barrier to market entry is the initial cost of the systems that, to a large extent, depends on increasing the production levels of components and systems. These two issues are being addressed. The following summarize the current status of Dish-Stirling system and market development:

1. High-value markets for Dish-Stirling will start to develop as reliability increases and the LEC of energy from the systems falls below 20¢ US/KWhr. As the cost of energy from Dish-Stirling continues to decrease, new markets emerge with even a modest share of these markets representing huge opportunities for sales.
2. Dish-Stirling systems are flexible power generators—they offer high levels of performance, are modular, operate in solar-only and hybrid modes, and have demonstrated grid-connected and stand-alone operation.
3. Four Dish-Stirling system designs, comprising four different solar concentrators and three Stirling engine/generators, are successfully demonstrating technical feasibility of solar power generation using this technology today.
4. One system, the ADDS Mod 2, is demonstrating off-grid operation for water pumping.
5. Like other renewable energy technologies, Dish-Stirling systems require stable, sustainable energy markets that "value" clean energy through green power programs, renewable portfolio standards, etc. in order to find deployment opportunities. The development of these markets has been impeded by the suspension of restructured, market-based programs in some states.

Acknowledgments

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Exhibit 610

Biological Conservation **37** (1986) 179–190

Genetics and the Conservation of Mountain Sheep *Ovis canadensis nelsoni*

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ABSTRACT

Recent hypotheses have proposed that mountain sheep were suffering from inbreeding depression. Here we present an alternative hypothesis. We have examined sheep migration abilities, the distances required for migration, and sheep mating patterns to challenge the inbreeding hypothesis and conclude that the sound application of more traditional wildlife management techniques will likely preclude short- and long-term genetic problems.

INTRODUCTION

Recent symposia, texts, and journal articles have begun to focus the techniques of population genetics on the problems of conservation (e.g. Soulé & Wilcox, 1980; Schonewald-Cox *et al.*, 1983; Lehmkuhl, 1984).

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Work has focused on many concerns including human impact on species, endangered species recovery, reserve size necessary for long-term species survival, evolutionary future of species, and population substructure.

The genetic models that have been applied to conservation problems have arisen largely from insular models (Wilcox, 1980; Lehmkuhl, 1984), and tend to view populations as closed, either because of the biology of a species or the limited size of reserves. As a result, a central focus of some papers (DeForge *et al.*, 1979) has been the deleterious consequences of inbreeding depression on closed populations. In a closed population, the level of inbreeding for each generation is given by the formula: $f = 1/2N_e$, where f is the inbreeding coefficient and N_e the adjustment in effective population size due to unequal breeding sex ratios; $N_e = 1/((1/4N_m) + (1/4N_f))$, where N_m and N_f are the actual numbers of males and females observed in a population. A reasonable value for f has been determined to be 0·01, which is necessary for short-term survival of a closed population (Franklin, 1980; Soulé, 1980). When so assumed, the equation can be solved to find that an effective number of 50 individuals is required to keep a closed population at 0·01 loss of heterozygosity per generation. However, when $f = 0{\cdot}01$ the population will show the effects of inbreeding, or it may become extinct, because a N_e of 50 would compound the effects of inbreeding to a value of $f = 0{\cdot}5$ to 0·6 in 50 to 60 generations. At $f = 0{\cdot}5$ to 0·6, inbreeding is deleterious to domestic animal breeding programmes, and it is thought that wild populations are more susceptible to those deleterious effects (Soulé, 1980). As a rule of thumb, an effective population of 500 is needed for long-term evolutionary success of a species (Franklin, 1980).

Mountain sheep *Ovis canadensis* have been fully protected in California since 1878, and the species has responded well to management. It has been postulated on several occasions that inbreeding depression is of major consequence to this species (Berwick, 1968; Wilson, 1974; DeForge *et al.*, 1979, 1981; Sausman, 1982, 1984). Recently this thinking has focused on a suppressed immune system making sheep susceptible to disease (DeForge *et al.*, 1979).

The concern about inbreeding in mountain sheep arose from: (1) a popular (Seton, 1929; Buechner, 1960; DeForge *et al.*, 1979) but largely unsubstantiated (Welles, 1962; V. C. Bleich and S. A. Holl, unpublished data) assumption that mountain sheep have declined to approximately 2% of their historical population level in North America; (2) their relatively isolated natural habitat, the rugged peaks of desert mountain ranges (Hansen, 1980); (3) a polygynous mating system (Wishart, 1978); and (4) the assumption that because of cultural features (construction by humans) developed in the last century, sheep do not leave the mountains and disperse across the relatively flat ground that occurs between desert ranges (Bailey, 1980). Through these mechanisms a small N_e would be maintained.

In this paper, using existing data, we challenge the hypothesis of inbreeding depression in *Ovis canadensis nelsoni*. Our hypothesis is based on the following: relatively large population sizes of mountain sheep in desert ranges; documented mountain sheep vagility; male breeding strategies that were largely unrecognised; the ability of mountain sheep to cross cultural obstacles; and the low levels of migration (number of sheep migrating into a range and breeding) necessary in a species to preclude inbreeding depression.

METHODS

We chose to evaluate the hypothesis of inbreeding depression in those desert-dwelling mountain sheep occupying an approximately 50 000 km^2 triangle in California and Nevada bordered on the north by Interstate Highway 15, on the south by Interstate Highway 40, on the west where these highways merge in Barstow, California, and on the east by the Colorado River. This triangle is bounded by cultural and natural features which may partially restrict the movement of sheep to within that triangle, but it is also an area in which there are no cultural features that should provide serious limitations to migration; as such, it is typical of much of the area occupied by mountain sheep in California. Estimated populations of sheep in each range in California are the latest (1984), based on aerial and ground observations by the California Department of Fish and Game. The estimates from the Nevada ranges are those of McQuivey (1978).

RESULTS AND DISCUSSION

Figure 1 shows the estimated number of adult sheep in the triangle and in several ranges adjacent to the study area. Also shown are the estimated effective population sizes based on the frequent observation of a ram : ewe

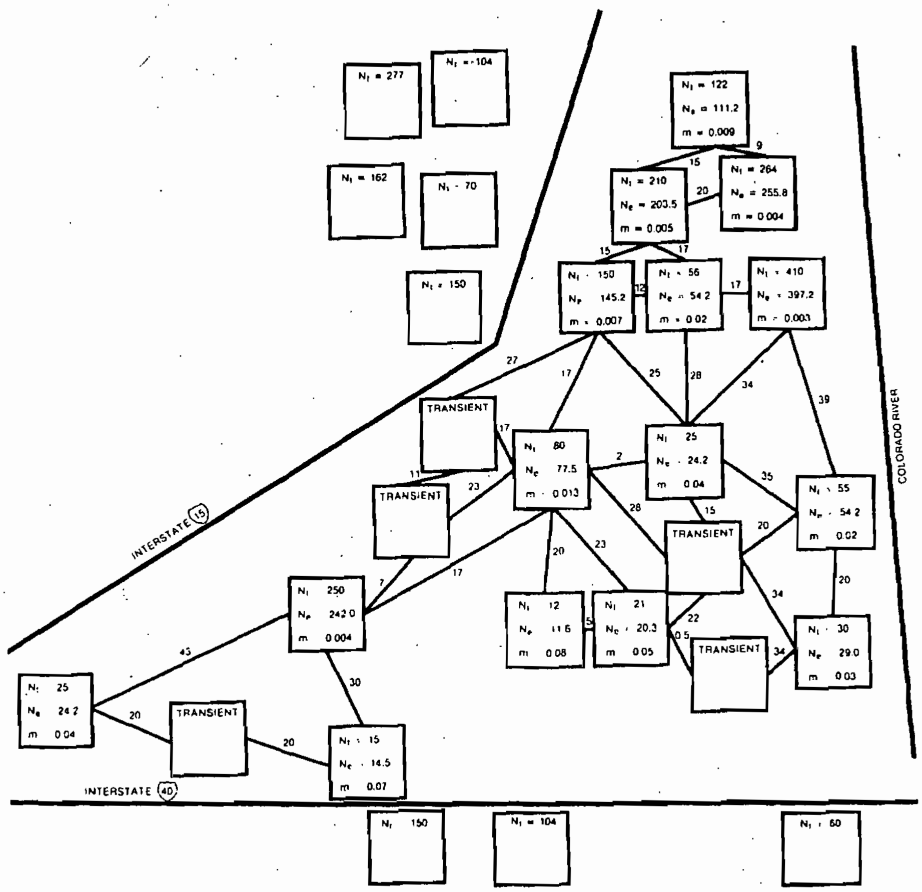

Fig. 1. In our triangular study area in the Mohave Desert of California and Nevada we report the estimated total population of desert-dwelling mountain sheep (N_t), effective population size (N_e), and the required migration rate (m) to maintain an equilibrium coefficient of inbreeding of 0·2. Distances between ranges are in kilometres, and the map is only roughly to scale.

ratio of 70:100 (Aldous, 1957; Leslie & Douglas, 1979; Wehausen *et al.*, in press), and the distance in kilometres between proximal ranges. The rate of migration into a range with a given effective population size was estimated with the formula: $F = 1/(4N_e m + 1)$ (Crow & Kimura, 1970 p. 269; Hartl, 1980 p. 195) where F is the equilibrium coefficient of inbreeding in a substructured population, here set to 0·2 (see below); N_e is as described above; and m the migration rate per generation, obtained by solving the equation with the N_e given for each range. An F of 0·2 is achieved when $N_em = 1$, a widely regarded rule of thumb that, when applicable, effectively makes subpopulations nearly panmictic (Camin & Ehrlich, 1958; Futuyma, 1979, p. 281). F can be further described as the probability for homozygosity under the conditions of drift and migration in subdivided populations (Spiess, 1977, p. 653). Figure 2 shows the relationship between F and N_em.

Migration capabilities of mountain sheep may be underestimated; available intermountain range movement data are presented in Table 1. These documented movements suggest no complete philopatry to a sheep's natal area and less hesitancy to negotiate cultural features than previously thought. Also, there is the potential for much previously undetected intermountain movement.

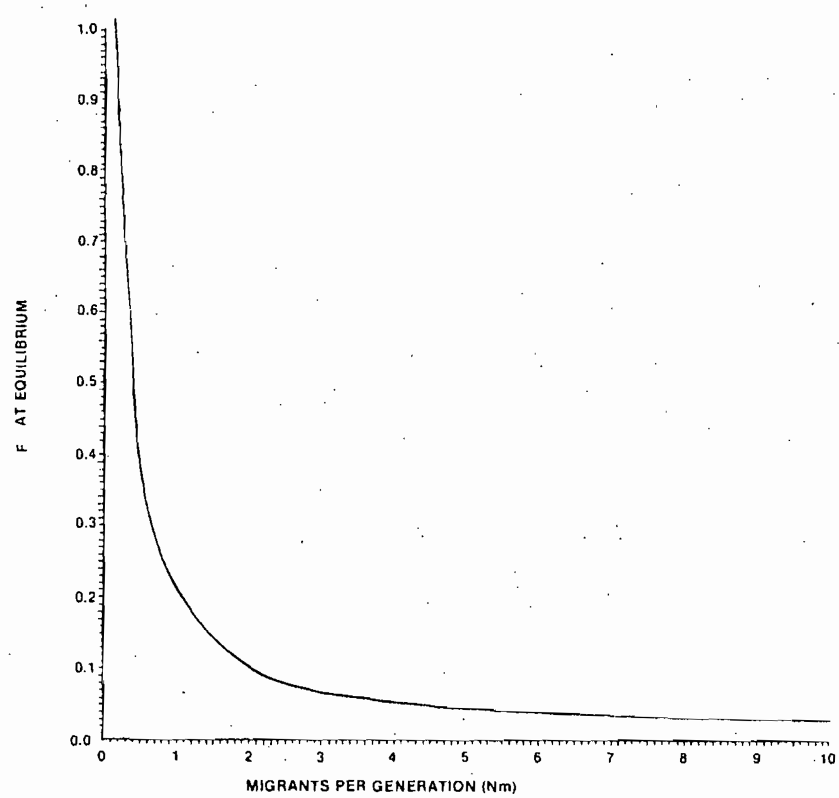

Fig. 2. The relationship between equilibrium inbreeding rate (F) and the number of migrants (N_em) per generation is shown (after Hartl, 1980).

TABLE 1
A Summary of Intermountain Movements by Mountain Sheep

Movement	*Source*
17 interrange movements by radio-tagged rams ($\bar{X}$ = 19·8 km, SE = 2·11, n = 17). 4 interrange movements by radio-tagged ewes ($\bar{X}$ = 17·4 km, SE = 4·95, n = 4).	Ough & deVos (1984)
Rams and ewes in ranges with no resident populations. Data are distances to nearest resident population. ($\bar{X}$ = 19·7 km, SE = 1·9, n = 25).	McQuivey (1978)
17·5 km movement across open desert and other movements of 30·6, 32·2, 40·2 and 51·5 km.	Cochran & Smith (1983)
Rapid movement of rams and ewes following a transplant. Crossed fences, highways, and flat terrain.	Elenowitz (1982)
Ewes and lambs crossed Interstate 10 (4 lane with fences) in SW Arizona	Witham & Smith (1979)
Sheep crossing US Highway 95 used by thousands of vehicles annually.	King & Workman (1983)
Observed young ram leave Old Dad Peak and disappear across flatland. Routinely cross railroad tracks in the Cady Mountains.	V. C. Bleich (unpublished)
Sheep drowned while crossing Colorado River.	C. Douglas (pers. comm.)
Other interrange movements.	Simmons (1980) Russo (1956)

Relative to the movements referenced above, the distances involved, and our hypothesised rates of migration ranging from 0·003 to 0·08 (Fig. 1), it is highly plausible that movements do occur at such rates. Some of the desert ranges have such large herds that they may be approaching overpopulation (V. C. Bleich, unpublished data); however, the role of such dense populations in motivating additional dispersal is unknown. We suggest that the triangular study area should be more appropriately thought of as a single metapopulation (Levins, 1970) rather than a completely or even mostly subdivided population. If so,

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LETTER

Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep

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Abstract

The rapid expansion of road networks has reduced connectivity among populations of flora and fauna. The resulting isolation is assumed to increase population extinction rates, in part because of the loss of genetic diversity. However, there are few cases where loss of genetic diversity has been linked directly to roads or other barriers. We analysed the effects of such barriers on connectivity and genetic diversity of 27 populations of *Ovis canadensis nelsoni* (desert bighorn sheep). We used partial Mantel tests, multiple linear regression and coalescent simulations to infer changes in gene flow and diversity of nuclear and mitochondrial DNA markers. Our findings link a rapid reduction in genetic diversity (up to 15%) to as few as 40 years of anthropogenic isolation. Interstate highways, canals and developed areas, where present, have apparently eliminated gene flow. These results suggest that anthropogenic barriers constitute a severe threat to the persistence of naturally fragmented populations.

Keywords

Gene flow, genetic diversity, habitat fragmentation, metapopulation, *Ovis canadensis*, road.

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INTRODUCTION

As the level of connectivity among human populations continues to increase, natural populations of plants and animals are becoming increasingly isolated. Today the earth's surface is partitioned by an estimated *c.* 28 million km of highways (CIA 2003) that restrict the movement of many species (Trombulak & Frissell 2000; Underhill & Angold 2000). This loss of connectivity is suspected to impede exchange of individuals among populations, thereby accelerating the loss of genetic diversity because of genetic drift (Frankel & Soule 1981; Hedrick 2005). Reduced genetic diversity is likely to increase population extinction rates both in the short term (because of inbreeding, Saccheri *et al.* 1998; Westemeier *et al.* 1998; Coltman *et al.* 1999) and in the long term by reducing evolutionary potential, i.e. the ability of a population to adapt to future changes in biotic and abiotic factors such as climate change (Frankel & Soule 1981; Lande 1998; Fraser & Bernatchez 2001; Hedrick 2005). However, recently constructed barriers have rarely been found to affect genetic diversity in natural populations, particularly for long-lived, large-bodied species (e.g. Kyle & Strobeck 2003; Sumner *et al.* 2004). While roads have been shown to restrict gene flow for species with small body size or relatively low vagility such as amphibians (Reh & Seitz 1990) and beetles (Keller & Largiader 2003), there is growing concern that a much wider variety of taxa may be affected (e.g. Kramer-Schadt *et al.* 2004; Malo *et al.* 2004).

The objective of this study was to assess the effects of major highways and other recently constructed anthropogenic barriers upon genetic diversity in a metapopulation of *Ovis canadensis nelsoni* (desert bighorn sheep). In the desert regions of California, local populations of this long-lived, vagile mammal are often less than 50 individuals (Torres *et al.* 1994). Restricted largely to the steep, rocky mountain ranges that are scattered across the region, these populations are demographically independent and naturally fragmented by the intervening desert (Bleich *et al.* 1990). As resources are variable and local population extinctions common (Epps *et al.* 2004), some connectivity among populations is presumed essential to maintain the regional bighorn sheep metapopulation (Bleich *et al.* 1996). However, the southwest USA has been subject to an increasing degree of urbanization by humans, marked by widespread construction of interstate highways and water canals in this desert region over the last 40–70 years. Anecdotal evidence suggests that bighorn sheep rarely cross these continuously fenced barriers (Bleich *et al.* 1996). Thus it is likely that these barriers on the landscape have reduced connectivity among populations of desert bighorn sheep and possibly many other terrestrial species.

We examined putatively neutral genetic variation across desert bighorn sheep populations in southeastern California (Fig. 1) to assess whether human-made barriers have affected dispersal and genetic diversity to a significant degree. We also defined the geographical scale of current gene flow among these populations and considered the conservation implications of continuing anthropogenic fragmentation.

METHODS

The study area was comprised of the central Mojave, southern Mojave and Sonoran Desert regions of California. Habitat quality for desert bighorn sheep in these arid areas was strongly affected by the spatial and temporal variation in climate and population turnover is high (Epps *et al.* 2004). Apparent dispersal barriers erected in the 20th century include the Colorado River Aqueduct (constructed in the 1930s), urban development, the establishment of large mining operations in Lucerne Valley, the portion of State Highway 62 with four lanes and a concrete median barrier, and interstates 10, 15 and 40 (constructed in the 1960s) (Nystrom 2003). These barriers are largely continuous and have direct physical impediments to locomotion by bighorn sheep, including fences and steep concrete walls. Underground portions of the Colorado River Aqueduct (passing beneath several populations in the southeastern part of the study area) were not considered to be barriers. Major highways were by far the most common barriers between study populations.

We collected genetic samples across the study area during 2000–2003 from 27 populations with varying levels of anthropogenic isolation (Fig. 1). Estimated median population size for these populations was 38 individuals, range was 12–300 (Torres *et al.* 1994). Populations were defined as previously in a geographical information system (GIS) (Torres *et al.* 1994; Epps *et al.* 2004, 2005a), based upon the topographical features of the mountain ranges where they are found. We collected samples from all known populations within the focal study area, except five ranges containing individuals translocated from other populations in the region (Torres *et al.* 1994) (Fig. 1).

We used faecal pellets as the primary source of genetic material, obtained mostly during summer months when desert bighorn sheep congregate at water sources. We collected fresh pellets from observed bighorn sheep or selected the most recent-appearing pellets in the vicinity. Faecal samples were air-dried and stored in paper bags in a dry environment. We also obtained blood and tissue samples from bighorn sheep captured by the California Department of Fish and Game or killed by hunters during 2000–2004. We extracted genomic DNA from faecal samples using a modified DNA Stool Mini-Kit™ (Qiagen, Valencia, CA, USA) protocol (Wehausen *et al.* 2004), and from blood and tissue samples using DNEasy Tissue Kits™

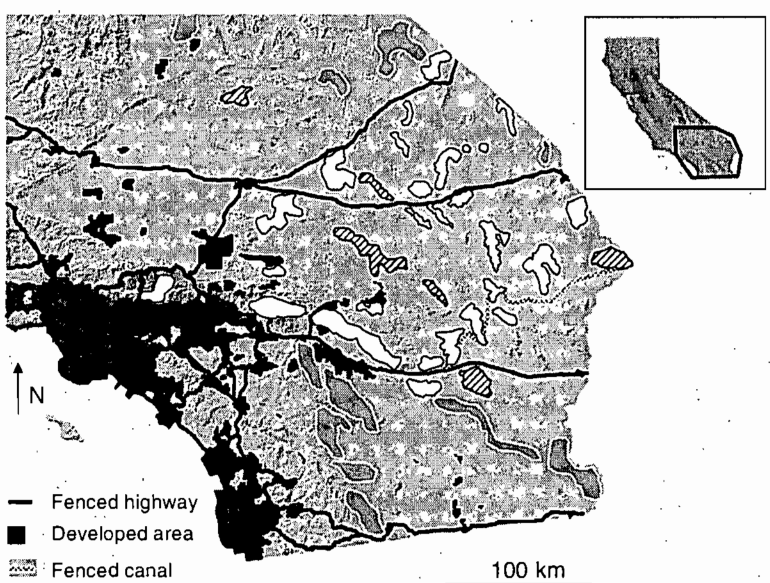

Figure 1 Topographical map of southern California with location and approximate size of the 27 desert bighorn sheep populations sampled (white polygons). Barriers, including canals, interstate highways, freeways, and urban areas, are represented in black or checkered (above-ground portions of the Colorado Aqueduct) patterns. Artificially translocated populations (cross-hatched) and other extant populations where sampling did not occur are also depicted (light grey polygons). Barriers outside the area of sampled populations are not fully represented.

(Qiagen). Before genotyping, we assessed extraction quality by amplifying a *c.* 200-bp fragment of nuclear DNA from the zinc-finger protein gene [Appendix S1(a)]. We visualized the amplification product on 2% agarose gels pre-stained with ethidium bromide; samples generating weak amplifications were not used in further analyses.

We genotyped 14 dinucleotide microsatellite loci for each DNA extraction [Appendix S1(b)]. We conducted a minimum of four replicate polymerase chain reactions (PCRs, Mullis *et al.* 1986) per faecal sample per locus to minimize genotyping errors resulting from degraded DNA (Taberlet *et al.* 1999), and conducted two replicate PCRs for blood and tissue samples. Alleles included in the final consensus genotypes were observed at least twice; if observed only once, an additional four replicates were conducted. We included two negative controls and two positive controls (samples with known genotypes) with every 96 PCR reactions as checks for contamination and to standardize genotypes among experiments.

We estimated the probability of an erroneous genotype because of allelic dropout (selective amplification of only one allele in a heterozygote because of low amounts of template DNA, Taberlet *et al.* 1999). We accomplished this by summing the observed number of allelic dropouts for each locus, and dividing this sum by the number of successful PCR reactions (i.e. the presence of an amplification product) for heterozygous individuals (allelic dropout could only be identified in the case of individuals determined to be heterozygous). Because we had a minimum criterion that each allele per sample per locus had to be observed at least twice (at least two successful replicate PCR reactions with identical results), we squared each per-locus dropout rate to estimate the probability of two dropouts in the same sample. We then summed these squared dropout rates over all loci, and added the average probability of a false allele over 14 loci (calculated from observed rates) to obtain our final estimated probability of a genotypic error per individual. While this method does not account for variability among samples (e.g. Miller *et al.* 2002), we assumed that pre-screening of extractions limited sample variability to a large degree.

We limited further data analyses to samples for which complete genotypes were obtained at all loci. We used the probability of identity (P_{ID}) to identify and eliminate duplicate genotypes resulting from the collection of more than one faecal sample from some individuals. DNA extractions from different faecal samples were inferred as originating from the same individual if the combined P_{ID} for a full-sib relationship was estimated at $< 10^{-2}$ using GIMLET (Valiere 2002), at the number of loci matching between a pair of different DNA extractions (which could be any number of loci less than the maximum of 14 employed in this study). This threshold level of P_{ID} was chosen because most population sizes were estimated at < 100 individuals (Torres *et al.* 1994); 10^{-3} was used for populations > 100. This analysis was undertaken in two steps; first within each population, and then subsequently for all populations combined and treated as a single panmictic population (after removal of all but one of each unique genotype in each population), to detect if any individuals were sampled in more than one population. We assessed the final data set obtained in this manner for any significant deviations from linkage disequilibrium and the expected Hardy–Weinberg genotype frequencies in each population using GENEPOP (Raymond & Rousset 1995).

We also assessed the diversity of mitochondrial DNA haplotypes in each population. Female bighorn sheep are less likely to move between mountain ranges (Festa-Bianchet 1991; Jorgenson *et al.* 1997); therefore maternally transmitted mitochondrial DNA provided an opportunity to assess female dispersal patterns. After identifying unique samples using the microsatellite data, we sequenced 515 nucleotides in the mitochondrial control region from each individual (except three samples that failed to amplify) [primers and protocols are described in Appendix S1(c)]. We sequenced all samples in both forward and reverse directions, editing and aligning them manually, to minimize sequence ambiguities. We used the number of unique haplotypes present in each population as a measure of female-mediated genetic diversity. To correct for variation in sample size, we subsampled each population 100 times using the minimum sample size and calculated the average number of unique haplotypes detected per population.

From the microsatellite data, we estimated the degree of genetic divergence among populations as F_{ST} (and thus Nm) for each population pair using GENEPOP (Raymond & Rousset 1995). F_{ST} rather than R_{ST} (Slatkin 1995) was used because F_{ST} is a more appropriate statistic for 'stepping stone' population models and systems where migration rate exceeds mutation rate (Hardy *et al.* 2003), as is most likely for these desert bighorn sheep populations given numerous observations of colonizations and dispersal between mountain ranges (e.g. Epps *et al.* 2005a,b). Furthermore, F_{ST} performs better when number of loci < 20 (Gaggiotti *et al.* 1999). We used allelic richness (the average number of alleles per locus or A) as our measure of genetic diversity in each population. We used FSTAT (Goudet 1995) to correct A for differences in sample size, as recommended by Leberg (2002). The smallest population sample size was employed as the global sample size.

To determine if human-made barriers (see below) had affected population genetic diversity, we used information theoretic model selection techniques (Burnham & Anderson 1998) to test multiple regression models incorporating either of two estimates of the degree of isolation for each population. We estimated isolation as (i) the harmonic mean of the geographical distance to the nearest three populations (e.g. Harrison & Ray 2002), which weights the mean towards the smallest distance, or (ii) the harmonic mean of the geographical distance to the nearest three populations, but with a 'barrier effect distance' added to the geographical distance between each population pair separated by a human-made barrier. These measures are referred as $isolation_{distance}$ and $isolation_{distance+barriers}$.

To quantify the above-mentioned barrier effect distance, we estimated the reduction in the relative gene flow parameter (*Nm*) caused by barriers among our study populations. The barrier effect distance was defined as the geographical distance yielding an equivalent decrease in the estimate of *Nm*. We first defined barriers as fenced highways, canals and areas of high-density urban development, and added them to the above employed GIS map. We then employed multiple regressions on all pairwise population comparisons to estimate the degree of correlation between geographical distance and *Nm* among populations that were (i) separated by human-made barriers and (ii) those that were not. Populations were considered as separated by human-made barriers if a straight line between the two closest edges of the population polygons intersected such a barrier. Connecting lines for all pairwise comparisons were generated in the GIS (Jenness 2004) and overlaid on the barrier map to determine which lines intersected barriers. Interpopulation geographical distances were estimated as the shortest distance between the edges of each population polygon (Jenness 2004).

Nm was estimated as $[F_{ST} = 1/(1 + 4\ Nm)]$ (Wright 1921). The difference between the intercepts of the *y*-axis in the two regressions (denoted as ΔNm) was inferred to result from the effect of human barriers on the degree of genetic isolation (Fig. 2). Finally, we used the coefficient of the regression of population pairs without barriers ($slope_{no\ barriers}$) to estimate the barrier effect distance (in km) as log(barrier effect distance) $= \Delta Nm/slope_{no\ barriers}$.

After defining these two measures of population isolation ($isolation_{distance}$ and $isolation_{distance+barriers}$), we tested which measure explained the most variance in both *A* and mtDNA haplotype diversity. For both sets of genetic data, we used Akaike's Information Criterion with the small sample size correction (AIC_c) and Akaike weights (Burnham & Anderson 1998) to infer the best regression models. We estimated the overdispersion correction factor ($\hat{c}$) from the deviance of the most saturated model, as described by Lindsey (1999), to ensure that AIC_c rather than the quasi-likelihood information criterion ($QAIC_c$) was most appropriate. We also tested whether other factors such as population polygon area and estimated current population size (which affects the rate of genetic drift) improved regression models.

We estimated the rate of reduction in genetic diversity (*A*) in those populations affected by human-made barriers by comparing the difference in the predicted level of genetic diversity with the existent barriers (obtained from the regression of *A* on $isolation_{distance+barriers}$ described above), and the predicted level of genetic diversity using the same equation but removing the barrier effect for each population. The resulting difference was then extrapolated over the average estimated age of the barriers.

We also analysed pairwise estimates of *Nm* using partial Mantel tests (Smouse *et al.* 1986; Manly 1991) to determine whether relative gene flow was affected by barriers, and at what spatial scale. We repeated this analysis using F_{ST} for comparison, although F_{ST} appeared to be subject to very high overdispersion in other analyses of this data set (not shown). *Nm* represents the amount of gene flow in an idealized Wright–Fisher island model that would yield the observed degree of genetic heterogeneity. Hence, *Nm* cannot be inferred to represent an estimate of the actual

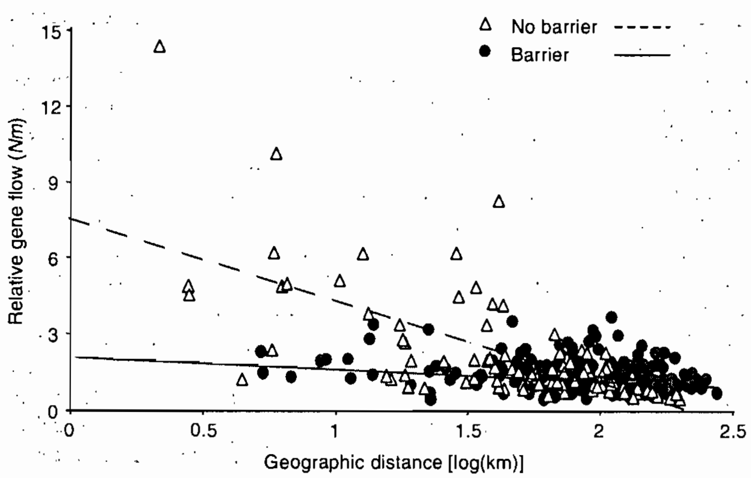

Figure 2 Pairwise population comparisons of migrants per generation (*Nm*, estimated from genetic distance F_{ST}) regressed on log(geographic distance in km). Comparisons are grouped by presence (dark circles) or absence (open triangles) of an intervening barrier. R^2 of pairs without barriers = 0.43, R^2 of pairs with barriers = 0.08. Regression lines are extended to cross the *y*-axis; difference in intercepts was used to calculate the 'barrier effect' (see text).

number of migrants (Whitlock & McCauley 1999). Under such a model Nm is correlated to F_{ST}, but in a nonlinear manner and thus we have used both metrics in our estimation. While our population is likely not in mutation-drift-migration equilibrium, Nm (and F_{ST}) can provide insights as to the relative levels of gene flow, especially when the rate of gene flow is larger than mutation (Slatkin 1993).

We employed partial Mantel tests over sequential geographical distance classes (0–15, 15–30, 30–60, 60–90, 90–120, 120–150 and > 150 km) (Legendre & Fortin 1989; Bjornstad *et al.* 1995; Dodd *et al.* 2002) to assess the partial correlation of barriers and geographical distance with Nm for each distance category. This allowed us to infer the spatial scale at which recent gene flow has occurred or has been disrupted by barriers. For a given distance category, interpopulation distances falling within that range were denoted as '1', all others as '0'. Similarly barriers were noted as '1' (present) or '0' (absent) for population comparisons within the given distance category. In this assessment, we excluded the Coxcomb Mountain population. Most of the bighorn in the Coxcomb Mountains were found to have immigrated from a nearby population, which was established by translocation from a distant population (Epps *et al.* 2005b). While the validity of estimates of type I error (here, falsely concluding that correlation of one independent matrix with the dependent matrix exists, because of correlation with a second independent matrix) in partial Mantel tests has been questioned (Raufaste & Rousset 2001; Rousset 2002), Castellano & Balletto (2002) argued that under even high levels of correlation between the independent matrices, partial Mantel tests closely approximate true type I error.

Finally, we employed the computer program SIMCOAL (Excoffier *et al.* 2000) to investigate if barriers could create a detectable increase in genetic distance between populations, given the time scale and data richness that apply to this study. Coalescent simulations were conducted under two different models, each simulating two adjacent populations 5 km apart. In the first model, we tested the effects of a recently constructed barrier by simulating two populations at mutation-drift-migration equilibrium except during the last seven generations (*c.* 42 years; Coltman *et al.* 2003), when Nm was set to zero. No such reduction in Nm was added to the second model. In each model 40 gene copies were sampled at each of 14 loci. SIMCOAL uses a pure stepwise migration model (in this case, without constraint on allele size), and requires the user to set migration rate m, effective population size N and mutation rate μ. SIMCOAL immediately multiplies these parameters to obtain Nm and θ, where $\theta = 4N\mu$. To obtain realistic values of Nm and θ for use in the model, we estimated $Nm = 6.2$ from the observed estimate of $F_{ST} = 0.039$ between a representative pair of mountain ranges, the Marble and South Bristol Mountains, that are separated by only 5 km with no intervening barrier. We estimated θ from the variance in allele size as $\theta = 2 \times$ (variance in allele size) (Wehrhahn 1975) for both of these mountain ranges ($\theta = 9.62$ and 8.32 respectively), and used the average of these values ($\theta = 8.97$) in our simulation. We also estimated θ from expected heterozygosity as $H_e = 1 - (1 + 2\theta)^{-1/2}$, giving an average of $\theta = 3.27$. For comparative purposes, we tested both of these measures of θ in our simulations, as well as $\theta = 1$. We varied values of Nm to include 2, 6.2 and 10. We calculated population pairwise F_{ST} between the two simulated populations for each simulation run using Arlequin (Schneider *et al.* 2000). For each parameter set, 1000 simulation runs from both models were compared to determine the average increase in F_{ST} because of barriers.

We compared this simulated average increase in F_{ST} because of barriers (for populations 5 km apart) to the observed increase in F_{ST} resulting from barriers for populations separated by this distance. We estimated the observed increase by regressing F_{ST} on log(geographic distance) for all population pairs with intervening barriers and for all population pairs without intervening barriers, and calculated the difference in the predicted F_{ST} values at 5 km using these two regression equations.

RESULTS

We obtained complete genotypes at all 14 microsatellite loci from 461 faecal and 47 blood or tissue samples. From our analyses of these 508 genotypes, we inferred that they represented a total of 397 individuals, yielding a mean sample size per population of 15 individuals (range 6–29, SD 5.9; Appendix S2). We identified 21 unique mtDNA haplotypes from 394 of these individuals; one haplotype had been previously described (GenBank no. AF076912, Boyce *et al.* 1999). New haplotype sequences were submitted to the GenBank database under the accession numbers AY903993–AY904012. Numbers of alleles and haplotypes per population, A, expected heterozygosity and other basic data are described in Appendix S2.

In the final microsatellite data set, we did not observe any case of allelic dropout among the consensus genotypes of the 111 samples that we identified as duplicates of previously sampled individuals. We found no evidence of linkage disequilibrium within populations after correcting for multiple comparisons.

The average rate of allelic dropout per locus per replicate for the faecal samples was estimated at 3.7%, while rate of occurrence of false alleles was estimated at 0.062%. Overall this yielded a final estimate of 0.022 genotypic errors per individual. Given an error rate of 0.022, in a sample set of *c.* 400 individuals typed at 14 loci, the expectation is approximately 10 single-locus errors in consensus genotypes.

Because this estimated error rate assumes that every sample is heterozygous at all loci, and that there were only two replicate PCR amplifications at each locus, this estimate of the genotype error rate is likely higher than the actual rate: most samples were successfully amplified three to four times. Assuming that genotype errors were randomly distributed with respect to population, this error rate was unlikely to bias our estimates of genetic diversity and divergence in a significant manner for the purposes of this study.

The 'barrier effect distance' was estimated at *c.* 40 km [$\Delta Nm = 5.05 = 3.177 \times \log$('barrier effect' in km)]. Genetic diversity was negatively correlated with both measures of population isolation ($\text{isolation}_{\text{distance}}$ and $\text{isolation}_{\text{distance+barriers}}$) (Fig. 3). However, using $\text{isolation}_{\text{distance+barriers}}$ significantly improved regression model fit for A (Table 1; Fig. 3), indicating that the presence of barriers reduced nuclear genetic diversity. The estimated decline in A for populations isolated by barriers from all three of the nearest populations was as high as 15%. Results for mtDNA haplotype diversity were more equivocal: although $\text{isolation}_{\text{distance+barriers}}$ had a better model fit than $\text{isolation}_{\text{distance+barriers}}$ as assessed by model

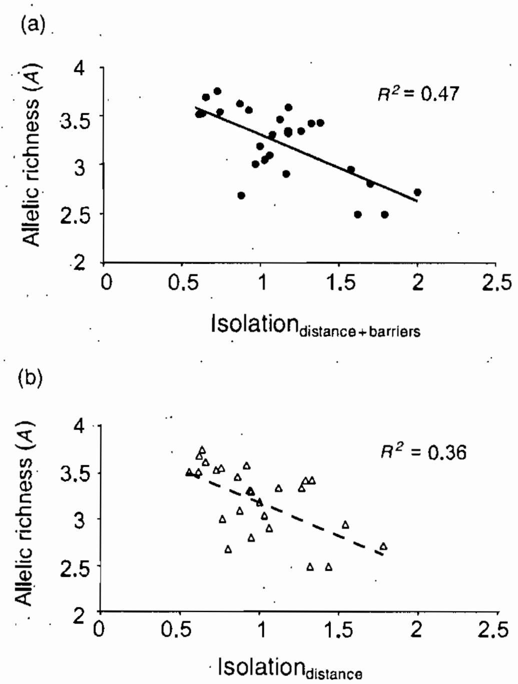

Figure 3 Regressions of allelic richness (A) on isolation as a function of distance and barriers (a) or distance alone (b). Isolation measures are based on log-transformed distances in km (see text).

F-statistic significance and R^2, and greater likelihood as assessed by AIC_c weight, the difference was not enough to clearly indicate that $\text{isolation}_{\text{distance+barriers}}$ was the best model (Table 1). Fits of both models for mtDNA haplotype diversity were poor ($R^2 < 0.20$), suggesting that neither model was adequate. Genetic diversity (nuclear and mitochondrial) was not correlated with population area or current estimated population size (Table 1).

The amount of gene flow among populations was strongly and negatively correlated with barriers at interpopulation distances of < 15 km (Mantel $r = -0.49$, $P = 0.0002$). When the effect of barriers was removed by partial correlation, Nm was strongly correlated among populations within 15 km (Mantel $r = 0.82$, $P = 0.0002$), weakly correlated among populations 15–30 km apart (Mantel $r = 0.16$, $P = 0.0448$), and not correlated among populations separated by greater distances. Plotting Nm as a function of distance also showed that Nm decreased sharply with distance for population pairs not separated by barriers (Fig. 2). Population pairs separated by barriers showed very low Nm values regardless of distance, suggesting that no exchange of individuals occurred across barriers (Fig. 2).

Partial correlations of pairwise F_{ST} values (genetic differentiation; Appendix S3) with barriers and distance showed a similar but weaker pattern. F_{ST} was positively correlated with the presence of barriers at interpopulation distances of < 15 km (Mantel $r = 0.168$, $P = 0.0220$) and 15–30 km (Mantel $r = 0.145$, $P = 0.0446$). F_{ST} was negatively correlated with the presence of populations within 15 km (Mantel $r = -0.444$, $P = 0.0002$), less strongly so at 15–30 km (Mantel $r = -0.174$, $P = 0.0264$), and not significantly correlated at greater distances. Because effects for both factors were detected in the first two distance classes, we also examined them across a 0–30-km distance class: F_{ST} was positively correlated with the presence of barriers (Mantel $r = 0.212$, $P = 0.0034$) and negatively correlated with the presence of populations within 30 km (Mantel $r = -0.441$, $P = 0.0002$).

Simulated datasets revealed that an increase in genetic distance (F_{ST}) because of barriers could be detected within the time frame of the age of the barriers in this study (*c.* 40 years). However, the increase in F_{ST} (0.012–0.018 depending on the parameter values used, Table 2) was not as large as the estimated increase in F_{ST} because of barriers for the actual study populations. The model of two simulated populations, 5 km apart with no intervening barrier, had an average F_{ST} ranging from 0.007 to 0.048 across the parameter set ($F_{ST} = 0.039$ between the study populations from which parameters were derived). Average F_{ST} between two simulated populations with a barrier present during the most recent seven generations increased for all parameter combinations; the increase did not appear to be greatly sensitive to the different values of Nm and θ

Table 1 Regression models of genetic diversity (corrected for sample size) as a function of human-made barriers, distance and other variables for $n = 27$ populations of desert bighorn sheep

Response variable	Model	*P*-value†	R^2‡	*k*§	ΔAIC_c	w_i¶
Allelic richness (corrected)	Log (isolation$_{distance+barriers}$)*	< 0.0001	0.47	3	0	0.88
	Log (isolation$_{distance}$)	0.0010	0.36	3	5.01	0.07
	Log (isolation$_{distance}$), population area	0.0031	0.38	4	6.96	0.03
	Log (isolation$_{distance}$), population size	0.0048	0.36	4	7.90	0.02
Number of mtDNA haplotypes (corrected)	Isolation$_{distance+barriers}$*	0.0388	0.16	3	0	0.63
	Isolation$_{distance}$*	0.0754	0.12	3	1.22	0.34
	Isolation$_{distance}$, population area, population size	0.3035	0.14	5	6.33	0.03

Model selection was performed using Akaike's Information Criterion (AIC_c): models with lowest AIC_c values are best fit, but models within two ΔAIC_c units of the best model are considered equally explanatory. AIC weights (w_i) may be interpreted as the likelihood that the given model is the best of the candidate models (Burnham & Anderson 1998).
*Best-fit or competing model (within two AIC_c units).
†Significance of model *F*-statistic.
‡Fit of linear regression model.
§Number of predictor variables + 2 for calculating AIC_c.
¶AIC_c weight.

Table 2 Increases in average F_{ST} (with standard error) because of elimination of gene flow by a barrier for seven generations between two simulated populations (based on 1000 simulations)

θ	$Nm = 2$	$Nm = 6.2$	$Nm = 10$
1.00	0.015 (0.002)	0.012 (0.003)	0.013 (0.003)
3.27	0.018 (0.005)	0.015 (0.003)*	0.013 (0.003)
8.97	0.013 (0.004)	0.014 (0.002)†	0.012 (0.002)

*Nm calculated from observed F_{ST}, θ estimated from observed heterozygosity.
†Nm calculated from observed F_{ST}, θ estimated from variance in allele size.

that we employed (Table 2). However, the relative increase was sensitive to Nm and θ, in that low values of Nm increased average F_{ST} values between populations but not the difference caused by barriers. Estimated F_{ST} between the actual study populations, 5 km apart with an intervening barrier, increased from 0.046 to 0.113. This estimated increase was based on the regression equations of F_{ST} on distance for population pairs without barriers [$F_{ST} = -0.029 + 0.108 \times \log(\text{geographic distance in km})$] and for population pairs with intervening barriers [$F_{ST} = 0.080 + 0.048 \times \log(\text{geographic distance in km})$].

DISCUSSION

Nuclear genetic diversity of desert bighorn sheep populations was negatively correlated with the presence of human-made barriers that blocked dispersal to nearby populations (Table 1; Fig. 3). This finding strongly suggests that these barriers have reduced genetic diversity for many of these populations. We estimate from our results that nuclear genetic diversity in populations completely isolated by human-made barriers has declined as much as 15% in the *c.* 40 years since most barriers were erected. This estimate implies that the rate of loss of genetic diversity in populations isolated by barriers was *c.* 0.4% per year; if this rate is constant, some populations may lose up to 40% of their pre-barrier genetic diversity in the next 60 years. Results for mtDNA markers were consistent with these findings, but did not clearly support the reduction of mitochondrial genetic diversity because of barriers. The low correlation of mtDNA diversity with either distance and barriers may reflect very low dispersal rates for female bighorn sheep, as suggested by Festa-Bianchet (1991) and Jorgenson *et al.* (1997). More probably, the ambiguous results for mtDNA may reflect the stochasiticity inherent in one genetic locus (as represented by the mtDNA genome) when compared with the results derived from 14 microsatellite loci.

We believe that genetic diversity declined so rapidly after isolation because N_e of each population was likely very small. Therefore, unless diversity was maintained by gene flow from other populations, genetic drift quickly eliminated diversity. Our analyses of gene flow based on regression and partial correlation of Nm and F_{ST} with barriers and distance showed that, where present, human-made barriers have essentially eliminated dispersal (Fig. 2). The suppression of migration by barriers was most detectable within the distances at which high relative gene flow was most detectable, in this case, at < 15 km. Populations < 15 km from other populations maintained higher genetic diversity unless a human-made barrier intervened.

Finally, genetic simulations demonstrated that barriers constructed only 40 years ago could create a detectable increase in genetic distance between populations, although the increase in genetic distance in the simulations was not as great as that observed. This discrepancy may have resulted from a variety of factors. For one, these simple simulations considered only two populations. Actual populations experienced gene flow from other nearby populations, and probably experienced strong fluctuations in population sizes (perhaps caused by strong environmental stochasticity), founder effects, and other demographic events not included in the simulations that may have increased genetic distances. Thus parameter estimates (based on equilibrium conditions) for these simulations may not have been correct, although simulations with varied parameter estimates showed similar increases in genetic distance because of barriers. Historical census data (Torres *et al.* 1994), tiny population sizes and frequent recent extinctions of populations of desert bighorn sheep in California (Epps *et al.* 2004) suggest that fluctuations and founder effects have been common in the decades since the barriers have been constructed. Such metapopulation dynamics may further explain why barriers had such a strong effect on genetic diversity and genetic distance in only *c.* 40 years; this question bears further investigation with more realistic models. However, the detectable differences that our simple simulations yielded support our inference that observed patterns of genetic diversity could be due to the effects of human erected barriers (i.e. occur over such short-time frame).

Because our analyses rely on correlation of the presence of barriers with decreased genetic diversity and increased genetic distance, we cannot exclude the possibility that the genetic structure apparently created by barriers is an artifact of historical genetic structure. However, no other biogeographical explanation for such structure is readily apparent. While it is possible that roads may be constructed preferentially in flat areas or valleys between mountain ranges, nearly all of the populations considered are topographically isolated by flat areas, regardless of the presence of barriers (Fig. 1). Distance thus appears to be the prevailing natural barrier in this system, as evidenced by the strong correlation of genetic diversity and gene flow with distance, and was included explicitly in this analysis. Non-equilibrium conditions may have also affected estimates of genetic distance and other analyses. Despite this, the large number of populations considered and the consistent relationships between genetic diversity, genetic distance and the presence of barriers suggest that these findings are robust.

Our analyses point to the conclusion that human-made barriers may greatly reduce stability of the system as a whole: populations are small and re-colonization of extinct habitat patches is critical for metapopulation persistence (Hanski & Gilpin 1997; Gonzalez *et al.* 1998). Extinction risk for many desert bighorn sheep populations in California is high, and may sharply increase in the coming century because of climate warming (Epps *et al.* 2004). If movement corridors from climatically stable refugia (high-elevation ranges in this case) to more ephemeral patches are severed, re-colonization or demographic 'rescue' will be unlikely to occur. Moreover, connectivity is critical to maintain genetic diversity over the whole metapopulation. Even though strong genetic drift may rapidly remove genetic diversity from individual populations in a functioning metapopulation, this loss can be off-set by gene flow from other populations. However, if barriers disrupt gene flow and recolonization, genetic diversity may be lost very rapidly from the system as a whole (given that the total number of populations in this instance is not large). Thus barriers can have severe consequences both for demographic and genetic processes in metapopulations and may increase the danger of metapopulation extinction.

We recommend that consideration be given to ways to mitigate existing human-made barriers, and that any future construction of major highways in desert bighorn habitat should be designed to minimize disruption of connectivity. Drainage tunnels under interstate highways already exist in some areas (e.g. under Interstate 40 between the Marble and Granite mountains); while presumably large enough to allow traversal by bighorn sheep, these tunnels are within the fenced interstate corridor. Underpasses and overpasses have been used successfully to aid dispersal of carnivores and ungulates (Foster & Humphrey 1995; Gloyne & Clevenger 2001). Changes in fencing could allow access to tunnels while still preventing livestock or wildlife from entering the highway corridor itself. Overpasses could be another, perhaps more effective means of reestablishing connectivity for bighorn sheep, although the cost of such structures could be very high.

As the human population continues to expand, the need to maintain connectivity of natural populations is even greater. Rapid development of highways and other barriers has reduced and fragmented habitat for many species, while global climate change is increasing local extinction rates and forcing latitudinal or elevational shifts in species' distributions (Walther *et al.* 2002). Species-specific solutions to restoring habitat connectivity both in previously fragmented landscapes and relative to future development must be implemented.

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SUPPLEMENTARY MATERIAL

The following supplementary material is available online for this article from http://www.Blackwell-Synergy.com:

Appendix S1 (a) Zinc-finger gene primers and protocol, (b) microsatellite analysis protocols and references, and (c) mitochondrial DNA sequencing protocols.

Appendix S2 Sample sizes for analyses of microsatellite genotypes and mtDNA sequences, and basic genetic and geographical statistics for the 27 populations of desert bighorn sheep used in this study.

Appendix S3 F_{ST} values for all sampled populations, estimated from 14 microsatellite loci using GENEPOP.

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Appendix 1-a Zinc-finger gene primers and protocol.

We used the following primers, designed by R. Ramey, to screen for and remove weakly-amplifying extractions: ZFYf2 5'-3' TTA CTG AAT CGC CAC CTT TTG GC and ZFYr1 5'-3' CTG CAG ACC TAT ATT CGC AGT ACT (annealing temperature 57°; same experimental conditions employed for microsatellite analyses in Wehausen et al. (2004)).

Appendix 1-b Microsatellite analysis protocols and references.

Experimental conditions and references for 11 of the 14 dinucleotide microsatellite loci used in this study were described previously (Wehausen *et al.* 2004); we used the additional loci OarFCB128 and OarFCB266 (Buchanan & Crawford 1993) (annealing temperature 57°) and D5S2 (Steffen *et al.* 1993) (annealing temperature 55°). Amplification products were visualized using an ABI Prism™ 377 (Applied Biosystem Inc., Foster City, USA); alleles were designated using GeneScan™ (version 3.7, Applied Biosystem Inc., Foster City, USA) and Genotyper™ (version 3.7 NT, Applied Biosystem Inc., Foster City, USA).

Appendix 1-c Mitochondrial DNA sequencing protocols.

For mtDNA sequencing, we used ABI Prism™ 377 and 3730 sequencers (Applied Biosystems, Inc., Foster City, USA) and the following primers designed by R. Ramey: L15712 5'-3' AAC CTC CCT AAG ACT CAA GG and BETH 5'-3' ATG GCC CTG

AAG AAA GAA CC. We used 20 μL PCR reactions with the following reaction conditions: 1x PCR Buffer I (Applied BioSystems Inc., Foster City, USA), 0.16 mM dNTPs, 10 μg bovine serum albumin (New England BioLabs, Beverly, USA), 1.9 mM $MgCl_2$, 400 nM each primer, 0.8 units of Amplitaq Gold DNA polymerase (Applied BioSystems Inc., Foster City, USA), and 1 μL of extracted DNA. We used an initial heating cycle of 94° C for 7 minutes 30 seconds, followed by 35 cycles of 94° C for 60 seconds, 61° C for 70 seconds, and 72° C for 90 seconds. We cleaned PCR reactions using 0.2 units of shrimp alkaline phospatase (USB, Cleveland, USA) and 2 units of Exo I (New England Biolabs, Beverly, USA) to clean 1 μL of amplified DNA. We cycle-sequenced with BigDye™ v3.1 (Applied Biosystem Inc., Foster City, USA) following standard protocols.

References (Appendix 1)

Buchanan, F.C. & Crawford, A.M. (1993). Ovine microsatellites at the OarFCB11, OarFCB128, OarFCB193, OarFCB266, and OarFCB304 loci. *Anim. Genet.*, 24, 145.

Steffen, P., Eggen, A., Dietz, A.B., Womack, J.E., Stranzinger, G. & Fries, R. (1993). Isolation and mapping of polymorphic microsatellites in cattle. *Anim. Genet.*, 24, 121-124.

Wehausen, J.D., Ramey II, R.R. & Epps, C.W. (2004). Experiments in DNA extraction and PCR amplification from bighorn sheep feces: the importance of DNA extraction method. *J. Hered.*, 95, 503-509.

Appendix 2 Sample sizes for analyses of microsatellite genotypes and mtDNA sequences (if different, noted parenthetically) and basic genetic and geographic statistics for the 27 populations of desert bighorn sheep used in this study. $Isolation_{\mathrm{DISTANCE}}$ is the harmonic mean of the distances to the nearest three populations; $Isolation_{\mathrm{DISTANCE+BARRIERS}}$ adds the "barrier effect distance" of 40 km to inter-population distances if a barrier intervened (see text).

Population	*n	†H_e	Total alleles	‡A	§N_{HAP}	¶N_{HAP} (corrected)	$Isolation_{\mathrm{DISTANCE}}$ (km)	$Isolation_{\mathrm{DISTANCE+BARRIERS}}$ (km)
Clark	12	0.614	57	3.52	2	1.92	4.1	4.3
Clipper	16	0.647	54	3.31	4	3.30	8.6	15.1
Coxcomb	7	0.622	51	3.46	3	2.86	7.3	13.5
Cushenbury	15	0.489	38	2.49	1	1	20.8	62.6
Chemehuevi	9	0.571	51	2.94	1	1	34.8	37.8
Eagle-Buzzard Spr.	17	0.653	61	3.68	1	1	4.2	4.5
Eagle-Lost Palms	14	0.627	62	3.75	3	2.31	4.4	5.3
Granite	21	0.627	66	3.62	6	3.52	4.6	7.5
Hackberry	13	0.637	49	3.18	1	1	10.0	10.0
Iron	11	0.537	43	2.68	2	1.51	6.4	7.6

Cady	12	0.591	53	3.34	4	3.28	13.2	15.1
Little San Bernardino	12	0.626	57	3.58	3	2.34	8.3	15.2
Marble	29 (28)	0.644	61	3.55	3	1.77	5.8	8.5
Newberry	15	0.496	37	2.49	2	1.93	27.2	42.0
Old Dad	25	0.561	51	3.04	3	2.75	10.7	10.7
Indian Spring	12	0.475	48	2.90	3	2.06	11.5	14.7
Orocopia	18	0.568	47	3.00	3	1.97	5.9	9.4
Old Woman	26	0.512	54	3.04	3	2.39	10.8	10.8
Piute Range	13	0.627	55	3.42	3	2.68	21.3	21.3
Providence	20	0.628	59	3.51	5	3.37	3.6	4.1
Queen	11	0.594	55	3.42	3	2.49	19.4	24.4
Riverside Granite	10 (8)	0.609	47	3.09	2	2.00	7.5	11.5
South Bristol	14	0.599	51	3.29	2	1.98	8.9	12.1

San Gorgonio	17	0.539	44	2.80	1	1	8.9	50.3
San Gabriel	6	0.549	38	2.71	1	1	60.6	101.8
Turtle	14	0.635	54	3.33	2	1.43	18.3	18.3
Wood	10	0.622	55	3.53	3	2.49	5.3	5.6

* number of individuals sampled per population

† expected heterozygosity

‡ allelic richness corrected for variation in sample size

§ number of mtDNA haplotypes detected

¶ number of mtDNA haplotypes corrected for variation in sample size

Appendix 3 F_{ST} values for all sampled populations, estimated from 14 microsatellite loci using GENEPOP. All values were significantly different ($p<0.05$). Population names are abbreviated but are presented in the same order as in Appendix 2.

	CL	CO	CU	CV	EABZ	EALP	GR	HA	IR	KD	LS	MA	NE	OD	OE	OR	OW	PI	PR	QU	RG	SB	SG	SL	TU	WO
CK	0.13	0.14	0.29	0.16	0.10	0.11	0.09	0.11	0.21	0.15	0.13	0.14	0.25	0.15	0.20	0.15	0.18	0.09	0.12	0.13	0.12	0.15	0.21	0.15	0.14	0.10
CL		0.15	0.24	0.18	0.10	0.10	0.08	0.14	0.21	0.13	0.13	0.05	0.20	0.15	0.19	0.18	0.17	0.12	0.11	0.15	0.11	0.07	0.20	0.20	0.16	0.13
CO			0.27	0.16	0.11	0.07	0.07	0.10	0.16	0.10	0.10	0.14	0.26	0.06	0.20	0.19	0.12	0.11	0.10	0.09	0.10	0.15	0.16	0.22	0.16	0.06
CU				0.35	0.18	0.18	0.20	0.31	0.26	0.28	0.20	0.25	0.37	0.27	0.32	0.29	0.22	0.26	0.27	0.23	0.22	0.24	0.07	0.37	0.31	0.26
CV					0.21	0.21	0.12	0.15	0.29	0.18	0.24	0.18	0.33	0.18	0.24	0.25	0.22	0.16	0.19	0.22	0.20	0.19	0.27	0.26	0.22	0.14
EABZ						0.02	0.07	0.13	0.17	0.14	0.04	0.13	0.25	0.15	0.19	0.15	0.13	0.10	0.09	0.06	0.07	0.12	0.12	0.21	0.13	0.12
EALP							0.06	0.12	0.13	0.13	0.04	0.12	0.23	0.11	0.18	0.16	0.10	0.10	0.08	0.03	0.07	0.10	0.12	0.20	0.12	0.09
GR								0.06	0.17	0.11	0.08	0.10	0.18	0.09	0.13	0.17	0.12	0.08	0.05	0.11	0.08	0.11	0.13	0.17	0.13	0.05
HA									0.21	0.14	0.13	0.13	0.21	0.14	0.19	0.22	0.18	0.08	0.06	0.16	0.17	0.16	0.21	0.17	0.18	0.02
IR										0.24	0.18	0.21	0.32	0.19	0.29	0.29	0.05	0.19	0.18	0.14	0.17	0.23	0.19	0.21	0.21	0.19
KD											0.15	0.09	0.26	0.11	0.10	0.17	0.17	0.12	0.15	0.16	0.12	0.12	0.20	0.21	0.18	0.12
LS												0.14	0.24	0.16	0.21	0.17	0.13	0.12	0.12	0.05	0.11	0.14	0.15	0.22	0.13	0.13
MA													0.14	0.16	0.18	0.17	0.15	0.10	0.11	0.16	0.12	0.04	0.19	0.20	0.15	0.13
NE														0.27	0.35	0.30	0.26	0.15	0.19	0.25	0.28	0.19	0.27	0.32	0.25	0.24
OD															0.10	0.23	0.16	0.13	0.11	0.17	0.15	0.15	0.18	0.21	0.20	0.11
OE																0.26	0.20	0.19	0.18	0.22	0.21	0.20	0.24	0.24	0.26	0.17
OR																	0.23	0.20	0.22	0.13	0.15	0.16	0.24	0.25	0.20	0.22
OW																		0.14	0.15	0.10	0.11	0.17	0.16	0.18	0.15	0.16
PI																			0.07	0.13	0.12	0.12	0.16	0.17	0.09	0.05
PR																				0.13	0.15	0.14	0.17	0.18	0.15	0.05
QU																					0.09	0.14	0.16	0.21	0.15	0.15
RG																						0.13	0.16	0.22	0.13	0.13
SB																							0.20	0.23	0.18	0.14
SG																								0.27	0.21	0.18
SL																									0.22	0.18
TU																										0.16

unit boundaries were based on proposed DWMAs in the Draft Recovery Plan for the Desert Tortoise (Mojave Population) (Fish and Wildlife Service 1993) (Appendix H). Further discussion of critical habitat and its relevance to recovery of the species can be found in Section II.E.

3. *Current population trends.*

It is estimated that many desert tortoise populations have declined at rates ranging between 3 and 59 % per year (Berry 1990, as amended). These declines have been attributed to direct take by humans (e.g., collection for pets or food, shooting, killing and injuring with motor vehicles); habitat loss, degradation, and fragmentation (e.g., due to roads, agriculture, residential development, military training); diseases; and recent drought (Sievers et al. 1988, Luckenbach 1982, Coombs 1977a and b, Appendix D). Populations in areas with a high incidence of known human-caused mortality exhibit the greatest declines (Figure 1).

B. *Reasons for Decline.*

The following account draws upon a large body of literature detailing the major causes of desert tortoise population decline (Table 1). This information is reviewed in Appendix D and in Jacobson (1994), except where otherwise cited.

The most serious problem facing the remaining desert tortoise populations in the Mojave region (the area occupied by the Mojave population of the desert tortoise) is the cumulative load of human and disease-related mortality accompanied by habitat destruction, degradation, and fragmentation. Virtually every extant desert tortoise population has been affected by one or more of these factors. While the recent drought undoubtedly exacerbated already difficult conditions for desert tortoises, current population declines are not simply the result of drought. Drought is a natural occurrence which desert tortoises have experienced and survived for thousands of years (VanDevender et al. 1987).

As a result of cumulative impacts, desert tortoise populations have been extirpated or almost extirpated from large portions of the western and northern parts of their geographic range in California (e.g., Antelope, Indian Wells, and Searles valleys) (Appendix D). Population declines or extirpations attributable to cumulative impacts have occurred in and near the California communities of Mojave, Boron, Kramer Junction, Barstow, Victorville, Apple Valley, Lucerne Valley, and Twentynine Palms. Similar patterns are evident near Las Vegas, Laughlin, and Mesquite, Nevada; and St. George, Utah. Future extirpations can be expected in the vicinity of all cities, towns, and settlements.

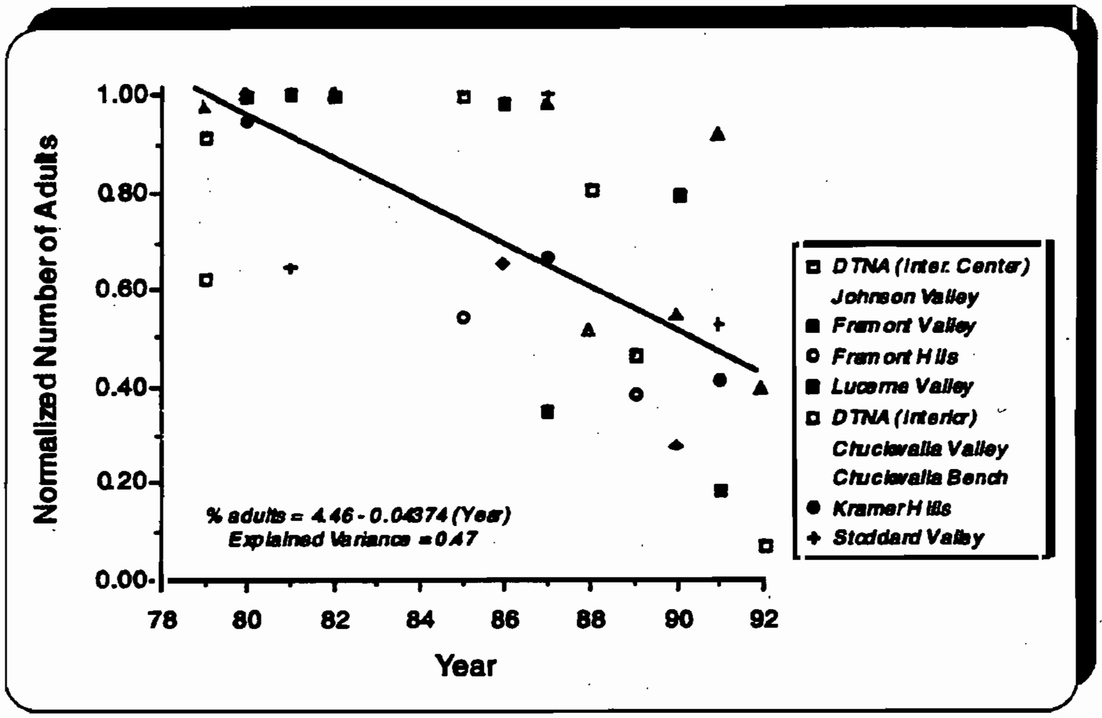

Figure 1. The number of adult desert tortoises found on desert tortoise trend plots located in California (Berry 1990, as amended) The study plots shown occur in areas with a high incidence of known human-caused mortality. All data are normalized to the highest population size recorded within the years populations were monitored. The downward trend in population density is highly significant ($F_{1,14} = 28.4$, $p < 0.0001$).

Table 1. Partial summary of references relating the effects (direct and indirect) of human activities, off highway vehicles (OHVs), and grazing of domestic cattle and sheep on desert tortoise habitat and on the desert tortoise (*Gopherus agassizii*).

HUMAN ACTIVITIES

Effects of Human Population Growth and Urbanization
- Biosystems 1992
- Berry 1984b
- Berry and Burge 1984
- Berry and Nicholson 1984b
- Klemens 1989
- Lamb 1991
- Swingland and Klemens 1989
- Tierra Madre 1991

Effects of Freeways, Highways, Paved and Dirt Roads, and Railroads
- Berry et al. 1986a
- Berry and Turner 1984
- Boarman et al. 1992
- Dames and Moore 1991
- Goodlett and Goodlett 1991, 1992
- Marlow and Hoff 1992
- Mount 1986
- Nicholson 1978a, 1978b
- U.S. Ecology 1989

Effects of Military Operations
- Berry and Nicholson 1984b
- Krzysik 1985
- Krzysik and Woodman 1991
- Prose 1985, 1986
- Prose and Metzger 1985
- Prose et al. 1987

Effects of Energy (transmission and pipelines), and Mineral Development
- Berry 1984b
- Berry and Nicholson 1984b
- Biosystems 1992
- Brum et al. 1983
- Riedy 1989
- Robinette 1973
- Woodman et al. 1983

Human Vandalism
- Berry 1984b, 1986a, 1990, as amended
- Berry and Nicholson 1984b
- Berry et al. 1986a
- Bury and Marlow 1973
- Campbell 1981
- Ginn 1990
- Jaeger 1950
- Jennings 1991

Human Predation for Food
- Ditzler 1991
- Swingland and Klemens 1989
- Schneider and Everson 1989

Collection and Commercial Trade
- Berry 1990, as amended
- Berry and Burge 1984
- Berry and Nicholson 1984b
- Ginn 1990
- Howland 1989
- Jennings 1991
- St. Amant 1984
- Stewart 1991

USE OF OHVs

Immediate Effects

Loss of Soil
- Wilshire 1977a, 1977b, 1979
- Wilshire et al. 1977

Loss of Annual Plants, Grasses
- BLM 1975
- Wilshire et al. 1977

Loss of Perennial Plants
- Wilshire 1979
- Wilshire et al. 1977

Loss of Desert Tortoise Burrows
- Burge 1983
- Bury 1978
- Bury and Luckenbach 1986
- Bury and Marlow 1973

Crushing Desert Tortoises
- Bury and Luckenbach 1986
- Luckenbach 1975

Delayed and Cumulative Effects

Loss of Soil
- Baldwin and Stoddard 1973
- Gilette and Adams 1983
- Hinckley et al. 1983
- Nakata 1983
- Sheridan 1979
- Stull et al. 1979
- Wilshire 1980
- Wilshire et al. 1977

Soil Compaction
- Adams et al. 1982a
- Bodman and Constantin 1965
- Dickey et al. 1973
- Webb 1983
- Webb et al. 1978
- Wilshire 1977a, b
- Wilshire and Nakata 1976
- Wilshire et al. 1977

Effect on Annual Plants
- Adams et al. 1982a, 1982b
- Rowlands et al. 1980

Effect on Perennial Plants
- Biosystems 1992
- Bury and Luckenbach 1983, 1986
- Bury et al. 1977
- Davidson and Fox 1974
- Keefe and Berry 1973
- Lathrop 1983a, b
- Vollmer et al. 1976

Effects on Live Desert Tortoises
- Bury 1987
- Bury and Luckenbach 1986
- Bury et al. 1977

Effects on Other Vertebrates
- Berry 1973
- Bondello 1976
- Brattstrom and Bondello 1983
- Bury and Luckenbach 1983
- Bury et al. 1977
- Busack and Bury 1974
- U.S. BLM 1975

GRAZING OF DOMESTIC SHEEP AND CATTLE

Changes in Habitat

Soil
- Arndt 1966
- Avery et al. 1992
- Ellison 1960
- Gifford and Hawkins 1978
- Klemmedson 1956
- Sharp et al. 1964

Vegetation
- Bentley 1898
- Clements 1934
- Coombs 1977a, b
- Corbett 1952
- Ellison 1960
- Frenkel 1970
- Gardner 1951
- Hardy 1945
- Humphrey 1958, 1987
- Janzen 1986
- Kay et al. 1988
- Mack 1981
- Nicholson and Humphreys 1981
- Orians 1984
- Reynolds 1958
- Rowlands et al. 1980
- BLM 1980a
- Webb and Stielstra 1979
- Wester 1981

Competition Between Tortoises and Livestock
- Berry 1978
- Biosystems 1992
- Coombs 1979
- Medica et al. 1982
- Nicholson and Humphreys 1981
- Sheppard 1981

Trampling
- Berry 1978
- Berry and Shields et al. 1986
- Knowles 1987
- Marlow 1974
- Nicholson and Humphreys 1981
- Rauzi and Smith 1973
- Webb and Wilshire 1980

Consequences of Altered Habitat
- Coe et al. 1976, 1979
- Congdon and Gibbons 1985
- Gibbons and Patterson 1982
- Gibbons et al. 1983
- Jarchow and May 1989
- Jones 1987
- Mitchell 1985
- Swingland and Coe 1979
- Tracy 1992
- Turner et al. 1984, 1987
- Wingfield 1983

Population Declines in the Tortoise and Other Native Herbivores
- Busack and Bury 1974
- Karl 1980, 1982
- Medin and Cleary 1989
- Phillips 1936
- Turner et al. 1981

1. Human contact and direct mortality.

Human "predation" is a major factor in the decline of the desert tortoise. Here predation is used in its broadest sense, meaning the taking of desert tortoises out of their natural populations either by death (accidental or intentional) or by removal. People illegally collect desert tortoises for pets, food, and commercial trade. Some new immigrants to the United States collect desert tortoises for medicinal or other cultural purposes (Section 4.1 of Appendix D). Stewart (1991) reported that from 12.5 to 43.7% of desert tortoises with radio transmitters were poached or suspected of being poached from his research site in the western Mojave Desert between 1987 and 1991. Berry (1990, as amended) presented similar evidence of illegal collections at a study plot near Stewart's site during the 1980's. Even in remote areas, desert tortoises on permanent study plots have been collected and later have appeared in cities or towns dozens of miles away from the plots.

Desert tortoises are often struck and killed by vehicles on roads and highways, and mortality of desert tortoises due to gunshot and off-highway vehicles is common in parts of the Mojave region, particularly near cities and towns where people and desert tortoises most frequently come in contact. For example, between 1981 and 1987, 40% of the desert tortoises found dead on a study plot in the Fremont Valley, California, were killed by gunshot or vehicles traveling cross-country or on trails (Berry 1990, as amended). Berry (1986a) reported that nearly 15% of 635 desert tortoise carcasses that were examined from several California study sites showed signs of gunshot.

2. Predation.

Desert tortoises, particularly hatchlings and juveniles, are preyed upon by several native species of mammals, reptiles, and birds. Domestic and feral dogs are a new, and probably significant, source of mortality (Causey and Cude 1978, Berry 1979). Predation by the common raven (*Corvus corax*) is intense on younger age classes of the desert tortoise, and the Fish and Wildlife Service's Breeding Bird Survey Program provided data to show a 15-fold increase in raven populations in the Mojave Desert and a 4.7-fold increase in raven populations in the Colorado and Sonoran deserts from 1968 and 1988 (Bureau of Land Management et al. 1989, Table 1). Raven population increases seem to be due to increased food supplies, (e.g., roadkills, landfills, trash, garbage dumps, agricultural developments), as well as new sites for perches and nests (e.g., fence posts, power poles and towers, signs, buildings, bridges, and freeway access-ramps).

The contribution of mammalian or avian predation to overall desert tortoise mortality is not well understood. The best-documented predator is the raven. Berry (1990, as amended) believes that predation pressure from ravens probably has resulted in such high losses of juveniles in some portions of the Mojave region that recruitment of immature desert tortoises into the adult population has been halted. Increased mortality of young desert tortoises combined with drastically lowered survivorship of adults is likely responsible for observed catastrophic population declines (Berry 1990, as amended).

3. *Disease.*

Disease has contributed to high mortality rates in the western Mojave Desert in the last four years (Berry 1990, as amended, Avery and Berry 1990, Jacobson 1994). Disease is also suspected of contributing to declines in desert tortoise populations in the Chuckwalla Bench area of the eastern Colorado Desert and at some sites on the Beaver Dam Slope in the northeastern Mojave Desert (Berry 1992, Jacobson et al. 1994).

An upper respiratory tract disease (URTD) is prevalent in captive desert tortoises and has been identified in wild desert tortoises in many localities in the Mojave region. The disease is currently a major cause of mortality in the western Mojave Desert and perhaps elsewhere. Recent studies have demonstrated *Mycoplasma agassizii* sp. nov. as the causative agent of URTD. A serological test has been developed to determine exposure status of desert tortoises to URTD (Schumacher et al. 1993). Predisposing factors such as habitat degradation, poor nutrition, and drought are also likely involved (Jacobson et al. 1991). Drought and concomitant poor nutrition have the potential to compromise desert tortoises immunologically and, therefore, make them more susceptible to URTD. However, in recent experimental studies, URTD was induced in apparently healthy desert tortoises when challenged with an isolate of *M. agassizii* obtained from an ill desert tortoise (M.B. Brown, University of Florida, pers. comm. 1993). Under certain conditions, even healthy desert tortoises may become infected with the causative organism and develop signs of URTD. Controlling human-related spread of URTD (Jacobson 1994), improving habitat conditions, and monitoring health status of desert tortoise populations are some of the more important management tools which can be used in controlling URTD in wild populations of the desert tortoise.

URTD appears to be spreading, and may have been introduced to wild populations through illegal releases of captive desert tortoises that were ill (Jacobson 1994). Wild desert tortoises with signs of URTD are commonly found near cities and towns with concentrations of captive desert tortoises (Marlow and Brussard 1992).

A shell disease, characterized by lesions, is correlated with desert tortoise decline in the Chuckwalla Bench population in the eastern Colorado Desert (Jacobson et al. 1994, Berry 1992). Lesions typically appear at seams between adjacent scutes and then spread toward the middle of each scute in an irregular pattern. A variety of mineral and metal deficiencies, as well as various toxicants, are known to cause integumentary pathology in mammals, suggesting a disease or toxicosis may be responsible for these observed shell abnormalities (Appendix D).

4. *Habitat destruction, degradation, and fragmentation.*

Changes in vegetation accumulating over almost a century and a half in the Mojave region have been substantial. In general, these changes are characterized by decreases in perennial grasses and native annuals and an increase in exotic ephemerals such as red brome (*Bromus rubens*). Continuous stands of exotic ephemerals provide fuel which can carry fire over large areas. Historically, fires were small or infrequent over vast areas of the Mojave region, and because native desert plants have not evolved with fire and are not adapted to it, they generally are killed by high-intensity fire. The increasing incidence and severity of fires in the Mojave region are already converting desert shrublands into ephemeral grasslands. The effects of invading exotic grasses on several ecosystems have recently been reviewed by D'Antonio and Vitousek (1992).

These vegetational changes can be detrimental to desert tortoises for a number of reasons. First, these animals require perennial shrubs for cover from the intense solar radiation in the desert. Second, perennial grasses are important secondary food sources for the desert tortoise in many areas. Third, recurrent fires and competition from exotic ephemerals may reduce the abundance and diversity of native forbs which are the major food source of the desert tortoise. Finally, major fires fragment desert tortoise habitat; fires can also kill desert tortoises (Appendix D).

Habitat fragmentation is a major contributor to population declines (Berry 1984b, Berry and Burge 1984, Berry and Nicholson 1984b, and Berry 1984c). Desert tortoises require a great deal of space to survive (Figure 2; see also Appendix C). Over its lifetime, each desert tortoise may require more than 1.5 square miles of habitat and may make forays of more than 7 miles at a time (Berry 1986b; Esque et al. in prep; K.H. Berry, pers. comm. 1993). In drought years, desert tortoises forage over larger areas (Figure 2) and thus have a greater probability of encountering potential sources of mortality. Roads and urban areas form barriers to movement and tend to create small, local populations which are much more susceptible to extinction than large, connected ones (Wilcox and Murphy 1985).

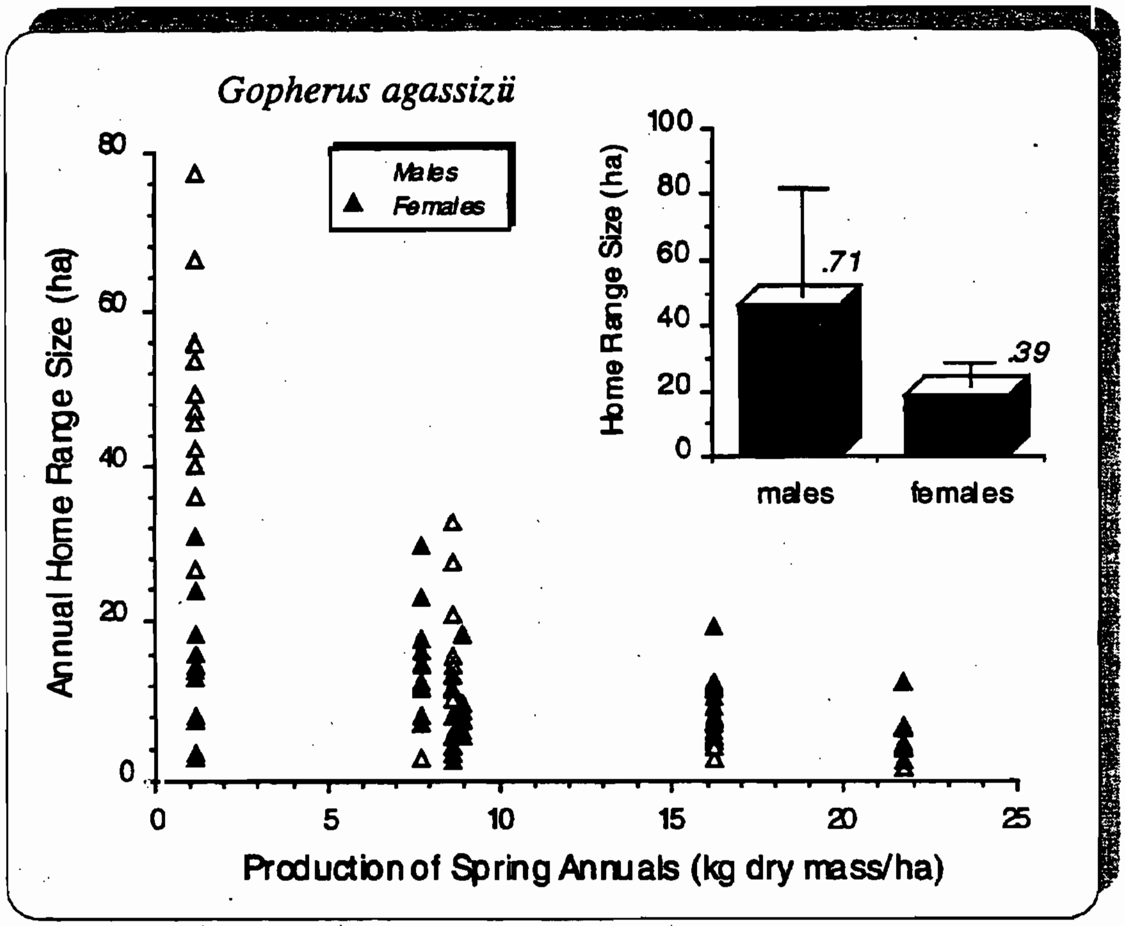

Figure 2. Annual home range sizes of desert tortoises as a function of the amount of food resources (spring annual plants) (from Esque et al., in prep.)

Grazing by cattle, domestic sheep, and feral equids can also affect desert tortoises and their habitats negatively. Livestock can kill desert tortoises and eggs directly by trampling. Grazing can also damage soil crusts, reduce water infiltration, promote erosion, inhibit nitrogen fixation in desert plants, and provide a favorable seed bed for exotic annual vegetation. Habitat destruction and degradation is especially evident in the vicinity of livestock water sources. Off-road vehicle (ORV) use also destroys, degrades, and fragments considerable areas of desert tortoise habitat; and disturbances from both grazing and ORVs facilitate the invasion of exotic plants and increased incidence of fire (Table 1, Appendix D).

A variety of other human uses have caused significant quantitative and qualitative losses of desert tortoise habitat. Urbanization; agricultural development; construction and use of transportation routes and corridors; development of utility corridors; exploration for and development of hard rock minerals, sand and gravel pits, oil and gas, and other mineral resources; and concentrated visitor use are all important causes of widespread habitat destruction. In some portions of the desert, military activities such as maneuvers, bombings, and explosions also contribute to the degradation and loss of desert tortoise habitat (Kryzik and Woodman 1991, Fish and Wildlife Service 1992). The combined effects of these various activities have resulted in extirpations and population declines of desert tortoises throughout the Mojave region. The relative contributions of these factors are well documented in some areas, but not in others (Table 1, Appendix D).

C. *Current Management*

1. *Endangered Species Act protection.*

Section 9 of the Endangered Species Act prohibits the take of any listed wildlife species, including the desert tortoise. The definition of "take" includes to harass, harm, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct. "Harm", in the definition of "take", includes significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). Sections 7 and 10 of the Endangered Species Act provide regulatory mechanisms for actions affecting desert tortoises on public and private lands, respectively. Section 7(a)(1) directs Federal agencies to use their authorities to carry out programs for the conservation of endangered and threatened species. Through the section 7(a)(2) process, all Federal agencies are required to ensure that any action they authorize, fund, or carry out in the United States or upon the high seas is not likely to jeopardize the continued existence of any listed species [50 CFR 402.01(a)]. Section 10(a)(1)(B) of the Endangered Species Act gives the Fish and Wildlife Service the authority to issue permits to non-Federal and private entities for the

Exhibit 013

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

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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

Russell Scofield, DOI Coordinator

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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

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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

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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.

Exhibit 614

Exhibit 615

2.2.4.10.23 White-margined Beardtongue

This species is a disjunct with a very limited range within California, all within the West Mojave. Incidental take would be limited to 50 acres of occupied and potential habitat.

(P-55) Acquire one private parcel where this plant occurs within the proposed Pisgah ACEC if feasible.

Designate the Pisgah area as an ACEC (see HCA-3, Map 2-12B). Designate routes within the ACEC as open or closed and restore or block routes to be closed. Change the multiple use class from M to L.