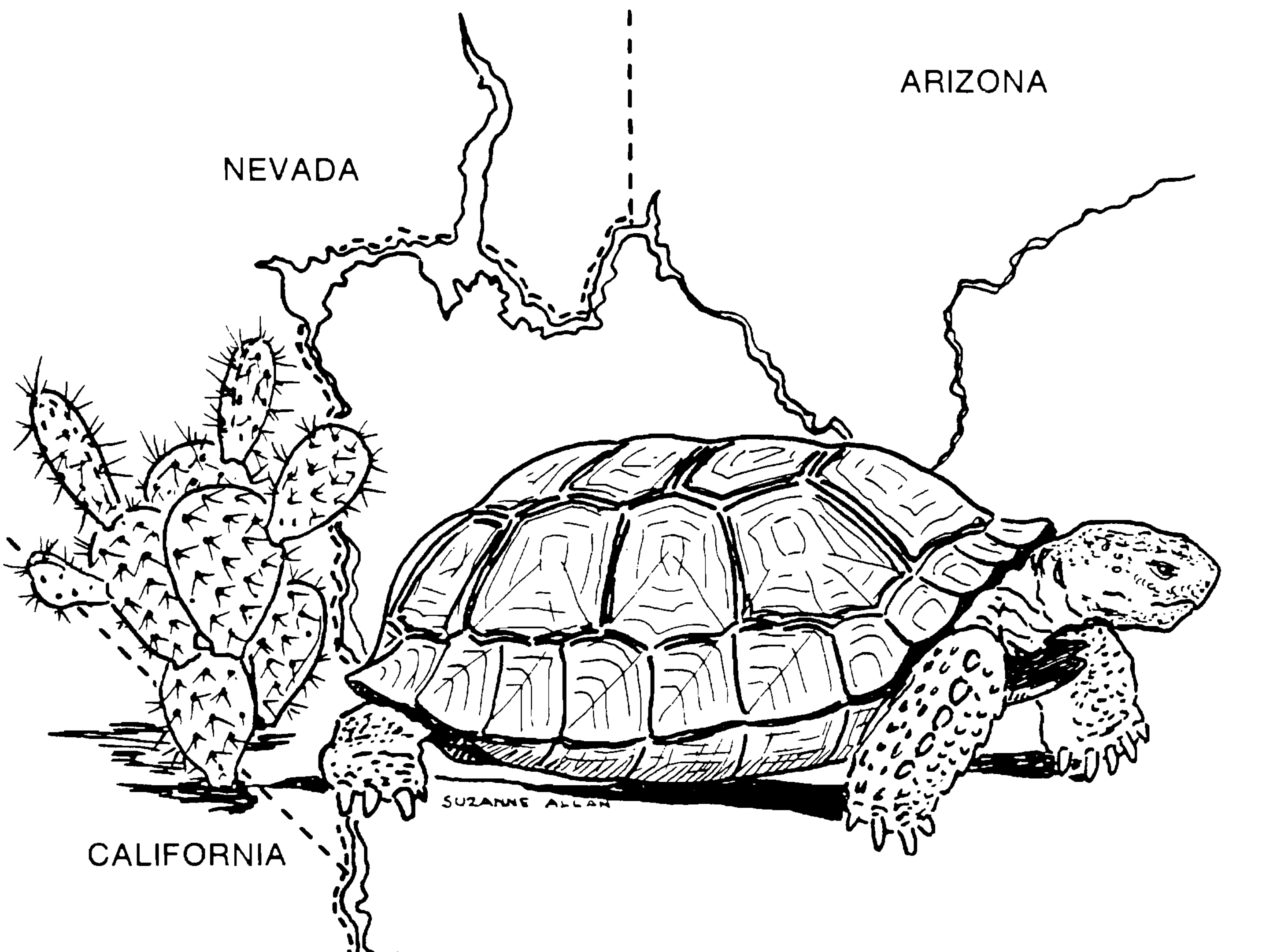
THE DESERT TORTOISE COUNCIL



PROCEEDINGS OF 1995 SYMPOSIUM

DESERT TORTOISE COUNCIL
PROCEEDINGS OF THE 1995 SYMPOSIUM

A compilation of reports and papers presented at
the twentieth annual symposium of the Desert Tortoise Council,
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DESERT TORTOISE COUNCIL
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TABLE OF CONTENTS

(* Denotes abstracts submitted in place of manuscripts that were either published elsewhere or not submitted by Proceedings deadline. Editor)

Health Profiles, Diseases, and Physiology of Desert and Gopher Tortoises

Mitigating the Impacts to Desert Tortoise Populations and Habitat: Fences, Easements, and Land-use Planning

Turtles of the United States

<u>Posters</u>

CONTRIBUTORS

Steve Ahmann
National Training Center
Directorate of Public Works
Environmental Div.-Natural Resources
ATTN: AFZJ-DPW-EN, Bldg. 385
Fort Irwin, CA 92310

Dr. Mary Allen
National Zoological Park
Smithsonian Institution
Washington, D.C. 20008

Dr. Patricia S. Ashton
Water and Air Research, Inc.
6821 SW Archer Rd.
Gainesville, Florida 32608

Dr. Ray E. Ashton, Jr.
Water and Air Research, Inc.
6821 SW Archer Rd.
Gainesville, Florida 32608

Dr. Ernst Baard
Chief Directorate, Nature and
Environmental Conservation
Western Cape Scientific Services
Private Bag X5019
Stellenbosch, 7600
REPUBLIC OF SOUTH AFRICA

Dr. David Baer
Allen and Baer Associates
713 Hillsboro Dr.
Silver Spring, MD 20902

John Behler
Dept. Of Herpetology
Bronx Zoo
185th Street and Southern Blvd.
Bronx, NY 10460

Dr. Joan E. Diemer Berish
Florida Game and Fresh Water
Fish Commission
Wildlife Research Laboratory
4005 S. Main St.
Gainesville, FL 32601-9099

Dr. Kristin H. Berry
National Biological Service
Riverside Field Station
6221 Box Springs Blvd.
Riverside, CA 92507-0714

Dr. William I. Boarman
National Biological Service
Riverside Field Station
6221 Box Springs Blvd.
Riverside, CA 92507-0714

Matthew Brooks
19654 Ave. 304
Exeter, CA 93221

Dr. Dan Brown
Dept. of Infectious Diseases
College of Veterinary Medicine
University of Florida
Gainesville, FL 32611-0926

Greg A. Brown
EG&G Energy Measurements, Inc.
P.O. Box 1912
Las Vegas, NV 89125

Dr. Mary Brown
Dept. of Infectious Diseases
College of Veterinary Medicine
Gainesville, FL 32611-0880

Betty Burge
Tortoise Group
5157 Poncho Circle
Las Vegas, NV 89119

Dr. Linda Cayot
Charles Darwin Research Station
Isla Santa Cruz, Galapagos Islands
ECUADOR

Dr. Mary Christopher
Dept. of Veterinary Pathology,
Microbiology and Immunology
School of Veterinary Medicine
University of California
Davis, CA 95616

Roger Dale
Nonprofit Counsel
16633 Ventura Blvd., Ste. 1200
Encino, CA 91436

Wanda S. Deal
Environmental Management
Edwards AFB, CA 93524

Dr. Jerry Freilich
Joshua Tree National Park
74485 National Park Dr.
Twentynine Palms, CA 92277

Rod G. Goodwin
EG&G Energy Measurements
P.O. Box 1912, Mail Stop P-03
Las Vegas, NV 89125

Dr. Marc Graff
Calif. Turtle and Tortoise Club
17259 Ballinger St.
Northridge, CA 91325-1929

Brian T. Henen
Dept. of Biology & Div. of
Environmental Biology
University of California
Los Angeles, CA 90024-1606

Dr. Karen von Seckendorff Hoff
Dept. of Biological Sciences
University of Nevada
Las Vegas, NV 89154-4004

Eric A. Holt
EG&G Energy Measurements, Inc.
P.O. Box 1912
Las Vegas, NV 89125

Dr. Bruce L. Homer
College of Veterinary Medicine
University of Florida
P.O. Box 100145
Gainesville, FL 32610-0145

Franklin G. Hoover
California Dept. of Fish and Game
4775 Bird Farm Rd.
Chino Hills, CA 91709

Jeffrey M. Howland
Nongame Branch
Arizona Game and Fish Dept.
2221 W. Greenway Rd.
Phoenix, AZ 85023

Jim Keeler
U.S. Dept. of the Interior
Bureau of Land Management
Ridgecrest Resource Area
Ridgecrest, CA 93555

Robert V. Keeran
R V Realty
26464 National Trails Hwy.
P.O. Drawer 59
Helendale, CA 92342

Anthony J. Krzysik
U.S. Army - CERL
University of Illinois
220 Davenport Hall
607 S. Mathews Ave.
Urbana, IL 61801

Dr. Valentine Lance
The Zoological Society of San Diego
P.O. Box 551
San Diego, CA 92112-0551

Dr. Jeff Lovich
National Biological Service
63-500 Garnet Ave.
North Palm Springs, CA 92258

Dr. Ronald William Marlow
Biology Dept.
University of Nevada
Reno, NV 89557

Dr. Grace S. McLaughlin
Dept. of Infectious Diseases
College of Veterinary Medicine
University of Florida
Gainesville, Florida 32611-0880

Ann McLuckie
Bureau of Land Management
Kingman Resource Area
2475 Beverly Ave.
Kingman, AZ 86401

Dr. David J. Morafka
Dept. of Biology
California State University
Dominquez Hills
Carson, CA 90747

Robert W. Murphy
Dept. of Ichthyology and Herpetology
Royal Ontario Museum
100 Queen's Park
Toronto, Ontario
CANADA M5S 2C6

Dr. Kenneth Nagy
Laboratory of Structural
Biology and Molecular Medicine
900 Veteran Ave.
Los Angeles, CA 90024-1786

Dr. Olav T. Oftedal
Dept. of Zoological Research
National Zoological Park
Smithsonian Institution
Washington D.C. 20008

Dr. John Oldemeyer
National Biological Service
4512 McMurry Ave.
Ft. Collins, CO 80525

Ernest Quintana
Park Superintendent
Joshua Tree National Park
Twentynine Palms, CA 92277

Anders G.J. Rhodin
Chelonian Research Foundation
168 Goodrich St.
Lunenburg, MA 01462

Dr. Laura K. Richman
Dept. of Pathology
National Zoological park
Smithsonian Institution
Washington, D.C. 20008

Dolores Savignano
U.S. Fish and Wildlife Service
1500 N. Decatur Blvd. #01
Las Vegas, NV 89108

Paul T. Selzer, Esq.
Best, Best & Krieger
800 E. Tanquitz Canyon Way
Palm Springs, CA 92263

Dr. Jay Schulkin
Dept. of Physiology and Biophysics
Georgetown University
Washington, D.C. 20027

E. Karen Spangenberg
Dept. of Biology
California State University
Dominguez Hills
Carson, CA 90747

Dr. Glenn Stewart
Biology Dept.
Cal Poly Pomona
3801 W. Temple Ave.
Pomona, CA 91768

Dan C. Steen
EG&G Energy Measurements
P.O. Box 1912
Las Vegas, NV 89125

Doug Threloff
Death Valley National Park
Death Valley, CA 92328

1995 AWARDS

DESERT TORTOISE COUNCIL ANNUAL AWARD

Mike Giusti

Each year, the Desert Tortoise Council, through its Board of Directors, determines whether an individual, group of individuals, or an entity merits recognition as a recipient of the Council's Annual Award. This award is presented to acknowledge significant contribution to the furtherance of preservation and protection of the desert tortoise throughout its range as a species important to the ecosystem it inhabits. This year, the Council not only recognizes an individual who has contributed to the well being of the desert tortoise through actions based on the biology of the animal and directed towards its conservation in relation to ever mounting pressures of human development and recreation, but one who has contributed immeasurably to the continued success of this organization over the years.

It is with great pleasure that the Council recognized Mr. Mike Giusti as this year's recipient of its Annual Award.

Mike is a biologist with the California Department of Fish and Game in Region 5. While not his sole responsibility, Mike has spent many hours, a considerable amount of it on his own time, dealing with problems associated with desert tortoise management and protection. He has contributed to the Council's project review and comment efforts by providing valuable input for consideration by project proponents and responsible regulatory bodies. In addition to these praiseworthy contributions to the desert tortoise as an important natural resource, Mike has assisted this organization immensely by making arrangements for many prior Council Symposia.

SPECIAL AWARD FOR DISTINGUISHED SERVICE

Dan Pearson

This year the Desert Tortoise Council is presenting a Special Award in recognition of distinguished service toward the conservation of the desert tortoise and its habitat. This award goes to a long-time Council member who served on the Council Board of Directors for over a decade. It goes to a two-time Senior co-chairperson of the Desert Tortoise Council. It goes to a dedicated professional who has sought conservation of the desert tortoise through extraordinary efforts both on-the-job and in countless volunteer hours for organizations like the Council. It goes to the primary organizer of the first desert tortoise field techniques workshop, and a person who has helped facilitate a host of innovative and privately-funded studies, research, and workshops on the desert tortoise.

This Special Award for long-time achievement toward conservation of the desert tortoise and its habitat goes to. . . Dan Pearson.

SPECIAL AWARD FOR DISTINGUISHED SERVICE

Mike Coffeen

A second special award is being presented this year to an individual who served the Council as a member of the Board of Directors for seven years. This person has held the post of Recording Secretary and Treasurer. As a matter of fact, both positions were capably handled by this resolute soul concurrently one year. But it is the Treasurer's role that was so ably fulfilled, resulting in a period of fiscal stability and resourcefulness that has given the Council considerable comfort with regard to its financial standing to this day. In addition to the contributions that promoted the operational well being of the Desert Tortoise Council, this individual was a direct and timely link to the issues facing the desert tortoise in Utah.

With these factors in mind, the Council wishes to thank and congratulate Mike Coffeen for a job well done.

CONSERVATION AWARDS

Desert Tortoise Recovery Team

A momentous occasion in late June of 1994 was the completion of the Desert Tortoise (Mojave population) Recovery Plan. A team of eight members with expertise in desert tortoise biology, conservation biology, epidemiology, population dynamics, and desert plant communities met 17 times between October 1990 and April 1994. They labored through countless hours of their time to forge the path not only for desert tortoise recovery, but necessarily, recovery of the ecosystem upon which the desert tortoise depends. This desert tortoise recovery team prepared perhaps the first ever recovery plan that was not only approved by the Fish and Wildlife Service, but endorsed by another governmental group as well, the Desert Tortoise Management Oversight Group.

We honor, on the 20th anniversary of the Desert Tortoise Council, the members of the Desert Tortoise Recovery Team, who have prepared the way for the tortoise's recovery in the 21st century. Our many thanks.

Dr. Peter F. Brussard
Dr. Kristin H. Berry
Dr. Michael E. Gilpin
Dr. Elliott R. Jacobson
Dr. Cecil R. Schwalbe
Dr. David J. Morafka
Dr. C. Richard Tracy
Dr. Frank C. Vasek

WELCOME TO 20TH ANNUAL DESERT TORTOISE COUNCIL SYMPOSIUM

John L. Behler
Department of Herpetology
Wildlife Conservation Society
Bronx Zoo, Bronx, New York

Tortoise biologists — chelonian specialists of many descriptions, ladies, gentlemen — it is my special honor to welcome you all to the 20th Annual Desert Tortoise Council Meeting and Symposium. This meeting promises to be an exceptional event. The program is broad and ranges from a retrospective of past accomplishments, to current state-of-the-art methodology, and it is an opportunity to look ahead to the next two decades of *Gopherus* research. My homework revealed that the idea of the Desert Tortoise Council (DTC) was conceived in the early hours, in a smoky hotel room, 21 years ago, right here in Las Vegas — the center of western culture and science. The DTC was officially born on April 21st, 1975. Our program chair, Kristin Berry, was there at the start, and so were Glenn Stewart and Jim St. Amant. Joined by others who saw difficult days ahead for the desert tortoise, they shepherded the Council through the two decades that have followed. Voices have already praised their dedication, and I add my salute.

The 1st DTC annual meeting was held in Las Vegas in 1976. That year, Murry Fowler, UC Davis, completed a Bureau of Land Management-funded study of reptile disease in captive tortoises. An omen for bad times ahead? Perhaps.

An adoption program for captive tortoises was established through cooperation with the California Department of Fish and Game and the California Turtle and Tortoise Club and a scheme to rehabilitate captive tortoises for release back into the wild was launched. 1976 — Those were the days when veterinarians practiced alchemy and voodoo medicine when it came to reptiles. Parenthetically our protocols for reintroduction and repatriation are still rather primitive and unproven. Here, we still are not very far advanced on the learning curve.

The years between 1976-1995 were filled with victories and setbacks for the DTC. Pitched battles took place at local, state, and federal levels to assure the continued survival of the desert tortoise throughout its range. Look at the record:

1980	USFWS lists desert tortoise as "threatened" in Utah.
1982	California reports 16,000 permits issued to private tortoise keepers.
1984	"The Status of Desert Tortoise in the U.S." was circulated. Based upon its content, Environmental Defense Fund, NRDC, and Defenders of Wildlife petitioned the U.S. Fish & Wildlife Service to declare the desert tortoise "endangered."
1987	DTC petitions California to list the tortoise as "threatened."
1988	Upper respiratory disease breaks in the Chuckwalla Bench and in Desert Tortoise Natural Area in California.
1989	Mojave populations of the desert tortoise emergency-listed as "endangered."
1990	*Mycoplasma* is discovered in the sinus tissues of tortoises and Fish & Wildlife Service lists the "Mojave population" as "threatened."

1992 The Desert Tortoise Conservation Center is completed.

1994 "Critical Habitat" is designated for the Mojave population and a recovery plan is published.

The aforementioned state and federal listings — largely won by DTC initiative — came at the expense of thousands of hours of tough work. Yet those who toiled were rewarded. These successes moved the DTC closer to its goal of ensuring the survival of the desert tortoise. These successes attracted members. Indeed the DTC grew from a handful of individuals to more than 300 members. Its ranks are filled with dedicated and distinguished chelonian biologists. Indeed some of the very brightest minds in the business are focused on saving the desert tortoise and its kin. And, by far, more money is being spent on desert tortoise conservation than for any other tortoise or freshwater turtle (perhaps more than the 260 other taxa combined).

For all of our attention, however, the Desert Tortoise is still in serious trouble in many parts of its range — more so than it was 20 years ago — and likely in its history.

The desert tortoise is not alone. Virtually all 40-odd tortoise species are facing tough times. South African biologist Ernst Baard who follows me will outline conservation problems facing the Geometric Tortoise and other South African tortoise species. Linda Cayot will reflect on Galapagos tortoise conservation issues. Last year disgruntled fisherman killed a group of tortoises and threatened wholesale slaughter if the Ecuadorian government imposed certain fishing laws.

1994 was not a good year for tortoises! Somewhere between 50,000-100,000 Russian tortoises broke with a virulent respiratory disease when an exotic pet marketing scheme fell apart and dealers couldn't move animals fast enough. Informants say that to avoid embarrassment, survivors and dying animals were dumped into the wild. One hundred-eighty smuggled Madagascar radiated tortoises were clandestinely returned from Rĕunion to Madagascar and released near Ft. Dauphine, even after strong opposition from the scientific community. Indian star tortoises smuggled from Calcutta continued to be exported from the United Arab Emirates with CITES documents saying they were captive-bred stock. Absolute rubbish. Some 7,607,362 red-eared sliders — many carrying *Salmonella* — and God knows what other hot enterics or viruses - were shipped out of the United States to pet shops around the globe. Turtle and tortoise diseases are breaking around the world as Elliott Jacobson will tell you. It is all very frightening.

There were some successes in 1994 however. Box turtles were listed on Appendix II of CITES. That should serve to dramatically reduce the 30,000 to 40,000 annual exports to the Old World pet markets. Egyptian tortoises went to Appendix I. The immediate impact was brutal. Before the rule went into effect, between ratification and implementation, thousands of these midget tortoises were sold in the exotic pet market. Prices dropped from $200/tortoise to $35-$40/tortoise so shops could quickly sell them before they died. Shipments continued after the rule went into effect. Now, our Fish and Wildlife Service is currently grappling with the disposition of 200 more confiscated specimens.

It is a troublesome old world we live in. Spring is not yet silent but it isn't the spring of our youth. Frogs are disappearing — even in the mountains of Eastern Australia — and fast. Songbirds are declining because of the fragmentation of our northern forests and those in tropical America. Entire fisheries are facing a bleak future. And what is driving me bats is the knowledge that the eastern *Clemmys* - the bog, wood, and spotted turtles — the critters I've studied for 30 years — are disappearing quickly from my "special" environments. They're vanishing for the same broad reasons desert tortoises are:

Habitat fragmentation and degradation. This, in the East, as a consequence of malignant urban-suburban sprawl; highway construction along riparian habitat, or through it.

Alien introductions. Purple loosestrife and phragmites form near monocultures in former turtle habitat. In 1993 Congress' Office of Technology Assessment documented 4500 exotic species in the U.S. Of them, 76 have caused $97 billion in damage and control efforts since 1906. OTA projects that just 15 species could cost $134 billion in the next 50 years.

Predators. Coyotes are in my backyard, 37 miles from the heart of the Big Apple — New York City. And raccoon numbers, following a population explosion in the mid-1940's, continue to grow and are believed to be about 20 fold from former numbers. Crows dominate the bird feeder, and gulls have taken over the zoo's parking lots.

"The sky is falling." Biodiversity is on the decline and the extinction rate will be accelerating totally out of control by the end of the century.

Absolutely horrendous decisions — life and death decisions — will have to be made for wildlife and flora. Some of you will be on the jury — or asked to provide expert testimony. Unfortunately some among us will embroil themselves in philosophical and unproductive disputes with other biologists about conservation action vs. rigorous scientific documentation. Management decisions may have to be made without a solid data base on aspects of a species' biology. Often, intervention will have to take place quickly if there is any hope of saving the species in question. If a public hearing were called for next month on the status of any freshwater turtle, for example, reviewers would certainly have to use unpublished wildlife agency reports, symposia papers, personal communications, and the opinions of "authorities" in making their decisions. Unfortunately the formal peer-reviewed literature often excludes the sources that are most applicable and most current in determining the real-world status of an endangered species. Effective conservation involves vigorous advocacy, grappling with the political machine, and rapid marshalling of information from all available — and perhaps unorthodox — sources. We cannot stand on ceremony when great issues — the wildlife resources we work with — are at stake and it is five minutes to midnight. Some of you know exactly what time it is — have seen the fenestrae in our knowledge of *Gopherus* — and brilliantly closed gaps. Two recent publications come to mind:

Conservation Biology of the Desert Tortoise - a 13 paper contribution of cutting edge material - published by The Herpetologists' League in their monograph series. My hat is off to Jim Spotila, Michael O'Connor, Linda Cayot Zimmerman, Susan Bulova, Dave Rostal, Douglas Ruby, and the others for your accomplishments.

Secondly, *Biology of North American Tortoises*, published by the National Biological Service, and edited by Bruce Bury and David Germano. Again hip-hip hooray to the contributors (it includes some 17 papers) and kudos to the editors.

These references are truly a luxury and few luxuries exist for the conservation biologist. They're now at our fingertips, they summarize knowledge, and point the way for others to follow. They too are proving helpful to tortoise biologists around the globe who look to the west for guidance.

Let me now close where I started by welcoming you to Nevada. I am particularly pleased to see that such a wide range of expertise will be sharing the stage. In particular, I want to welcome the dream-team from the University of Florida, School of Veterinary Medicine, the National Zoo — USDA nutrition team, and the ecologists and resource managers of many descriptions from academia, state and federal wildlife agencies, and contract services who will be with us over the weekend. I'm also delighted that you've been able to attract a dozen or so members of the IUCN Tortoise and Freshwater Turtle Specialist Group.

Program chairs Drs. Allan Muth, Marc Graff, Kristin Berry, and the host and arrangements committee chaired by Bob Turner deserve special recognition for putting such a diverse program together.

Lastly, I have it on good authority, that Robert Stebbins is enjoying his 80th birthday today. Happy Birthday Dr. Stebbins.

THE CONSERVATION BIOLOGY OF SOUTH AFRICAN TORTOISES - PERSPECTIVES AND OPPORTUNITIES

Ernst Baard
Cape Nature Conservation, Western Cape Scientific Services, Stellenbosch, South Africa

Situated at the southern tip of the African continent, South Africa is a country with vast climatic, geological and topographical variety. Travelling through the country one encounters landmarks and landscapes such as the well-known Table Mountain in Cape Town which annually draws many thousands of tourists, and the floral splendour of Namaqualand where annual blooms of breathtaking scenes awaits the traveller. Further north, the Richtersveld, a mountain desert with its harsh landscape, guards part of the border with the country of Namibia. South Africa was previously divided into four provinces. Following the birth of the new South Africa in 1994, it now comprises nine provinces or States each with its own Legislative Assembly.

Nature, however, does not follow political boundaries and within South Africa's international boundary one finds six vegetation biomes, namely the Cape Floral Kingdom, locally known as the Fynbos Biome, the Karoo and Nama Biomes, the Forest Biome, the Grassland Biorne and finally the Savanna Biome. This variety is the product of wide seasonal contrasts in rainfall and temperature and, generally speaking, South Africa may be divided into three rainfall regions. The southwestern part receives rnost of its rain during winter, while the southern and eastern parts receive rain almost throughout the year. In contrast, the central and northeastern parts receive most of their rainfall during summer. The coastal regions experience moderate temperatures while sharper contrasts exist in the interior. Occasional snowfalls are experienced during winter, but they are mainly confined to the Cape Fold Mountains and the high altitude interior escarpment regions such as the Drakensberg region.

South African tortoises

Species assemblage

South Africa currently hosts probably the largest assemblage of terrestrial tortoise species in the world. No less than 16 taxa (species and subspecies included) are found here and, evolutionarily speaking, if one includes *Homopus bergeri* from Namibia, it is the most diverse mixed bag of chelonians found anywhere. The following taxa are found in South Africa: *Geochelone pardalis*, *Chersina angulata*, *Psammobates geometricus*, *P. oculifer*, *P. t. tentorius*, *P. t. trimeni*, *P. t. verroxii*, *Homopus areolatus*, *H. boulengeri*, *H. femoralis*, *H. s. signatus*, *H. s. cafer*, *Kinixys belliana belliana*, *K. lobatsiana*, *K. natalensis* and *K. spekii* (Boycott and Bourquin 1988).

Habitat occupation

This species assemblage occupies a diverse array of habitats found from almost sea level to mountain escarpment. In the Western Cape Province, for example, in a transect running from the Atlantic Coast to the Cape Fold Mountains, it is possible to find three species with particular habitat requirements replacing each other, while occurring sympatrically in "contact zones." Another example of diverse habitat occupation is the fact that in the Karoo National Park, an area of approximately 33,000 ha, one may find up to five tortoise taxa occupying different levels of the landscape at the sarne time. Tortoise habitats include coastal strandveld and coastal fynbos inhabited mainly by angulate tortoises (*C. angulata*) along the coastal belt from the Orange River Mouth in the northwest to Port Elizabeth and East London in the East. Low-lying fynbos biome habitats of the southwestern Cape support angulate, southern padloper (*H. areolatus*) and geometric tortoises (*P. geometricus*), as well as southern speckled padloper tortoise (*H. signatus cafer*). Karoo and Nama Biome habitats support all three tent tortoise taxa, namely tent tortoise (*P. tentorius tentorius,*) Namaqualand tent tortoise (*P. t. trimeni*) and Bushmanland tent tortoise (*P. t. verroxii*), as well as angulate tortoises, southern padloper tortoise and three other padloper species, namely the Karoo padloper (*H. boulengeri*), the greater padloper (*H. femoralis*) and the Namaqualand speckled padloper (*H. signatus signatus*). Speckled, Karoo and greater padlopers have interesting habits in that they frequent rocky ridges and low hills, sheltering amongst and under rocks and rock slabs, rather than under vegetation. Towards the east and north of the country, eastern Cape bushveld and grassland, and savanna and Kalahari thornveld habitats support species such as leopard tortoise (*G. pardalis*), serrated tortoise (*P. oculifer*) and the four hingeback species, namely *K. b. belliana, K. lobatsiana, K. natalensis* and *K. spekii*. Interestingly, the Natal hingeback tortoise exhibits habits similar to the padloper tortoises of the northwest in that it is partial to granite outcrops and may be found hiding under rocks on the summit of the Lebombo Mountains in Swaziland.

Spatial distribution of taxa

If an imaginary line with a northwest-southeast orientation is drawn diagonally across South Africa, the distribution of terrestrial tortoises may be spatially divided into two main groups. The first group comprises the angulate tortoise, geometric tortoise, Namaqualand tent tortoise, southern padloper tortoise, Karoo padloper, Namaqualand speckled padloper, and the southern speckled padloper. These species are typified by range disjunctions and restricted, scattered distribution ranges. They form part of the general herpetofaunal species assemblage of the western half of South Africa, also characterised by small, restricted ranges. This region is further characterised by cold, wet winters, hot dry summers, and vegetation types comprising fynbos and Karoo biomes. It has been hypothesized that this species assemblage is the result of historical climatic changes in this region, producing vicariant events which lead to reciprocal spreading and withdrawing of the interlocking cool- and warm-adapted forms, following the cyclic changes in the Quaternary climate (Poynton 1989).

The second group of taxa comprises the leopard, serrated, tent, Bushmanland tent, greater padloper, Bell's hingeback, northern Transvaal hingeback, Natal hingeback and savanna hingeback tortoises. These taxa are characterised by extensive distribution ranges typifying that of the herpetofauna of the eastern half of South Africa and classified as a group with more tropical affinities. This group, in general, experiences cold, dry winters, very often frosty nights and snow, and summer rains over virtually the whole region. Habitats are typically grassland and savanna.

Conservation and status of South African tortoises

Legal protection

Currently, only the geometric tortoise (*P. geometricus*) is listed in the International Red Data Book for Reptiles and Amphibians (Groombridge 1982). Classified as "Vulnerable", it receives the attention of conservationists because of its precarious status. Regarded as one of the world's rarest tortoises, its international profile is fairly good due to publication of research results and communication of its plight.

All South African taxa, except for the geometric tortoise which is listed in Appendix I, are listed in Appendix II of the CITES convention (Groombridge 1988), and trade in these taxa is strictly controlled by local conservation authorities. Trade in common species with husbandry potential is allowed, while adequate motivation is required for more specialised taxa. However, despite fairly strict regulatory measures, unscrupulous dealers still manage to by-pass ports of exit and entry, and smuggle animals out by means of so-called "country-hopping".

The South African Red Data Book (Branch 1988) lists three taxa as threatened, to some degree: the geometric tortoise as "Endangered", the Natal hingeback tortoise as "Rare" and the southern speckled padloper tortoise as "Restricted". Extensive species profiles of these taxa have been compiled, highlighting their plight and pointing out measures to be taken to ensure their survival.

Under the previous political dispensation, the four provincial conservation authorities each administered their own conservation ordinances and regulations, and until a new system is implemented, these ordinances will continue to be in force. In a nutshell, this translates into the fact that South African indigenous tortoises are classified as either endangered or protected wild animals and may not be collected, possessed, received, purchased, donated, sold, set free, transported, imported or exported without proper approval from the relevant conservation authority. To a large extent these ordinances have managed to prevent the unscrupulous exploitation of South African tortoises, and have benefited the status of many sought-after taxa.

Protective measures

It is encouraging to report that every South African terrestrial tortoise taxon is represented in at least one conservation area within the borders of the country (see various authors in Swingland and Klemens 1989). These areas range from national parks to provincial and private nature reserves, and from declared wilderness areas to sites of special scientific interest and Natural Heritage Sites. The latter two kinds of conservation areas have no legal status and rely heavily on the attitude of private and corporate land owners for continued protection. Most of South Africa's terrestrial tortoise habitat types receive protection within the officially proclaimed conservation areas constituting approximately 6-8% of South Africa's land surface (Huntley 1989).

When addressing the question of how South Africa manages to conserve such a diverse array of tortoise taxa, it must be pointed out that, unlike the situation in the Desert District of the state of California where vast stretches of public land are interspersed by private land, the situation in South Africa is quite the opposite. Here most of the land is privately owned with public or state land dotted all over the country. In establishing official conservation areas, conservation authorities have three options: either to buy the land from the landowner, thus transforming it into state land, or to lease the land from the owner and proclaim it as an official conservation area, or to convince the private land owner to proclaim part of his land as a private nature reserve. In the latter two instances, however, the onus is entirely on the private landowner, allowing him to change his mind at any time. The answer to the above question, therefore, is simply that it is very difficult to conserve viable populations of tortoise taxa, since first, the state usually does not have the money to buy all the land it wants and, secondly, convincing landowners, as the "primary producers" of the nation's food, to set aside land for conservation, remains difficult at best. It must be reported, however, that in the case of the conservation of the endangered geometric tortoise, private land owners take pride in the fact that they play guardian to the remaining populations and have pledged their support to ensure the survival of at least some of the remaining populations.

As a general rule, the managers of official conservation areas in South Africa are required to compile reserve management plans which incorporate all aspects of the administrative, managerial and biological management of the area. These plans address biological management in terms of the protection afforded to biological components within the conservation area. While habitat conservation takes priority, plants and animals are indirectly managed to optimise their survival in the proclaimed area (except in special cases such as geometric tortoise reserves or reserves specifically created to protect endangered plant taxa). Regarding strategic conservation plans or strategies for South African tortoises, there is currently only one namely for the endangered geometric tortoise (Baard 1993). Hopefully that will stimulate the development of further plans for other taxa of concern.

Threats to South African tortoises

Throughout South Africa habitat deterioration and destruction is taking place. In the Western Cape Province, for example, more than 95% of one particular habitat type has already been irreversibly destroyed (McDowell and Moll 1992), while in other parts of the country, overstocking of farm stock leads to the general deterioration of tortoise habitat. Farmers make extensive use of rotational grazing regimes which, if not managed properly, can result in extensive habitat change and damage. The trampling effect of grazing stock and reduction in plant cover are important determining factors in the breeding and nutrtional support of many species, especially in inland areas where cattle farming is prominent. Some landowners follow old-fashioned management techniques believing that they are best, but they damage the land while trying to maximise production.

Deliberate, uncontrolled and unseasonal burning of land to enhance grazing for cattle and sheep could further the deterioration of tortoise populations in specific regions. Especially in the Cape Floral Kingdom, and the grassland and savanna biomes, this factor can be severely damaging to local tortoise populations.

The uncontrolled, aggressive spread of Australian *Acacia* species in South African indigenous plant communities, as well as other more obscure alien annual and perennial herbaceous species throughout the country, is fast becoming a major problem. In the Western Cape Province, for example, water runoff from mountain catchment areas, providing clean, high-quality water to people, is compromised by the spread of alien vegetation in catchments. In the lowlands, these alien species, if unchecked, form dense impenetrable thickets which outgrow indigenous vegetation and lead to general habitat deterioration. This aspect is of particular importance on private land where landowners do not always have the resources to control alien species.

Drought conditions and poor veld management have severe implications for terrestrial tortoise habitats in South Africa. Many inland farms suffer as a result of prevailing droughts, and overgrazing by stock further adds to already stressed habitats. This results in general desertification in some areas, with soil erosion adding to the loss of topsoil and seedbanks, and impairing the habitat's ability to recover.

The fragmentation of South African terrestrial habitats is most prevalent in the fynbos regions of the Western Cape Province, and in the grassland biome towards the east. Agricultural expansion, urban development and high-altitude afforestation account for the loss of thousands of hectares of viable natural habitat units, and create situations which will eventually lead to the loss of many isolated habitat fragments through undue pressure. Fragmentation of historically continuous tortoise habitats results in major losses of corridors required for gene flow between populations, it elevates the probability of major catastrophes wiping out populations, and increases the concentration of real and potential predators by forcing them off the open spaces and into habitat refugia, thus inflating the "natural" predation pressure there. Therefore, one of the most pressing issues in conservation biology today is not only to identify those species and habitats which are threatened, but also to identify those processes and role players which inflict negative pressure on these fragmented and isolated habitats.

Research opportunities

In an analogy between South Africa and the United States of America, it is interesting to note that the four species of terrestrial tortoise found in the USA are perhaps studied by tens or hundreds of tortoise researchers, while the 16 taxa in South Africa are currently studied by maybe less than five researchers. South Africa, therefore, finds itself in a unique situation where research on its tortoises could be solicited, but cannot always be funded. What follows is a summary and highlighting of possible research directions and aspects where information is lacking. This is perhaps best reflected by South African texts on tortoises in which only very basic and anecdotal information exists.

1. Distribution surveys, even of the common taxa, are required to update previous accounts and confirm doubtful records.

2. Ecological studies, including studies on resource partitioning of taxa and general ecology (e.g. population dynamics, feeding, reproduction, etc.) are required for many taxa.

3. Studies on habitat ecology of many taxa are lacking. Certain taxa have received some attention, but little is known about animal-habitat relationships and habitat modelling.

4. There is a serious lack of genealogical research on South African tortoises, especially inter- and intra-taxon relationships. Given the remarkable assemblage of taxa, this is perhaps the most pressing issue for conservationists, since we desperately need to know what we should conserve.

5. Currently, status surveys of not only threatened, but other more common species are urgently required. For example, very little is known about population densities, as well as threats operating at population and taxon levels and requirements for protection.

Add to this research into the effecta of habitat fragmentation and loss, inbreeding depression, temperature dependant sex determination, and the vast field of physiological research, and South Africa can truly be called the tortoise researcher's dream. Or is it perhaps a nightmare??

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HOW MANY SPECIES OF DESERT TORTOISE (*GOPHERUS AGASSIZII*): WHAT DO WE KNOW, WHAT WILL WE NEED TO KNOW, AND HOW WILL WE DECIDE?

David J. Morafka
Department of Biology, California State University - Dominguez Hills, Carson, California

Abstract. Despite a distribution stretching from Sinaloa state in Mexico north to Washington County, Utah, and west to Kern County, California, only a single monotypic form of desert tortoise is currently recognized taxonomically. Yet evidence from shell morphology and pigmentation, mitochondrial DNA, gene sequencing, electrophoresis, ethology and ecology all indicate very significant regional variations at either subspecific or specific levels. Morphological and genetic evidence for differentiation indicate that some populations are as distinct as species. Comparisons among populations and species of North American gopher tortoises based on mtDNA and electrophoresis further indicate that the nominal "*Gopherus agassizii*" populations of the Sonoran Desert of Arizona are considerably closer to the Texas tortoise, *G. berlandieri*, than they are to supposedly conspecific desert tortoises occurring west of the Colorado River.

If this genealogy is sustained by other lines of evidence, *G. agassizii* is currently configured as a "paraphyletic" species which excludes a closest relative and includes more distantly related forms. Such taxonomy is intolerable and obscures more than it reveals. Problems remain to be addressed before the relationships are completely resolved. Critical among these are: (1) the presence or absence of gene flow/clinal gradients along the Colorado River populations; (2) the lack of congruence between mtDNA and some other data bases including gene sequencing; and (3) a complete characterization of the morphology and genetics of the Sinaloan haplotype.

A course of action is proposed for eliminating critical deficits in our data, and for utilizing more complete information to ascertain whether Mojave, Sonoran, Texas and Sinaloan tortoise populations satisfy the criteria necessary to establish them as evolutionary species.

PHYLOGENY AND TAXONOMY OF THE GOPHER TORTOISES, GENUS *GOPHERUS*

Robert W. Murphy, Amy Lathrop, and Jinzhong Fu
Department of Ichthyology and Herpetology, Royal Ontario Museum
Toronto, Ontario, Canada

Abstract. Some recent molecular evidence suggests that populations of desert tortoises, *Gopherus agassizii*, on the east side of the Colorado River might be more closely related to *G. berlandieri* than to populations on the west side of the river. Recent theory in phylogenetic systematics, including application of the evolutionary and phylogenetic species concepts, would find the current taxonomy unacceptable because *G. agassizii* would constitute a non-monophyletic taxon if the pattern is true. Two acceptable alternative taxonomic arrangements would be to either: (1) synonymize *G. berlandieri* into *G. agassizii*; or (2) describe the eastern population of *G. agassizii* as a distinct species.

The published data suggesting the association of the eastern desert tortoises with *G. berlandieri* violated assumptions of data analysis and thus the conclusions are suspect. These results will be discussed in light of more recent mitochondrial DNA sequence data.

TORTOISE MITIGATION OPTIONS: CHOOSING THE BEST OF THE BAD

Joan E. Diemer Berish
Florida Game and Fresh Water Fish Commission, Wildlife Research Laboratory,
Gainesville, Florida

Conservation of tortoises in urbanizing areas requires difficult choices. There is no ideal solution except the cessation of development in xeric habitats. Unfortunately, this seemingly simple solution is generally not an option. The available choices involve efforts to mitigate or offset the effects of development.

Mitigation requirements for gopher tortoises on development sites in Florida have evolved over the last decade. Current options include avoidance of individual burrows during development, habitat protection on or off-site (usually an area equal to 15-25% of the occupied tortoise habitat being affected), or relocation of tortoises to suitable habitat. The habitat protection option may be fulfilled by contributing to a mitigation banking fund used to buy the requisite acreage in an existing or proposed mitigation park. Protecting tortoise habitat in large, manageable tracts serves a conservation function for the species; ideally, the set-aside would equal the amount of habitat lost to development, but tortoise mitigation has not evolved that far. The dark side to most habitat protection deals is the concomitant incidental take permit. Mitigation banking saves habitat elsewhere, but allows the tortoises on the development site to be destroyed. Relocation, on the other hand, spares the individuals on the site, but allows the habitat to be destroyed. The result is an ever-decreasing habitat base and an ever-increasing number of refugee tortoises.

Tortoise relocation remains a controversial, costly, time- and labor-intensive option. Biological concerns include disruption of locally adapted gene pools at recipient sites, disease and parasite transmission, population disruption, and dispersal-related mortality. Approximately 10,000 gopher tortoises were relocated between 1978 and 1995 due to impending development in Florida. Average site fidelity on designated recipient sites ca. one year post-relocation was 39%. Most of the gopher tortoises were relocated to ranches, reclaimed mining lands, scout camps, and parks. Low site-fidelity, the threat of transmitting upper respiratory tract disease (URTD), and the absence of permanent protection, e.g., conservation easements, on most recipient sites call for re-evaluation of current relocation guidelines.

Adoption of tortoises may alleviate some of the biological concerns regarding impacts of relocated tortoises on recipient sites; however, the capture and distribution of adoptees can also prove costly and time-consuming. Moreover, caring for these long-lived reptiles is a long-term responsibility. Disposition of unwanted captives poses difficult dilemmas for wildlife agencies and rehabilitators. Release of former pet tortoises can be detrimental or deadly to resident tortoise populations. Adopting out individuals does little for the conservation of the species.

Humanely killing tortoises that would not be protected on-site or moved prior to development has also been suggested. From a humane standpoint, there would appear to be equal justification for moving or euthanizing all the other animals likely to be crushed, entombed, stunned, or displaced into hostile habitat to await starvation or predation. Euthanasia has no conservation value, would be expensive and time-consuming (especially if each animal was dug out and killed), and eliminates the "feel good" factor associated with relocation or adoption. Pumping lethal substances down burrows presents questions regarding safety and even humaneness. Finally, although viable populations probably won't remain in developed areas, some individuals may survive. Euthanasia should be reserved for tortoises with advanced clinical signs of URTD.

Mitigation for tortoises on development sites is a complicated, often political, and emotionally-charged issue. Biological, practical, economical, ethical, and humane aspects must be factored into decisions, but the ultimate goal should be the conservation of the species. Several questions can be posed to help rank the various mitigation options: Does this mitigation action have conservation value for the species? Is it practical in terms of time, manpower, and cost? Is it humane? What is the post-mitigation "feel good" factor? Incidental take permits have conservation value for the species only when habitat is concomitantly protected. Mitigation banking and the corresponding incidental take permits rank high in practicality, but low in the humane and "feel good" areas. However, some "feel good" benefit is gleaned from knowing that tortoise habitat will be permanently protected. Relocation has minimal conservation value (unless repatriation/restocking is needed), is not practical, and may or may not be humane (tortoises may wander for weeks, be killed by predators or vehicles, etc.), but it does make some people "feel good." Adoption has little conservation value (except for rare educational purposes) and is not practical, but it is humane and makes people "feel good." Finally, euthanasia has no conservation value, is not practical, and makes very few people "feel good", but it is humane. If conservation of the species is truly the goal, incidental take permits issued after habitat protection requirements have been met may be the best, albeit difficult, choice. This does not imply that, in some cases, relocation/restocking can't be an option. But those cases should be rare and carefully scrutinized. In certain local situations, carefully monitored adoptions, particularly for research or educational purposes, may also be undertaken. As indicated above, euthanasia seems most appropriate for sick tortoises already removed from development sites.

Choosing the best of the bad alternatives takes fortitude and genuine commitment to the species' long-term survival. With limited conservation dollars available, wise use of funds is imperative. Loss of tortoises and habitat is inevitable in urbanizing areas; energy and money can be poured down that drain, or they can be used to protect tortoise habitat in perpetuity. Tortoise populations and habitat areas with the highest priority should be acquired, protected, and managed, with the understanding that such acquisitions benefit numerous other species as well.

TERMS OF THE CLARK COUNTY DESERT CONSERVATION PLAN

Paul T. Selzer
Best, Best & Krieger, Palm Springs, California

Abstract. I outlined the terms of the Clark County Desert Conservation Plan recently adopted by Clark County and the cities to fund conservation measures for the desert tortoise in southern Nevada. I described the process and the competing ideas which were discussed and debated by the environmental groups, resource managers, builders and land users in reaching the terms finally agreed upon and incorporated in the conservation plan. It is my position that, while individual components of the plan may not satisfy each and every concern raised during the planning process and debate, implementation of the terms of the Desert Conservation Plan and the planned expenditure of over $1,000,000 per year for the next 30 years for conservation measures will leave the desert tortoise in a better position than it would have been had the conservation plan not been adopted and implemented.

HOW MUCH IS A TORTOISE WORTH?

Marc D. Graff
California Turtle and Tortoise Club, Van Nuys, California

Abstract. What is the market value of a desert tortoise? Mitigation decisions implicitly provide a measure of value of the damage done to the environment and to its inhabitants. Past guidelines in Nevada have created a price of $550 per cleared hectare of land as total payment for environmental destruction and lifetime development of a site.

With payment made, the fate of the removed desert tortoise is not often examined. Clearly preserves are preferable to extinction. Controversy arises about location and cost of preserves, the theoretical accumulation of significant stocks of "captive" tortoises, and the possibility of adoption (as pets) both within and without the state of Nevada.

The California Turtle and Tortoise Club (CTTC) has had an adoption program for over 20 years and yearly places hundreds of animals with eager hobbyists. There is a chronic waiting list for desert tortoises in most of the 10 chapters of CTTC. Many CTTC members have tried to obtain tortoises from Nevada but have been thwarted by legal and political roadblocks. The fact that a threatened species is also a favorite southern California pet is an anomaly not addressed by federal regulations. Most current tortoise owners are not affiliated with any organized herpetological or hobbyist group and are not particularly environmentally aware. Other tortoises on the commercial market fetch significant sums as pets.

What then of tortoise costs? The legal supply of tortoises in California, now that state and federal listing has occurred, comes solely from captive breeding. Owners, often when in failing health or when moving out of state, give mature adults or hatchlings to each other or to intermediaries such as CTTC and similar organizations which redistribute the tortoises to those on waiting lists. Waiting lists can be several years long. Observers believe that an advertising campaign to encourage tortoise adoption in California would increase demand abruptly and dramatically.

The present situation in Nevada is far different. There may well be less people in Nevada who wish to adopt tortoises than is sufficient for a market for even the current tortoise supply. What happens when a vast number of tortoises are available through the long-term Habitat Conservation Plan?

The current situation in California is not unlike the monopoly diamond market. Only a few have the privilege of even bidding on diamonds or tortoises. Failure to follow the prescribed etiquette means permanent loss of an opportunity to obtain the product. Price has no relation to cost. Demand has no relation to supply. Substitute products are obtainable but (certainly from the point of view of the purchaser) are clearly inferior.

The current situation in Nevada is potentially at the opposite extreme. With few "buyers" and a future large output through clearance and development, tortoises may be considered expendable and cheap. What in California is valued and sought after, in Nevada may be impossible to give away and "quick fixes" may become the norm.

HOW THE TORTOISE GROUP ADOPTION PROGRAM AIDS CONSERVATION AND THE PLACE OF ADOPTION IN CLARK COUNTY HABITAT CONSERVATION PLANNING

Betty L. Burge
Tortoise Group, Las Vegas, Nevada

Abstract. In Nevada, prior to November 1983, desert tortoises could not be possessed without a state permit. Few were given, yet, it was estimated that thousands of tortoises were in captivity, illegally. People wanting to give up their tortoises for various reasons, could not always find new homes and many were released in the desert. Tortoise Group was unable to help place unwanted tortoises because there was no legal way to arrange adoptions. In 1983, it became legal to possess tortoises in urban areas of Clark County without registration or permit. Then, essentially all tortoises in captivity were "grandfathered in" as they were in 1989 when the tortoise was federally listed. Soon after the listing, possession without the need for a permit or registration was extended throughout the state. Since 1983 we have been able to offer an alternative to poaching--adoption of legally held tortoises. To persons with unwanted tortoises, we offer an alternative to releasing them in the desert. We accept as many as we can and adopt them into households where the tendency for the tortoise to escape has been anticipated and thus the potential threat to the wild tortoise, prevented. Disposition of tortoises collected under the Clark County 10(a) permit for take has not kept up with collections--adoptions 50%, other avenues, 5%. The increasing cost of collection and maintenance is an issue that Clark County needs to address, particularly when more than 80% of the collected tortoises are not wild but are strays, presumed to be escaped pets.

In Nevada, prior to November 1983, the desert tortoise could not be possessed legally without a state permit. Few permits were given, yet it was estimated that there were thousands of illegal captives. People wanting to give up their tortoises for various reason, could not always find new homes and many were released in the desert. Tortoise Group was unable to help place these tortoises because there was no legal way to arrange adoptions.

In November 1983, state statutes were revised and it became legal to possess tortoises in urban areas of Clark County without registration or permit. Captive tortoises were "grandfathered in", as they were in 1989 when the tortoise was federally listed. Soon after listing, possession without the need for a permit or registration was extended to include the entire state.

After the change in state statutes, we could then help the wild tortoise through a controlled program with pet tortoises. We were then allowed to offer an alternative to poaching --the adoption of legally held tortoises and to persons with unwanted tortoises, an alternative to releasing them in the desert. We accept as many as possible and adopt them to people to whom we have shown what constitutes responsible care and how to anticipated the tortoises' tendency to escape.

A common practice continues locally, for tortoise owners to give away their unwanted tortoises without ensuring that they will be cared for properly. Thus, many escape and find their way to the street. We know that well-meaning but ill-informed persons finding these tortoises frequently release them in the desert or take them home. Most people underestimate the climbing and digging abilities of tortoises and are not aware of the importance of making the yard escape-proof. As a result, many of those tortoises escape again.

The captive population is a known reservoir of upper respiratory tract disease. At the Desert Tortoise Council Symposium, in 1992, we heard about the legal removal of 903 free living tortoises in the Las Vegas area. Obvious signs of having been captives and of upper respiratory tract disease were greater in tortoises found close to the urban center. The data suggest that preventing escape or release of captives into the desert may be a factor in controlling the incidence of upper respiratory tract disease in wild tortoises. Uneducated tortoise keepers are unaware of this. The Tortoise Group educational efforts and adoption standards work to remedy the situation.

Under the Clark County Short-Term Habitat Conservation Plan, the 10(a) permit from the Fish and Wildlife Service and the Draft Long-Term Desert Conservation Plan, tortoises are, and will continue to be, collected — from sites to be developed and from unconfined situations like city streets. The latter group are presumed to be mainly escaped pets. The avenues of disposition authorized by the Service include adoption, research, placement in zoos and educational institutions, translocation and as a last resort, euthanasia.

Collections under the 10(a) permit started in September 1991 and within days the widespread, negative response to the euthanasia option resulted in the Clark County Board of Commissioners adopting a resolution that in essence prevented euthanasia of healthy tortoises. Immediately, the number of collected tortoises was beyond the capabilities of the holding facility. Tortoise Group and the Reno Tur-Toise Club were the only entities authorized by the Service to adopt these tortoises to Nevada Residents.

How effective is adoption as a mode of disposition? Even before collections started, the number of unwanted pet tortoises donated directly to Tortoise Group exceeded the adoption demand. In addition, our adoption program for both tortoises collected under the permit and those given to us directly by the public is in competition with the thousands of persons in the area with their tens of thousands of reproducing tortoises that are being given away. Also, we know that illegal collecting continues.

As a result of this competition, less than 10% of the 1,481 tortoises collected under the 10(a) permit between September 1991 and January 1995 have been adopted through Tortoise Group. The Reno Club handles adoptions in the northern part of the state. Unlike southern Nevada, northern Nevada is a virgin market and is not tortoise habitat where animals are easily available for poaching by local residents. Almost 40% of the tortoises collected have gone to Reno for adoption. This has somewhat alleviated the burden of excess tortoises at the holding facility, but as the northern Nevada market saturates, the Reno Tur-Toise Club probably will not be able to provide the same degree of relief if occupancy at the holding facility continues to increase.

As for the other acceptable avenues of disposition, research has utilized only 5% of the collected tortoises. No zoos or educational institutions have shown an interest other than local schools to which Tortoise Group has adopted tortoises for their outdoor atria. Ron Marlow will be addressing the translocation alternative, today.

In sum, adoption has not kept up with collection. As of the end of December 1994 there were 337 tortoises at a holding facility designed for about 250 and where the construction of additional pens is an ongoing task. The staff there projects that 550 tortoises will be admitted during 1995--a 12% increase over the average for the first three years of collecting. Eighty-six percent of those tortoises will not be wild tortoises removed from land to be developed, but will be found as strays--mostly pets--wandering in the street. This group of tortoises may not be eligible for translocation.

Over a year ago, county staff and others expressed the belief that adoption should relieve the ever-increasing excess of collected tortoises and they suggested looking outside Nevada for clients to adopt tortoises. To increase the local utilization of excess tortoises the county actively solicited a commercial entity to develop an adoption program that would make adoption easier for the clients, suggesting that the Tortoise Group safeguards required before adoption are too stringent.

We felt that these attitudes and proposed actions would lead to trafficking in a threatened species. Not the message to promote. As it is, the large captive population locally undermines the acceptance of many people of the need for conservation measures. In response to the trend in thinking that adoption, one way or another, should be able prevent congestion at the holding facility, the Tortoise Group Board of Directors adopted the following policy regarding tortoises collected under the permit: We will use for adoption only those tortoises found as strays (escaped pets for the most part). We expect displaced wild tortoise to be used for conservation-related purposes such as translocation and research.

The Environmental Impact Statement for the draft Clark County Desert Conservation Plan includes the question of the inappropriateness of adoption of a threatened species. Allowing the public to possess the threatened desert tortoise is a unique situation. However, we see no practical way to reverse this, for example, by removing all the tortoises presently held in captivity and preventing people from acquiring tortoises.

Considering the thousands that we believe were held in captivity prior to 1983 and how readily they reproduce in southern Nevada, there must be many more now. Consider having to provide housing for them if they were confiscated. Voluntary turn-in would not be effective. Too many persons are too fond of their tortoises.

In the face of this, we believe that the best that Tortoise Group can do is to promote responsible care of captives and try to prevent the release of captives into the desert by unauthorized persons by educating the public and ensuring that prior to adoption reasonable safeguards against escape are in place. In addition, if people with hatchlings were required by law to place them in an authorized adoption program, not only would there be fewer deaths from living indoors on lettuce, but far fewer would escape or be released in the desert.

We will continue to remind the wildlife and land managers of their responsibility for preventing any action that may jeopardize the wild population. This is stated repeatedly as being implicit in minimizing the impact of take. An example would be the threat posed to the wild tortoises if unauthorized persons are allowed to remove tortoises from development sites. This may result in immediate translocation or eventual translocation if taken home to where disease and escape are likely to occur.

Finally, in the face of the ease with which a tortoise can be removed from the desert, we believe the best we can do is educate the general public and continue to offer an alternative--adoption of tortoises already in captivity.

As for the increasing overpopulation at the holding facility, the County needs to find a solution. Euthanasia was not accepted and adoption has not been the answer. Meanwhile, the number of tortoises increases. The cost of tortoise rescue and maintenance has more than doubled since 1992. It is now over $105,000/yr and this does not include the cost of building additional pens.

We believe that long-term husbandry of the ever-increasing number of tortoises is not tortoise conservation. Dollars used for prolonged captive maintenance are dollars that are not available to facilitate tortoise recovery--the primary condition on which the 10(a) permit was awarded.

THE CLARK COUNTY HABITAT CONSERVATION PLANNING EXPERIENCE ISSUE: SURVEY AND REMOVAL OF TORTOISES

Karin von Seckendorff Hoff
Department of Biological Sciences, University of Nevada, Las Vegas, Nevada

Abstract. Clark County's Short-term Habitat Conservation Plan required that all land to be developed would be first surveyed for tortoises and that any tortoises would be removed prior to land disturbance. Clark County was required to count and account for all tortoises "taken" pursuant to their permit. Due to complaints of administrative awkwardness and expense, Clark County has elected to discontinue the requirement for survey and removal of tortoises in their proposed Desert Conservation Plan (DCP). Clark County plans neither to count "taken" tortoises nor to account for their whereabouts. The disposition of an unknown number of "taken" tortoises will be entirely at the discretion of the developer or any other person. This lack of accountability will guarantee public confusion and will weaken support for the plan. According to the DCP, people will be allowed to rescue a federally protected species "...if they so choose." Individual "taken" tortoises are treated by the DCP as if they are of no consequence to conservation plans for the species.

Unfortunately, this is far from true. Desert tortoises are very commonly kept as pets in Las Vegas and throughout their range and the level of public concern for individual tortoises is thus much higher than would be expected for non-pet animals. The rescue and release of displaced tortoises and unwanted pets has already been implicated in the introduction and spread of diseases such as the upper respiratory tract disease (URTD). Incidence of disease and other physical indications of previous captivity or human proximity is highest in those desert areas that are most accessible to people. It is clear that people, acting out of concern for individual tortoises, have been moving tortoises out of harms way and into desert areas for many years. Although the DCP will provide a free pick-up service for all tortoises found wandering in harms way, the DCP's lack of explicit and attractive plans for those displaced tortoises will guarantee that independent rescue efforts, that are damaging to tortoise conservation, will continue. Clark County's DCP will make a bad situation worse by failing to recognize the desert tortoise's entrenched status as a pet with devoted and sometimes fanatical adherents.

Two things must be done to improve public acceptance of the plan and cooperation with its provisions relating to individual tortoises. First, survey and removal of tortoises must be required in some form. If the County follows Bureau of Land Management (BLM) guidelines and requires surveys only on parcels of land that are 2 ha or larger, the total expense for survey and removal would be less than 4% of the development fees collected. Clark County estimates that approximately 90% of development in the Las Vegas Valley over the next 10 years will be on these larger parcels. The expense to the large developer would be trivial, as would the administrative cost to Clark County. The second and more problematic step is to develop an attractive disposition for the displaced tortoises so that voluntary public participation will enhance the conservation value of the plan rather than detract from it.

THE CLARK COUNTY CONSERVATION PLANNING EXPERIENCE ISSUES: TRANSLOCATION AND ADOPTION

Ronald William Marlow
Biology Department, University of Nevada, Reno, Nevada

Abstract. Translocation of tortoise species for conservation and management is widely practiced and has, in some cases, been extremely successful (e.g., the Pinta Island giant tortoise of the Galapagos). In some of those cases study preceded implementation and in others necessity dictated a more expedient approach. While some uncontrolled translocations of desert tortoises have occurred for decades and several limited studies have been initiated, no definitive study of translocation techniques, long-term success or the implications for conservation and management has been conducted. The Clark County Short-term Habitat Conservation Plan (STHCP) contained an explicit commitment to initiate just such a study. To date Clark County has not initiated any translocation study. Clark County's long-term HCP (the Desert Conservation Plan) also contains a commitment to fund such a study. As of December 1994, 1,482 tortoises have been "taken" under the terms of the STHCP. The Desert Conservation Plan is expected to result in the "take" of 14,000 tortoises.

The National Biological Service (NBS), responding to a request by Clark County, has put forward a preliminary draft proposal to use up to 100 of the "taken" tortoises to study some aspects of translocation in an unfenced valley. According to the draft proposal, the remaining nearly 14,000 "taken" tortoise would be dumped into an unfenced "sanctuary" along Interstate Highway 15 (I-15) south of Las Vegas to the state line. Current models of tortoise movements near roads predict that most of these 14,000 tortoises would be killed by vehicles on I-15 and would not result i a permanent tortoise population. Ethical, scientific and humane considerations aside, the preliminary draft NBS plan is still inconsistent with the *Desert Tortoise Recovery Plan: Guidelines for Translocation of Desert Tortoise.* It is hoped that future drafts will correct these short-comings.

The Clark County STHCP identified adoption as a low priority disposition for "taken" tortoises. Yet most "taken" tortoises have gone into adoption programs in Las Vegas and Reno. Most urban areas in the Southwest have long harbored captive tortoise populations and such groups as the Tortoise Group in Las Vegas and the Los Angeles Turtle and Tortoise Club have administered responsible and humane adoption programs. However, it is difficult to justify large scale adoption of wild tortoises under the Endangered Species Act (ESA). It is counter to the intent of the ESA. In addition, programs that expend significant resources in the active promotion of adoption of federally protected species come perilously close to "trafficking," an activity that is clearly prohibited by the ESA. Clark County has paid formerly non-profit adoption groups to adopt wild tortoises in the past, and the Desert Conservation Plan lists payments to adoption groups among its preferred options to facilitate the placement of taken tortoises in the future.

THE DESERT TORTOISE COUNCIL, 1975-1995: A BRIEF HISTORY

Glenn R. Stewart
California State Polytechnic University, Pomona, California

Kristin H. Berry
National Biological Service, Riverside, California

The Desert Tortoise Council was conceived in a smoke-filled room of a Las Vegas hotel in the early morning hours of February 21, 1974. Initially called the Four State Desert Tortoise Recovery Team, it was formed by members of the Prohibited and Protected Fishes, Amphibians and Reptiles Committee of the Seven State's Colorado River Wildlife Council. At the urging of James A. St. Amant, representatives of the California Department of Fish and Game, Nevada Department of Fish and Game (now Nevada Division of Wildlife), Arizona Game and Fish Department, U.S. Bureau of Sport Fisheries and Wildlife (now U.S. Fish and Wildlife Service), Utah State University, and Southern California Edison Company met to try to find ways to help the desert tortoise (*Gopherus agassizii*) because it appeared to be declining in all four states where it is endemic. Those present at the meeting included Charles W. Marshall, Ronald Lee, Tom Robinson, Gail C. Kobetich, Charles Osborn, Eric M. Coombs, and Norman Alstot.

Several basic problems were identified at that first meeting:

1. Very little was known regarding the true status of the desert tortoise in the wild, such as distribution, abundance, and population trends.

2. Information on diseases of wild desert tortoises was virtually non-existent.

3. Public education on the legal status, general biology, and ecological role of the desert tortoise was lacking.

4. Existing state regulations did not provide adequate protection for the desert tortoise.

5. Research on the desert tortoise was badly needed.

6. Facilities were needed to handle unwanted captive tortoises.

Charles Marshall of the California Department of Fish and Game agreed to become the "Recovery Team" leader. The Team met five more times in 1974. However, because the desert tortoise was not listed as a threatened or endangered species under the terms of the federal Endangered Species Act of 1973, the Team recognized that a different form of organization, one which could bring in a variety of people from private groups and academia as well as government agencies, could help to achieve its goals. Consequently, at the December 1974 meeting of the Team, James St. Amant, Kristin Berry, and Glenn Stewart were appointed as a committee to develop a proposal for reorganization.

In early 1975, the appointed committee had a long meeting at California State Polytechnic (Cal Poly) University, Pomona. The proposal developed was presented to the Team and adopted at its next meeting on April 21, 1975. Thus, "The Desert Tortoise Council" (Council) was born. Charles Marshall continued as the leader and first Chairman of the Council. Due to a new job and location assignment, however, he soon had to resign. During the following six months, Kristin Berry drafted a set of bylaws for the Council. These bylaws were similar to those of the Desert Tortoise Preserve

Committee, also founded in 1974, and actually modeled after those of the Desert Fishes Council, which Philip Pister of the California Department of Fish and Game had provided.

The founding members quickly realized the importance of having a diverse group of people on the Council's Executive Committee - representatives from the academic community, biologists and managers from state and federal agencies, and recognized experts in the husbandry of tortoises. From the very beginning, representation also was sought from the four states within the geographic range of the desert tortoise in the United States, a legacy of the Colorado River Wildlife Council. It was felt that leadership should be shared, so a staggered Co-Chairperson succession was devised whereby there would be two Co-Chairpersons, each serving two years with an overlap of one year. A Co-chairperson Elect would be elected each year and succeed to the junior Co-chairperson position the following year. One of the advantages of the staggered succession was to alleviate the problem of executive signatures on letters to state and federal agencies when officers of the Council found it inappropriate (perhaps suicidal) to sign letters directed to their supervisors in the agencies. The fourth office established was Secretary-Treasurer.

Kristin Berry and James St. Amant served as the first Co-Chairpersons, Glenn Stewart was the first Co-Chairperson Elect, and Tilly Barling was the first Secretary-Treasurer. Mary Trotter soon replaced Tilly. In 1977, the office of Recording Secretary was established and filled by David Stevens. By 1980, the activities of the Council had become so complex that the office of Secretary-Treasurer was split. While Mary Trotter continued as Treasurer, Evelyn St. Amant became the first Secretary. Up to the present, we have had 15 dedicated people who served as Co-Chairpersons and 15 equally dedicated individuals who served in the Secretary and Treasurer positions (Appendix 1). Two Co-Chairpersons also have held Recording Secretary positions (David Stevens and Theodore Cordery, Jr.), and four Co-Chairpersons have been recycled once each (Glenn Stewart, James St. Amant, Daniel Pearson, and Robert Turner).

Goal and Objectives

The single overriding goal of the Desert Tortoise Council is to assure the survival of viable populations of the desert tortoise throughout its range - a goal that sounds much like those of conservation biology and recovery plans today! To achieve this goal, the Council set the following objectives:

1. To serve in a professional advisory manner on matters involving management, conservation and protection of the desert tortoise.

2. To promote such measures as shall work to insure the maintenance of desert tortoise habitat.

3. To encourage studies on the biology, management, and protection of the desert tortoise, and the ecosystems on which it depends.

4. To provide a clearinghouse of information among all agencies, organizations and individuals engaged in work on the desert tortoise.

5. To disseminate current information by publishing the proceedings of meetings and other papers as deemed useful.

6. To maintain an active public information and conservation education program.

7. To commend outstanding action and dedication by individuals and organizations fostering the objectives of the Council.

Yearly Highlights

Briefly, we would like to review a few of the highlights in the Council's work toward our goal and objectives. All of the achievements noted below are, in some way, a result of the Council's efforts.

1976: The first annual meeting and symposium of the Council is held in Las Vegas on March 23-24. By this time, preliminary surveys of selected tortoise populations have been initiated in California, Arizona, and Utah. A study of respiratory disease in captive tortoises, funded by the Bureau of Land management (BLM), is completed by Murray Fowler of the University of California at Davis, and a registration and adoption program for captive tortoises is established in California through the cooperation of the California Department of Fish and Game and the California Turtle and Tortoise Club. (These are examples of the "cross-fertilization" of ideas and knowledge between academic and agency professionals and captive husbandry experts like Mary Trotter and Walter Allen.) Also, facilities dubbed the "Halfway House" are constructed at Zzyzx, California to rehabilitate captive tortoises for eventual release to the wild. With funding from BLM, an educational slide program is developed and made available to schools and interested organizations.

1977: On behalf of the Council, Glenn Stewart submits a petition to the U.S. Fish and Wildlife Service to list the Utah population of the desert tortoise as "Endangered." C. Kenneth Dodd, Jr. is the Fish and Wildlife biologist who writes the listing proposal for the Federal Register. Betty Burge starts major surveys to determine the distribution and relative abundance of tortoises in Arizona. Judy Hohman, with her major professor, Robert Ohmart, begins research on the distribution and abundance of tortoises on the Beaver Dam Slope in Arizona, and on the effects of livestock grazing there.

1978: The Council begins reviewing and commenting on environmental statements and reports - for example, proposed Ivanpah Valley oil and gas leases and the Hot Desert Grazing Plan. The oil and gas leases include a plan to drill a well field that will draw down the water table. At this point, current board member Marc Sazaki, representing the California Energy Commission, first enters the desert tortoise scene. The Hot Desert Grazing Plan includes considerable data on desert tortoises collected by Eric Coombs of Utah State University. Betty Burge samples 1,287 km of transects, primarily in west-central Arizona, to gather data on the distribution and relative abundance of tortoises in the Sonoran Desert.

1979: A two-year study on the survival of captive tortoises released from the Halfway House is completed by Cal Poly graduate student James Cook. David Stevens, as Co-Chairperson Elect, survives a meeting in St. George, Utah where, among 125 local ranchers and a few agency biologists, he is the only person to support Critical Habitat designation for the Utah tortoise population. Kristin Berry, with the assistance of Lori Nicholson, begins working on a status report for the tortoise in California.

1980: The U.S. Fish and Wildlife Service lists the desert tortoise as "Threatened" in Utah - the first federal listing of a desert tortoise population! The Council creates a Research Advisory Committee to review and coordinate tortoise research proposals from various agencies and individuals. The Council produces its first Special Publication: "An Annotated Bibliography of the

Desert Tortoise " by Judy Hohman and Robert Ohmart. Hohman and Ohmart also prepare a major report on the ecology of the desert tortoise on the Beaver Dam Slope in Arizona. The BLM publishes the California Desert Conservation Area Plan which establishes two reserves, or Areas of Critical Environmental Concern, and identifies several major and minor tortoise populations for protection.

1981: Due to the large number of environmental documents being received, the Council establishes a special committee to review them. Margaret Fusari publishes her California Department of Transportation report on the feasibility of a highway crossing system for desert tortoises. The Council receives a contract from the U.S. Navy to study tortoise distribution and density in the Chocolate Mountains Aerial Gunnery Range in Imperial County, California. The Council provides funding to A. Peter Woodman to conduct monitoring of the Parker 400 vehicle race to obtain information on compliance. (Previous Parker 400 races had contributed to degradation of prime tortoise habitat in the Chemehuevi Valley.)

1982: Betty Burge works diligently and contributes many weeks of time to federal and state agencies in Nevada. She also monitors the Frontier 500 vehicle race to obtain information on compliance. James St. Amant reports that 16,000 permits have been issued for the private possession of desert tortoises in California. The first after-banquet raffle is held to help raise money for Council activities.

1983: A Recovery Plan for the Utah desert tortoise population is released by the U.S. Fish and Wildlife Service. A major four-year study, headed by Fred Turner, on the population ecology of the desert tortoise is initiated at Goffs, California through the support of Southern California Edison Company and BLM. The Council fulfills its contract with the U.S. Navy and provides a report on the distribution and abundance of tortoises on the Chocolate Mountains Aerial Gunnery Range. Contributors to the report are Kristin Berry, A. Peter Woodman, Lori Nicholson, and Betty Burge. The Council begins discussion of relocation as a possible mitigation tool, and a pamphlet on tortoise field survey methods is drafted.

1984: The Council becomes a corporation with tax exempt status and decides to buy about 30 acres of tortoise habitat on the Chuckwalla Bench in southeastern California. After five years of exhausting work, contracted to the Council by the U.S. Fish and Wildlife Service, Kristin Berry completes the massive report entitled "The Status of the Desert Tortoise in the United States." Co-authors of the status report include Fred Turner, Lori Nicholson Humphreys, A. Peter Woodman, Betty Burge, James St. Amant, and Laura Stockton. The document is distributed to appropriate parties, and three organizations - Defenders of Wildlife, the Environmental Defense Fund, and the Natural Resources Defense Council - petition the U.S. Fish and Wildlife Service to list the desert tortoise as "Endangered." Martha Stout of Defenders of Wildlife sets up a peer review panel for the status report, drawing on turtle experts from the United States and Britain. Glenn Stewart, Betty Burge, and Ronald Baxter conduct a short distance relocation project for the U.S. Navy at the Twenty-nine Palms Marine Corps Air Ground Combat Center. This project leads to a larger study of the density and movements of tortoises on a portion of the Marine Corps facility, which becomes Baxter's master's degree thesis.

1985: The Council holds its 10th anniversary meeting and symposium in Laughlin, Nevada. The U.S. Fish and Wildlife Service responds to the listing petition, finding that "...listing of the desert tortoise throughout its range is warranted, but precluded by other pending proposals of higher priority." Supervised by Glenn Stewart, Cal Poly University students undertake a rescue mission for tortoises about to be bulldozed by initial construction of the Luz Solar Power Plant at Kramer Junction, California.

1986: The Council is still discussing the pros and cons of controlled captive releases, though none have been conducted since Jim Cook's 1978-79 study. With urging by the Council and California Energy Commission, the Luz Corporation agrees to fund a three-year study of the effectiveness of tortoise relocation efforts associated with its Kramer Junction project. Major concerns are raised about habitat loss in conjunction with a large project proposed by Aerojet Corporation for Nevada's Coyote Springs Valley.

1987: On behalf of the Council, Glenn Stewart submits a petition to the California Fish and Game Commission to list the desert tortoise as "Threatened." Kristin Berry and Glenn Stewart attend a Commission meeting in San Diego where the petition is to be considered. We, and several tortoise supporters rounded up by Mary Trotter, are not given a chance to testify when the Commission postpones a hearing on the subject. New information about the rapid growth of Las Vegas and a land exchange between the Summa Corporation and BLM alarms Council members.

1988: Council members become even more alarmed about the discovery of disease outbreaks and dead tortoises on the Chuckwalla Bench and Desert Tortoise Research Natural Area in California. With Glenn Stewart as its representative, the Council participates in a panel formed by the California Department of Health to review plans and make recommendations on a proposed nuclear waste disposal site in Ward Valley, California, which is prime desert tortoise habitat. Council members Jeff Aardahl, Kristin Berry, Betty Burge, Larry Foreman, George Moncsko, and James St. Amant complete two years of toil under BLM's Alden Sievers as the "California Desert Tortoise Workgroup." They submit a major report entitled "Recommendations for Management of the Desert Tortoise in the California Desert."

1989: California lists the desert tortoise as a "Threatened" species. Under threat of a suit by the environmental organizations that filed the listing petition, the U.S. Fish and Wildlife Service finally comes through with an emergency "Endangered" listing, as well! The State of Nevada, City of Las Vegas, and developers sue the Department of the Interior over the endangered listing. With help from the Environmental Defense Fund, the suit is settled out of court for an amount in excess of $1,000,000. James St. Amant represents the Council and Kristin Berry is one of the Department of Interior representatives in numerous discussions of the suit settlement and fate of some 800 tortoises to be removed from their habitat by development near Las Vegas. Funds are set aside for research on upper respiratory tract disease, nutrition, reproduction, and many other topics. Kristin Berry and Allan Muth serve on the panel of reviewers for research proposals. Elliott Jacobson, Mary Brown, and Harold Adams of the University of Florida discover a mycoplasma organism in desert tortoise sinus tissues and suggest a new etiology for the respiratory disease syndrome. The Council takes a strong position on not releasing captive tortoises into natural habitats.

1990: Participants at the annual meeting and symposium in Victorville, California hear Robert Smith of the U.S. Fish and Wildlife Service announce the listing of the desert tortoise as "Threatened." The listing is restricted to the population west and north of the Colorado River ("Mojave population"). BLM cancels the Barstow to Vegas motorcycle race, hopefully forever! Steve Johnson is commissioned to represent the Council on the Steering committee for Nevada's Clark County Habitat Conservation Plan. The Desert Tortoise Conservation Center is built in Las Vegas and 800+ tortoises have new homes. The Luz tortoise relocation study is completed. Daniel Pearson initiates the Council's annual Desert Tortoise Workshop. The U.S. Fish and Wildlife

Service selects members of the Desert Tortoise Recovery Team and Council member Kristin Berry is appointed to the team. James and Evelyn St. Amant retire from the California Department of Fish and Game and the Council. They will be sorely missed!

1991: The provision for euthanasia of wild desert tortoises in the Clark County Habitat Conservation Plan generates much public concern and is opposed by the Council. Clark County decides against it. Relocation, research, adoption, and other beneficial outlets for displaced tortoises are discussed. With the cooperation of Terry Correll and the Living Desert Museum in Palm Desert, California, Elliott Jacobson and Mary Brown continue research on the upper respiratory tract disease.

1992: Edward LaRue, Jr. takes over the helm of the fall Desert Tortoise Workshops. They continue to be very successful - the focus of attention for businesses and a new cadre of field crews that undertake monitoring of pipeline projects, land clearances, and other activities detrimental to tortoises and their habitat. The Council reviews documents pertaining to the West Mojave Coordinated Management Plan, Eagle Mountain trash train, Luz Harper Lake project, and Fort Irwin expansion. Through Tom Dodson's efforts, we intervene with the Sierra Club in the woolgrower's appeal of BLM restrictions on sheep grazing the California desert tortoise habitat. Land the Council acquired on the Chuckwalla Bench is transferred to the Desert Tortoise Preserve Committee.

1993: The Council makes a financial contribution to the Sierra Club Legal Defense Fund's intervention, on behalf of BLM, in the sheep grazer's challenge to BLM's grazing regulations in Nevada desert tortoise habitat. The Council also starts making small matching funds grants to organizations working with threatened and endangered species. A grant is made to the Desert Tortoise Preserve Committee to purchase a mobile display system. Because federal listing of the desert tortoise requires that all research with the species must be approved by the U.S. Fish and Wildlife Service, no proposals have been coming to the Council's Research Advisory Committee and the committee is disbanded.

1994: Critical Habitat is designated for the Mojave population of the desert tortoise and a Recovery Plan is finally published! The woolgrower's appeal of BLM grazing restrictions in California is defeated. This also is a year for major publications. Mary Brown et al.'s definitive work on the organism causing upper respiratory tract disease, *Mycoplasma agassizii*, is published. Led by Elliott Jacobson, the team of scientists working on the shell disease at the Chuckwalla Bench in California publishes a paper. Three years of research at the Conservation Center in Las Vegas is described in a series of 13 papers in Herpetological Monographs No. 8.

Summary

The accomplishments of the Desert Tortoise Council are numerous - some obvious, some subtle. Our origins were, in part, grassroots; we were fulfilling a role that our colleagues in state and federal agencies and academia were unwilling, unable, or too beleaguered or ill-trained to play. Critical to the Council's success was the team approach. There has been no one figure-head, but always a team and new blood.

The development of the Council has been intertwined with changes in wildlife programs on both the state and federal levels. The Council appeared on the scene at a time when interest in state and federal agencies was shifting from user-oriented commodities and recreation (fish, furbearers, waterfowl, upland game and big game) to a broader approach that also included nongame, threatened, endangered, and rare species and ecosystems. Perhaps, the Council helped to direct these changes. Certainly, the southwestern desert ecosystems supported the new approach to wildlife management because traditional game species were scarce.

The annual symposia have provided opportunities for students to develop their professional skills and to meet scientists and specialists from all over the world. Students have used the symposia for discussions of project designs, to present progress and final reports, and to find positions and new research projects. Many student projects were supported in whole or in part, by state or federal agencies. Well over a dozen students (Appendix 2) have obtained master's or doctoral degrees on desert tortoise studies and have benefited from the Council symposia, and from the professors and mentors who are Council members. Several other students currently are conducting graduate research projects on the desert tortoise. Students, in turn, have provided the skills and labor to undertake numerous projects at low costs, and some have become active members of the Council.

Through the symposia and workshops, the Council also has provided opportunities for individuals, employees, owners, and managers of large and small businesses to learn about the latest research findings and techniques, obtain classroom and field training, locate employees or employment, and become aware of new or upcoming projects. In turn, businesses have donated funds for publication or proceedings and supported workshops, and business owners and managers have served on the Council's Board of Directors.

From the beginning, the Desert Tortoise Council has published the proceedings of its symposia, though not always as promptly as we would like, and annually has given special recognition to outstanding individuals and organizations that have fostered its objectives. All things considered, we believe that the Council has made significant progress toward achieving its objectives. In the process, we have grown from a membership of a few dozen individuals to over three hundred - not large by most standards, but distinguished by quality and dedication. The federal and state listings, mostly due to our efforts, have also taken us a big step toward our ultimate goal of assuring the survival of viable populations of the desert tortoise throughout its range.

The Future

Much still remains to be done. For example, we must carefully monitor the progress of the federal recovery plan and see that is provisions are enforced. We must obtain federal protection of tortoise populations in Arizona. We must learn more about the systematics and status of desert tortoise populations in Mexico, and encourage their protection as well. We must become more effective in educating the general public and decision makers about the needs of the desert tortoise. Considering the evident anti-environmental sentiment in the current Congress, the increasingly aggressive attempts by private interests to take control of the public lands, and the political and economic turmoil in Mexico, it is an obvious understatement to say that our job will not be easy. With younger people and new energy coming into the Council, however, we believe that the accomplishments of the past 20 years can be equaled or surpassed in the next 20. We accept this challenge!

APPENDIX 1

LIST OF DTC OFFICERS: 1975-1995*

Co-Chairperson

Kristin H. Berry	1975-76
James A. St. Amant	1976-77
Glenn R. Stewart	1977-78
Donald J. Seibert	1978-79
David W. Stevens	1980-82
Franklin Hoover	1980-83
Robert Turner	1983
George P. Sheppard	1984
Theodore E. Cordery, Jr.	1984-85
Daniel Pearson	1985-86
John Brode	1986-87
Glenn R. Stewart	1987-88
James A. St. Amant	1988-90
Daniel Pearson	1990-91
Michael Giusti	1991-92
Allan Muth	1992-93
Marc Graff	1993-94
Tom Dodson	1994-95
Robert Turner	1995-

Secretary-Treasurer

Tilly Barling	1975
Mary Trotter	1976-79

Secretary

Evelyn St. Amant	1980-89
Terrie Correll Muth	1990-93
Lisa Kegarice	1994-

Recording Secretary

David W. Stevens	1977-78
Lori Nicholson Humphrys	1979-80
Michael Coffeen	1981-83
Judy Hohman	1984-86
Theodore E. Cordery, Jr.	1987-92
Edward L. LaRue, Jr.	1993-

Treasurer

Mary Trotter	1980
Norman Edmonston	1981-82
Martha Young	1983-85
Cheryl Pearson	1986-87
Michael Coffeen	1988-93
Kit Turner	1994-

*Years of service are approximate.

APPENDIX 2

GRADUATE DEGREES OBTAINED STUDYING THE DESERT TORTOISE*

Master's Degrees

Betty Burge, 1977 - University of Nevada, Las Vegas
James Cook, 1979 - California State Polytechnic University, Pomona
Jan Bickett, 1980 - California State University, Sacramento
Alice Karl, 1980 - California State University, Northridge
Judy Hohman, 1980 - Arizona State University, Tempe
Sherry Barrett, 1985 - University of Arizona, Tucson
Ronald Baxter, 1987 - California State Polytechnic University, Pomona
Randy Jennings, 1990 - University of New Mexico, Albuquerque
Michele Joyner Griffith, 1992 - California State University, Dominguez Hills
Matthew Brooks, 1993 - California State University, Fresno
W. Bryan Jennings, 1993 - University of Texas, Arlington
Todd Esque, 1994 - Colorado State University, Fort Collins
Scott Bailey, 1994 - University of Arizona, Tucson
Roy Murray, 1994 - University of Arizona, Tucson

Doctoral Degrees

Ronald Marlow, 1979 - University of California, Berkeley
David Germano, 1988 - University of New Mexico, Albuquerque
Michael Weinstein, 1988 - University of California, Los Angeles
Charles Peterson, 1993 - University of California, Los Angeles
Brian Henen, 1994 - University of California, Los Angeles

*Years are approximate. We apologize for any errors or people omitted.

THE IMPORTANCE OF OBSERVER EXPERIENCE IN FINDING TORTOISES AND SIGN: RESULTS FROM A STUDY USING SEEDED TORTOISE PLOTS AND STYROFOAM TORTOISES

Jerry Freilich
National Park Service, Joshua Tree National Park, Twentynine Palms, California

Edward L. LaRue, Jr.
Circle Mountain Biological Consultants, Wrightwood, California

Abstract. An experiment was conducted in which 78 observers of differing experience levels were allowed to search for tortoises, burrows and scat in one of eight replicated 1-ha fields. Each site was seeded with a known number of tortoise scat, realistic-looking tortoise burrows, and nine styrofoam tortoises of three size classes. Observers were asked questions about their previous experience at surveying for tortoises. The observers were divided between being experienced (1-7000 h surveyed, $n = 45$) and inexperienced (0 h surveyed, $n = 33$). Results showed that inexperienced and experienced observers did not differ significantly in their ability to find tortoises or sign. In comparing tortoise size classes found, total tortoises, scat, and two burrow size classes the two groups did not differ (all $P \geq 0.2$) except in one comparison. The exception was that inexperienced observers found significantly ($P = 0.03$) more burrows than experienced observers, perhaps due to less selectivity (perhaps counting a kangaroo rat burrow). Additional analyses were run dividing experience into four and five levels (e.g., novice, beginner, intermediate, advanced) based on both raw data and log transformed hours surveyed. In all comparisons, results were the same as those reported for two groups. These results suggest that many variables can explain a person's tortoise-finding ability. State of mind, hunger or thirst, ambient temperature and other factors may effect a person's ability to find tortoises, but previous experience, in this experiment, did not.

DESERT TORTOISE RECOVERY PLAN:
BLUEPRINT FOR TORTOISE MANAGEMENT AND RECOVERY

Dolores A. Savignano
U.S. Fish and Widlife Service, Las Vegas, Nevada

Abstract. In 1994 the U.S. Fish and Wildlife Service issued the Recovery Plan for the Desert Tortoise (Mojave Population). The Recovery Plan (Plan) designated six recovery units based on differences in the genetics, morphology, ecology, and behavior of desert tortoises. The Plan recommends designation of at least one Desert Wildlife Management Area (DWMA) per recovery unit and implementation of reserve level protection within each DWMA. DWMAs should be selected based on the principles of reserve design, be redundant, protect sensitive species and ecosystems functions, support at least 10 adult tortoises/square mile and be at least 1000 square miles in size (or be intensively managed). Recovery actions will include: selection and delineation of DWMAs; securing habitat; developing and implementing management actions; an environmental education program and research activities to guide and monitor recovery; and monitoring recovery. All of these actions are in progress.

The Plan also provides guidance on the consistency of activities with tortoise recovery. The following activities are considered consistent with tortoise recovery: non-intrusive desert tortoise monitoring, travel on designated roads, hiking, horseback riding, bird watching, photography, parking and camping in designated areas, aerial fire suppression, maintenance of utility structures, beneficial surface disturbance, enhancement of native game, mining with mitigation, and non-intrusive, non-manipulative biological and/or geological research. The following activities are considered incompatible with tortoise recovery: off-road vehicle use; adverse surface disturbance: sheep, burro, horse, or cattle grazing (except in Experimental Management Zone); vegetation harvest; biological specimen collection; dumping; littering; depositing desert tortoises or other animals; unleashed/uncontrolled dogs; firearm discharge not associated with hunting; and rock hounding.

Habitat Conservation Plans can assist in recovery by providing funding for recovery actions, and by policy cannot hinder recovery.

MANAGEMENT STRATEGIES FOR PROTECTION OF THE DESERT TORTOISE WITHIN JOSHUA TREE NATIONAL MONUMENT

Ernest Quintana
National Park Service, Joshua Tree National Park, Twentynine Palms, California

Abstract. Joshua Tree National Park (NP), in southern California, represents unique and pristine examples of the Mojave and Colorado Deserts. In addition to it's natural, cultural, and historical significance the park contains one of the few remaining large expanse of pristine desert tortoise habitat. Joshua Tree NP has been active in tortoise monitoring and research and is recording valuable data pertaining to the status of the tortoise within the park boundaries.

Because of the protected nature of the park, as well as the park's continuous desert tortoise monitoring program, Joshua Tree NP should be viewed and used by science as a "control" with which to compare other Desert Wildlife Management Area responses. Studies of desert tortoise have identified numerous possible causes for the animals decline, Joshua Tree NP is perhaps the only place that can serve as the critical experimental control to tortoise recovery.

Research to determine the best methodology for sampling/evaluating the status of desert tortoise populations need to be completed. A validation study of sampling methods is needed now. We strongly urge that a cooperative study be done to arrive at an objective, efficient, and unified sampling method.

DESERT TORTOISE INVENTORY RESULTS IN DEATH VALLEY NATIONAL PARK

Doug Threloff and Jeff Aardahl
Death Valley National Park, California

Abstract. Systematic surveys to detect the presence of desert tortoises (*Gopherus agassizii*) in Death Valley National Monument were conducted under contract in 1992. Survey technique was the standard 2.4 km long triangular transect with three transects nested at each survey location. A total of 186 transects were completed at 62 separate locations between June and December.

Desert tortoise sign (burrows, scat) was observed on 24 of the 62 locations, or 39% of survey locations. The maximum amount of sign was two per survey location. It was not possible to determine relative density of tortoises due to the very low amount of sign detected. The results simply indicated a presence or absence of desert tortoises. Tortoises are present in very low density over much of Death Valley extending from the Owlshead Mountains north to the east slope of the Grapevine Mountains.

THE ROLE OF THE NATIONAL BIOLOGICAL SERVICE IN DESERT TORTOISE RESEARCH

John L. Oldemeyer
Mid-Continent Ecological Science Center
National Biological Service
Fort Collins, Colorado

Abstract: In the Mojave Desert, natural resources managers have long recognized the declining trends in desert tortoise populations and the threats to the Mojave Desert ecosystem because of increasing human use of the desert. These trends and threats led to the April 1990 listing of the tortoise as Threatened throughout the Mojave and Colorado deserts. Increasing numbers of other species of plants and animals that share desert ecosystems with the tortoise are listed as either Threatened or Endangered or are on the Fish and Wildlife Service's list of Candidate species.

Most of the Mojave and Colorado deserts are public land managed by the Bureau of Land Management with a multiple use mandate; however, a number of unique areas are protected as national parks, national wildlife refuges, or military installations and are managed with more restrictions to public uses than occurs on Bureau lands. More recently, the Fish and Wildlife Service designated over 2.4 million ha as Critical Habitat for the tortoise. Nonetheless, human impacts continue to threaten the long-term stability of the deserts and create conflicts between development and conservation. Populations of plants and animals are fragmented by roads and highways, cities and towns, power lines and pipelines. Because of the multiple impacts on a landscape level, emphasis is shifting from management of single species to a focus on biodiversity and functioning of ecosystems. Knowledge will be the foundation for ecosystem management, and the needs for that knowledge are likely to grow as impacts increase and management requires more sophistication.

When the National Biological Survey was formed in November 1993, desert tortoise research biologists from the Bureau of Land Management and the U.S. Fish and Wildlife Service were merged into one organizational group, the Desert Tortoise Research Project. The Project is assigned to the Endangered Species Research Section of the Midcontinent Ecological Science Center, Fort Collins, Colorado, and has field stations in St. George, Utah; Las Vegas, Nevada; and Riverside and Palm Springs, California. Within the Project are eight scientists, some who have conducted research on the tortoise and desert ecology for over 20 years. Project scientists have expertise ranging from botany to nutritional ecology to population analysis.

The goals of the Desert Tortoise Research Project are to establish a regional, national, and international reputation for high quality scientific research on issues related to the ecology, conservation, and recovery of desert tortoise populations and their ecosystems with emphasis on the Mojave and Colorado deserts; to assure a useful and productive relationship with resource managers within the Department of Interior, other Federal and State Agencies, and public and private organizations that are interested in desert tortoise populations and associated ecosystems; and, to encourage and develop partnerships for identifying issues and solving problems of arid land management.

High quality science cannot be accomplished without review by the scientific community and by those who will potentially use the information gained. Although Project scientists are expected to develop hypotheses for new research based on their current research results, expertise, and knowledge, they must also rely on the Desert Tortoise Recovery Plan and upon the perceptions and needs of land managers to assure that topics chosen for research are pertinent and of high priority. It is especially important that our research be reviewed to assure that it is without bias and ambiguity. We recognize that the best method for communicating our results to resource managers is through one-on-one discussions, field trips, and workshops; however, as scientists, we believe

that the ultimate test of our research is publication of manuscripts in peer-review journals where the broader scientific community may review our analyses and interpretations, compare our data to theirs, and test our hypotheses in other areas and with other organisms. Lastly, because our expertise and resources are limited, we must draw upon the strengths of others through partnerships and by cultivating a diverse work force so that we can maximize our efforts to enhance conservation of the desert tortoise and desert ecosystems.

AN INVESTIGATION OF DESERT TORTOISE MORTALITY IN UPLAND GAME GUZZLERS IN THE DESERTS OF SOUTHERN CALIFORNIA

Franklin G. Hoover
California Department of Fish and Game, Chino Hills, California

Abstract. An investigation was made to determine if desert tortoise mortality is occurring in upland game watering devices (guzzlers) in the desert areas of southern California. Eighty-nine guzzlers within the four areas designated by BLM as Desert Tortoise Habitat Areas were examined to determine if they contained tortoise remains.

The remains of 26 tortoises and one live tortoise were found in 18 of the guzzlers. It seems likely the tortoises died in the water tanks rather than elsewhere and then transported there by scavengers or water flow. The locations of guzzlers containing desert tortoise remains are scattered among the four habitat areas.

Guzzler water tank construction material appears to be a significant factor contributing to desert tortoise entrapment. Tanks are constructed of either concrete or fiberglass. Slightly over half (58%) of the guzzler tanks are fiberglass. Of the 18 guzzlers containing tortoise remains however, 15 (83%) of the tanks were fiberglass while only 3 (17%) were concrete. A Chi-square test found this difference to be significant.

Another potential entrapment factor was the presence in many fiberglass guzzler tanks of a vertical wall up to 10 cm in height at the top of the ramp leading to the water. Such a wall would seem to impede tortoises from exiting the tank and contribute to their deaths. Although more fiberglass tanks with these walls had tortoise remains than those without them, a chi-square test found the difference to be not significant. Presumably the type of construction material is so important that it overshadows the importance of the presence of this vertical wall.

The rate of tortoise mortality is difficult to estimate since guzzler tanks are occasionally cleaned out and no comprehensive records are kept as to when this occurs. Also there is no information about tortoise decomposition rates in conditions found in the guzzler tanks. All that is known for certain about the rate of deaths is that during the 3.75 years of the study, three tortoises died or, in the case of the live tortoise, would likely have died, in the 89 guzzlers examined.

In addition to tortoises, the remains of 173 other vertebrate animal species were collected from the guzzler tanks.

The data indicate that small but, over time, significant numbers of desert tortoises may be dying in upland game guzzlers.

INTRODUCTION

Hundreds of upland game watering devices (guzzlers) have been constructed in the deserts of southern California and elsewhere to increase populations of game species of birds and mammals. Many have been in place since the 1950's. In 1988 the California Department of Fish and Game received information from the Bureau of Land Management (BLM) that the remains of desert tortoises (*Gopherus agassizii*) had been found in some of these guzzlers. This was disturbing because populations of wild desert tortoises in many areas of California and elsewhere have been declining precipitously due to both natural causes (e.g. disease and drought) and human related causes (e.g. development, grazing, off-highway vehicle use and collecting). Many desert tortoise populations have declined at rates ranging from 3 to 59% per year (Berry 1990). These declines have resulted in the species being listed both state and federally as threatened.

Since only occasional observations of desert tortoise remains being found in guzzlers have been made, an investigation of guzzlers in portions of the deserts of southern California was initiated in October 1990 and continued through May 1994. The purpose of this investigation was to gather additional information about desert tortoise losses in guzzlers, and to determine what factors contribute to these losses.

Although there are several different upland game guzzler designs, all those examined in this investigation function the same. Rainwater is captured on a concrete apron (see Fig. 1 for guzzler nomenclature) and directed into an underground tank where it is stored. Animals enter the tank through the mouth and go down a ramp to get to the water. Tanks encountered in this study were constructed of either concrete or fiberglass.

With most of the guzzlers, the top of the apron was flush with the upper edge of the ramp leading down to the tank floor. In a significant number of guzzlers (42%), the top of the apron was higher than the upper edge of the ramp. This formed a more or less vertical face at the tank mouth. This vertical face, or drop, ranged from 2.5 to 10.2 cm in height and averaged about 6.1 cm.

Since the original purpose of these guzzlers was to provide water to small upland game animals, most guzzler tanks originally had bars installed at the tank mouths to prevent access by larger animals. Later, after a change in philosophy, one or more bars were removed from most guzzlers to admit larger animals such as coyotes. The largest opening at the water tank mouths therefore varies from 11.0 to 125 cm or more.

METHODS

The California Desert Conservation Area Plan (Bureau of Land Management 1980) designated four areas with high density populations of desert tortoises as Desert Tortoise Crucial Habitat. In 1992 these areas, with modified boundaries, were designated by BLM as Category 1 and 2 Tortoise Habitat Areas in recognition of their habitat values (Bureau of Land Management 1993). The four areas are known as the Western Mojave, Ivanpah-Shadow-Kelso, Fenner-Chemehuevi, and Chuckwalla habitat areas (Fig. 2). This report is based on results of guzzlers examined within these areas.

The Western Mojave Habitat Area, as the name implies, is in the western Mojave Desert. Although the majority of it lies in San Bernardino County, the western boundary overlaps into Kern County and, to a lesser extent, into Los Angeles County. This is one of the largest Habitat Areas and it contains approximately 38 guzzlers, most of which are in Kern County.

The Ivanpah-Shadow-Kelso Habitat Area lies in eastern San Bernardino County and entirely in the Mojave Desert. It contains approximately 25 guzzlers.

The Fenner-Chemehuevi Habitat Area is primarily in eastern San Bernardino County although a small portion at the extreme south end extends into Riverside County. This area encompasses parts of both the Mojave and the Colorado deserts. There is a high concentration of guzzlers in this area (about 85) and it contains almost as many as all of the other three areas combined. Most are in the area's northern and northwestern portions, which are mostly in the Mojave Desert.

The Chuckwalla Habitat Area lies in eastern Riverside and northeastern Imperial County and entirely within the Colorado Desert. The area contains 24 guzzlers. Major washes in the Colorado Desert are heavily wooded with palo verde, ironwood, and smoke trees. Many guzzlers in this area are located adjacent to these washes and are difficult to locate because of the trees and the flat topography.

Upland game guzzlers are generally located near a geographic feature such as a dry wash or a hill that provides cover and habitat for upland game species. The guzzlers may be relatively isolated or clustered within a few kilometers of each other. Some are within a kilometer of a major highway or well used paved or dirt roads, but most are much farther away than that with some being 16 or more kilometers from paved roads.

Because of the limited time available for field work, guzzlers to be examined were selected largely for their accessibility. Nevertheless, at least representative numbers of guzzlers were examined in all Habitat Areas.

Because of the varied conditions encountered at the guzzlers, there was no standard approach to sampling the material on the water tank floors where tortoise remains were found. Guzzler tanks were examined with a stiff-tinned garden rake and/or a 0.3 centimeter mesh dip net. Sampling was accomplished through the tank mouth and/or through the hatch on the tank cover. The material on the tank floors was removed until it was subjectively judged to be adequately sampled. The sampling time varied from about 15 to 30 minutes depending on the amount of material present on the tank floor. Because of time constraints, no attempt was made to remove and examine all of the material on the tank floor. In most situations, this would have been a major undertaking since typically there were several inches of sand, gravel and decomposed organic matter. Rocks up to 15 cm or more in diameter were not uncommon.

All bottom material removed from the tanks was examined by hand and all animal remains and unusual objects were inspected. All tortoise remains were retained and later examined to determine how many tortoises were represented.

The aprons of all guzzlers visited were examined for the presence of tortoise remains.

RESULTS

Eighty-nine guzzlers were examined, and 17 contained the remains of at least one desert tortoise while a single live tortoise was found in an additional guzzler tank. (For wording convenience, the live tortoise will be included in further references to tortoises remains.) Thus tortoise remains were found in 20% of the guzzlers examined. Thirteen guzzler tanks contained remains of one tortoise each. Three guzzlers had two sets of tortoise remains, one guzzler had the remains of three tortoises and one guzzler had five sets of remains. The live tortoise was found in a unique situation. Much sand and gravel had washed down from nearby slopes and had half filled the water tank. There was only about 2.5 cm of water near the front of the tank so the tortoise did not drown.

Two entire tortoises were found that had recently died, but in most cases only disarticulated carapace and plastron bones and/or scutes were recovered. Leg skin was found in four guzzler tanks.

There was considerable variation in the condition of recovered remains. In several cases, scutes were badly decomposed and were so faded and flexible that they had the appearance of tattered pieces of parchment. In other cases, scutes and bones were in good condition with little deterioration.

Tortoise remains were found in guzzler tanks in all four of the Habitat Areas (Table 1).

Of the 89 guzzlers examined, 37 had tanks constructed of concrete and 52 were fiberglass. The remains of 20 tortoises were found in 15 fiberglass tanks and seven were found in three concrete tanks.

Thirty-seven of the 89 guzzlers examined had drops formed by the apron edge at the tank mouth. Drops were found only in some of the fiberglass tanks and never in concrete tanks. Twelve tortoises were found in nine guzzlers with drops and 15 were found in nine guzzlers without drops.

No tortoise remains were found on the aprons of any of the guzzlers examined in this investigation.

In addition to tortoise remains, the remains of 173 other animal species were found in the 89 guzzler tanks examined. These remains were from 98 canids (mostly if not entirely coyotes), 33 birds, 12 rabbits, 8 rodents, 12 lizards, 8 badgers, and 2 snakes.

DISCUSSION

Results of this investigation tend to demonstrate that small but, over time, probably significant numbers of desert tortoises are dying in upland game guzzlers. One factor that complicates analysis of the data is that the guzzler water tanks are cleaned out occasionally by volunteer organizations and no comprehensive records are kept concerning this work. Lack of tortoise remains in a guzzler tank may therefore be a result of its having been cleaned in the somewhat recent past.

How many of the desert tortoises found in this investigation actually died in the guzzler water tanks is open to speculation. It is possible that some of the tortoises could have died upslope of the guzzlers or on their aprons and later been washed into the tanks. The chances of this occurring are probably not great however and there is evidence of mortality occurring in the tanks. Pieces of leg skin were found in four guzzler tanks. It seems likely that if the tortoises died elsewhere, scavengers would have rather quickly removed and eaten the legs. In addition, the behavior of the live tortoise after its removal from the water tank indicated that it was in a seriously chilled condition and it seems likely that it would have left the tank had it been able to do so and that if not removed it would probably have died there.

Factors evaluated as contributing to tortoise mortality in guzzlers were water tank construction material and the presence of a drop at the apron/ramp interface. These appear to be the only significant variables among the guzzlers examined.

The surface of concrete tanks is slightly rough. This may provide more traction to tortoises when they are walking on the ramp and might help to prevent them from sliding into the water. Fiberglass tanks, however, are smooth-surfaced and seem to provide little traction. Of the 89 guzzlers examined, 52 (58%) had water tanks constructed of fiberglass and 37 (42%) were made of concrete. Of the 18 guzzlers containing tortoise remains however, 15 (83%) had fiberglass tanks while only 3 (17%) were concrete. A chi-square analysis of this data revealed that this difference is significant ($X^2_{df=1}$ = 5.8, P = <0.020).

Intuitively one would expect that vertical faces (i.e. drops) averaging about 5.0 cm high at the top of ramps would present a formidable obstacle to tortoises attempting to leave water tanks and increase their chances of eventually slipping into the water and drowning. Only guzzlers with fiberglass water tanks have drops but not all such tanks have them. A chi-square analysis of the data reveals that the difference between the numbers of fiberglass guzzler tanks with drops having tortoise remains (9) and those without drops having such remains (6) is not significant ($X^2_{df=1}$ = 1.32, P = >0.20).

Since very little is known about decomposition rates of desert tortoises in water, no firm conclusions can be made about the rate of tortoise mortalities in guzzler tanks except that the data collected in the 3.75 years of this study demonstrate that at least three tortoises are known to have died (or in the case of the live tortoise, would likely have died) in this period in the 89 guzzlers examined. Except for the live tortoise and the two that had recently died, it can not be determined with any degree of certainty how long the other remains had been in the water tanks. All of them were discolored and mostly disarticulated. In one case, bones and scutes from a tortoise were recovered from a water tank and then three years later additional such remains from that animal were collected from the tank. All of these remains were in good condition and there were few obvious differences in appearance between the two sets of remains. If three years makes so little change, one can only speculate how old the scutes are that were collected elsewhere which are so deteriorated as to be hardly recognizable.

If the fundamental reason why tortoises are dying in guzzler water tanks is lack of traction on the tank ramp then modifying the tanks to overcome this problem should not be too difficult. There are however approximately 170 upland game guzzlers within the study area. Even though only about half of them are fiberglass, all ultimately should be modified to minimize tortoises losses in them. This represents a formidable task but one which, through cooperative effort, can be accomplished over time.

ACKNOWLEDGEMENTS

This investigation was initiated as a result of information provided by K. Berry. E. La Rue, J. Easton and P. Lowe assisted in data collection. K. Nicol and G. Black provided valuable editorial advice.

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Table 1. Location of Guzzlers Examined and Results of Examination

	Habitat Area				
	Western Mojave	Fenner-Chemehuevi	Ivanpah-Shadow-Kelso	Chuckwalla	Total
No. of guzzlers examined	13	51	17	8	89
No. of guzzlers with tortoise remains	2	13	2	1	18
No. of tortoise remains	2	22	2	1	27

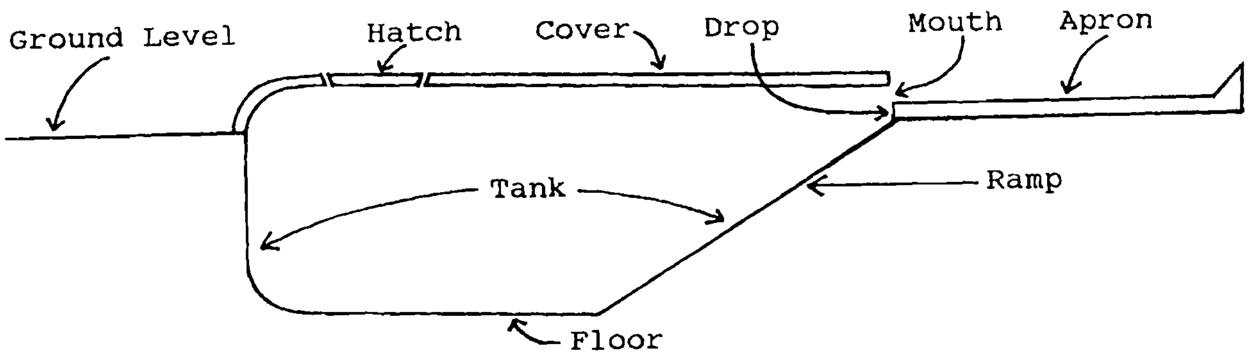

Figure 1. Upland Game Guzzler Terminology

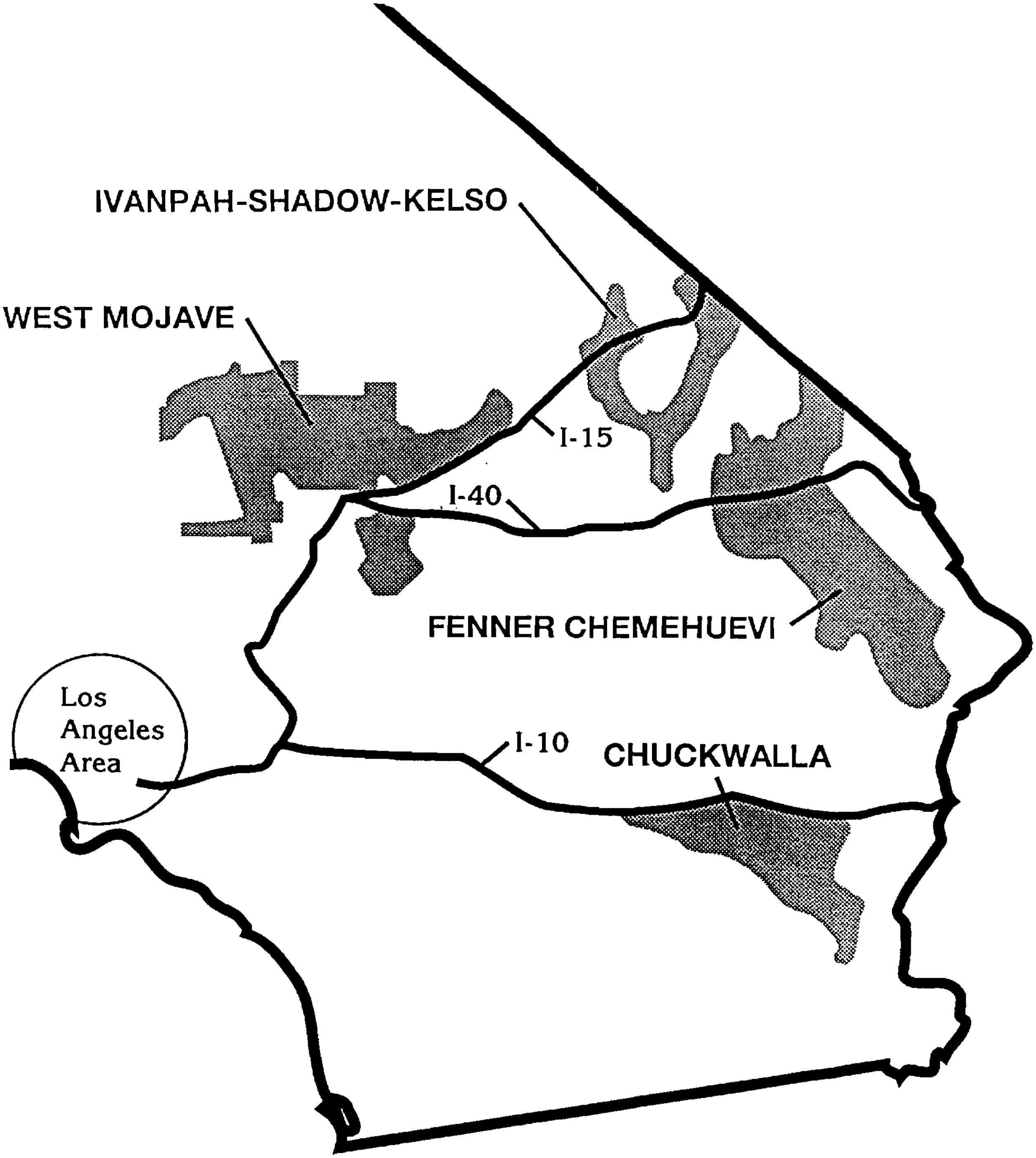

Figure 2. Location of the Western Mojave, Ivanpah-Shadow-Kelso, Fenner-Chemehuevi, and Chuckwalla habitat areas.

ALIEN ANNUAL GRASSES AND FIRES IN THE WESTERN MOJAVE DESERT: A PLAN TO EVALUATE THEIR EFFECTS ON DESERT ANNUAL PLANT COMMUNITIES

Matthew Brooks
University of California, Riverside

Kristin H. Berry
National Biological Service, Riverside Field Station, Riverside, California

Abstract. Over the past few decades alien annual grasses (AAG) such as *Bromus* and *Schismus* spp. have become more abundant and widespread in the western Mojave Desert. Their spread has been associated with a concomitant increase in fire frequency and intensity which has resulted in the conversion of large tracts of desert scrub into lower diversity alien annual grassland. These changes have prompted the U.S. Department of the Interior to support research on the effects of AAGs and fire on plants in desert tortoise habitat. We were awarded a three-year grant to conduct research and experiments on distribution, abundance, and impacts of alien annual grasses on desert tortoise habitat in the western Mojave Desert.

We hypothesize that early season fires occurring before AAG seeds mature completely may be effective at destroying those seeds still on grass stalks and suspended in the flame zone, resulting in reduced above-ground vegetative AAG density and biomass during the years following the fire. A higher percentage of AAG compared to native forb individuals (including both germinated plants and remaining seeds) may be destroyed since a high percentage of AAG seeds are likely to germinate each year, and most native desert species typically germinate a lower percentage of their total seed bank. If this hypothesis is substantiated, early season fires may be a method by which AAG population sizes can be reduced in areas heavily infested with them while minimizing impact on native plant communities.

We also plan to conduct experimental burns at the height of the fire season in August, and predict that typical late summer burns such as these will not destroy AAG seeds which are on the ground and will simply open up the habitat resulting in greater above-ground vegetative AAG density and biomass during the years following the fire. The effects of both early and late season burns will be determined by measuring the composition of resultant annual plant communities and soil nutrient changes during the two spring seasons following the fires.

It is assumed that AAGs also negatively impact native Mojave Desert plant communities through competition with extant species for limiting resources. The effect of AAG removal on forb density, biomass, and community diversity will be tested to determine if this premise is true. We will also test the effects of experimental manipulation of soil nutrient levels on AAG dominance and community diversity. We hypothesize that AAG density and biomass will be greater, and forb diversity lower, at soil nutrient levels raised above those which occur naturally. In addition to these field manipulations, we will also conduct a regional survey of 34 sites across the western Mojave desert to determine if any correlations exist between specific habitat and environmental variables and annual plant community structure.

All of the studies will be conducted in or near three of the four Desert Wildlife Management Areas (DWMAs) identified in the Desert Tortoise (Mojave Population) Recovery Plan (1994): the Fremont-Kramer DWMA, the Superior-Cronese DWMA, and the Ord-Rodman DWMA.

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THE RESPONSE OF GEOMETRIC TORTOISE *PSAMMOBATES GEOMETRICUS* POPULATIONS TO WILDFIRES IN THEIR HABITAT

Ernst Baard
Cape Nature Conservation, Western Cape Scientific Services, Stellenbosch, South Africa

During the dry, hot summers of the Western Cape Province, South Africa, the potential for wildfires in Cape Floral Kingdom (fynbos) habitats rises substantially, and runaway fires often rage for days in inaccessible mountainous terrain. Fire frequency in fynbos communities depends on a) fuel loads, b) sources of ignition, and c) weather conditions that coincide with both these (Van Wilgen 1987). In fynbos communities fuel loads increase with vegetation age, thus elevating fire hazard, but low incidence of naturally occurring ignition sources (e.g. lightning flashes) explain the relatively long average period between fires (on average once every 15 years) (Van Wilgen *op. cit.*). Being a fire-prone habitat, Cape Floral Kingdom plant communities, and many plant species within, largely depend on fire to rejuvenate itself and to overcome senescence. Canopy-stored seedbanks for example require fire to be released and primed for germination, while smoke was recently found to play an important role in the germination processes of many species (Brown, Botha, Kotze and Jamieson 1993).

Low-lying habitats occupied by the endemic geometric tortoise, *Psammobates geometricus*, often escape wildfires due to their isolated and fragmented nature, but when a runaway fire hits a small habitat patch or if a fire is deliberately lit, tortoise populations are usually negatively affected. Together with mortalities as a result of the fire, the loss of vegetative cover which in turn may result in higher predation, especially by avian predators, hold serious implications for geometric tortoise populations occurring in isolation, and this paper attempts to highlight two cases where the response of populations has been documented and is being monitored.

Geometric tortoises cannot escape wildfires in their habitat since a) they cannot run away, b) they cannot hide in dense vegetation only and c) they cannot escape into sub-terranean burrows. Therefore, during evolutionary time geometric tortoise populations had to live with catastrophes such as fires and had to adapt their life history in order to minimize the effect on population dynamics. One such adaptation is the fact that geometric tortoise females lay their eggs during late spring to early summer (October to December) and the eggs take five to eight months to hatch, usually after the onset of the first autumn rains (March to April) (Boycott and Bourquin 1988). It stands to reason that at this point a) the fire hazard has dropped substantially and b) the first annual, herbaceous plants have started appearing, therefore enhancing the survival potential of hatchlings. Still, what happens when a catastrophe eventually hits a population?

In March 1982, a runaway wildfire hit the largest remaining geometric tortoise population in the Elandsberg Private Nature Reserve, near Hermon. Burning with a strong southeasterly wind behind it, the fire swept down from the mountains into the low-lying parts where the occurrence of geometric tortoises is concentrated. After destroying approximately 60% of the entire reserve, the fire left in its wake a sad sight of dead and dying tortoises, and it was realised that the population was hit severely (Greig and De Villiers 1982). In fact, five years later in 1987, surveys confirmed that the 1982 fire had had a severe impact on the hatchling and yearling cohorts, with an obvious gap appearing in the age structure (Fig. 1). The only reasonable explanation for this was the effect of the fire, but it also highlighted the fact that the years following the fire were conducive to hatchling recruitment (confirmed subsequently by higher than long term average rainfall figures; Baard 1990). Subsequent surveys in 1990 (Fig. 2) and 1993 (Fig. 3) further confirmed the shift in the so-called "catastrophe gap", with its effect apparently phased out after approximately 10 years. No fire has occurred here since 1982 and adequate recruitment appeared to have taken place, leading us to believe that large geometric tortoise populations, and for that matter any large, nonburrowing terrestrial tortoise population, living in a fire-prone habitat may be able to "absorb" catastrophes such as these without detrimentally disrupting the overall dynamics of the population.

In historic times, Khoi-San hunter-gatherer people of the Western Cape burned large patches of natural lowland habitat, occupied among others by geometric tortoises, to enhance grazing for their cattle and sheep (Deacon, Hendey and Lambrechts 1983). It is thought that this practice promoted habitat quality and resulted in a mosaic of differently aged vegetation communities which were occupied by different densities of grazing herbivores and stock. From the little available evidence today, geometric tortoises appear to select recently-burned, young habitat and avoid dense, old stands of renosterveld, their primary habitat in the low-lying areas. It would therefore appear that geometric tortoise densities would have changed accordingly in historic times, and that populations were able to ride out catastrophes by means of recruitment from adjacent habitats. However, with modern-day agricultural expansion in the Western Cape and resultant fragmentation of geometric tortoise habitat, recruitment patterns have been affected to such an extent that populations virtually have to "look after themselves", confirming the fact that the larger the population is, the easier it is to "absorb" the effect of the catastrophe.

However, this optimistic picture changes dramatically when small, isolated geometric tortoise populations such as that of the Harmony Flats Nature Reserve are continuously hit by catastrophes and not given adequate time to recover. Annual census data on this population indicate that since receiving protective status in 1986, there has been a steady decrease of population numbers following catastrophes in the form of four fires; some of which were deliberately lit by humans (Fig. 4). This population is completely isolated from any adjacent natural area and surrounded by formal and informal housing developments. To date, intensive management has been necessary to maintain the reserve in a natural state, but despite this, it appears that this population is inevitably headed for extinction in the face of socio-economic pressure. Under a new political dispensation, the rezoning and allocation of undeveloped government land to prospective land owners have become a reality, and this nature reserve may be abolished in favour of low-cost housing in future. In fact, computer modelling of the population dynamics and stochastic events resulting from this external pressure, indicates a high probability of extinction before the year 2000, and looking at the visual presentation of this process, it is hard not to realise that this is in fact what is happening, and the process could even be called "*The slow death of a tortoise population*". Unless this population is supplemented from the outside and vigorously protected with the aid of the local community and authorities, this last natural area of its kind in the general region will be lost.

In conclusion, it is evident that a) geometric tortoise habitat requires periodic fire to revitalise itself and to keep natural processes operating, b) geometric tortoise populations appear to be adapted to the "natural" fire regime in their habitat and large populations are able to "absorb" catastrophes, c) population dynamics are disrupted by catastrophes, for example too frequent fires, d) populations need to recover adequately following a catastrophe and juvenile cohorts need to reach sexual maturity to ensure proper recruitment, and e) extinction is inevitable in isolated, unmanaged populations continuously hit by catastrophes.

Finally, habitat deterioration and destruction remain the two main factors in this extinction game and are leading to the world-wide loss of more and more terrestrial tortoise and freshwater turtle habitats. While very little can be done about the onslaught of development, conservationists can and should work hard at communicating the conservation plight of tortoises to land owners, developers and the general public, because only when attitudes towards these creatures are positively influenced, will there be hope in preserving part of this natural heritage.

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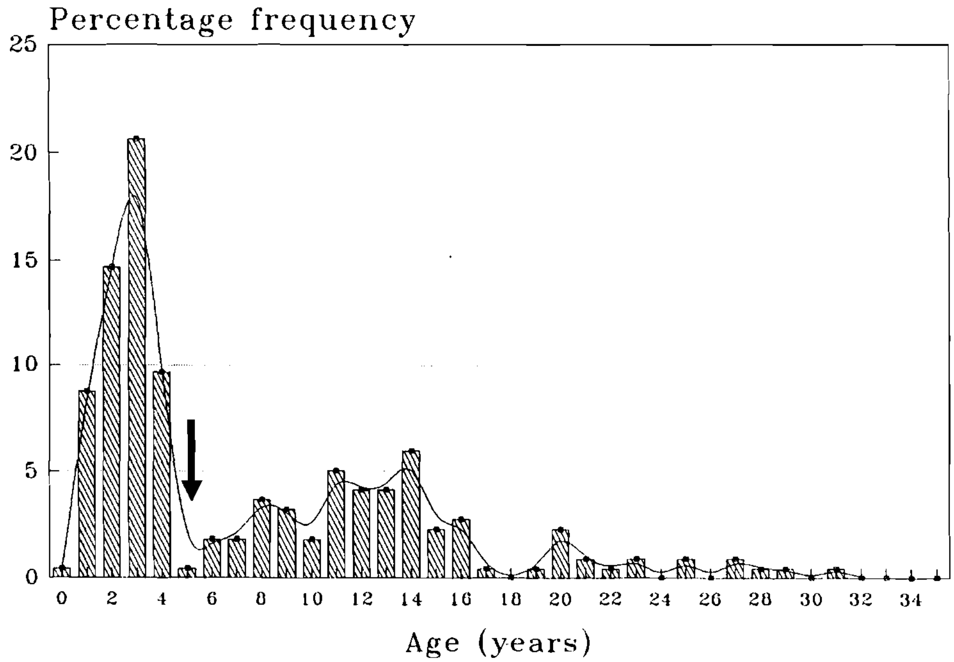

Figure 1. Age structure of the Elandsberg Private Nature Reserve geometric tortoise population as determined during 1987. Arrow indicates the effect of a wildfire which occurred in March 1982 on survival of hatchlings and yearlings. Note relatively good recruitment in the years following the fire (ages 1 to 4).

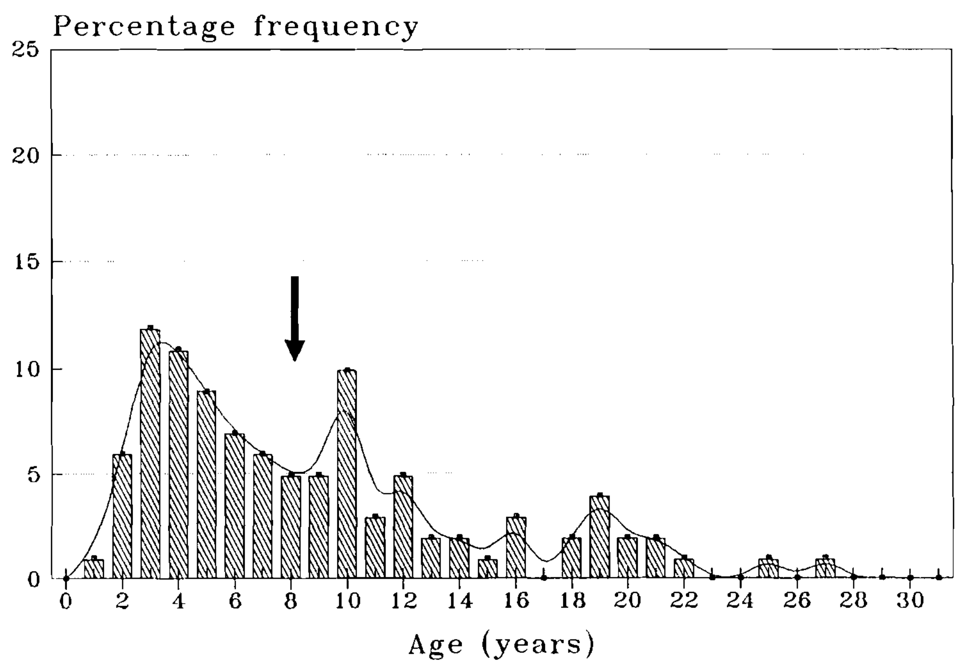

Figure 2. Age structure of the Elandsberg Private Nature Reserve geometric tortoise population as determined during 1990. Arrow indicates the effect of a wildfire which occurred in March 1982.

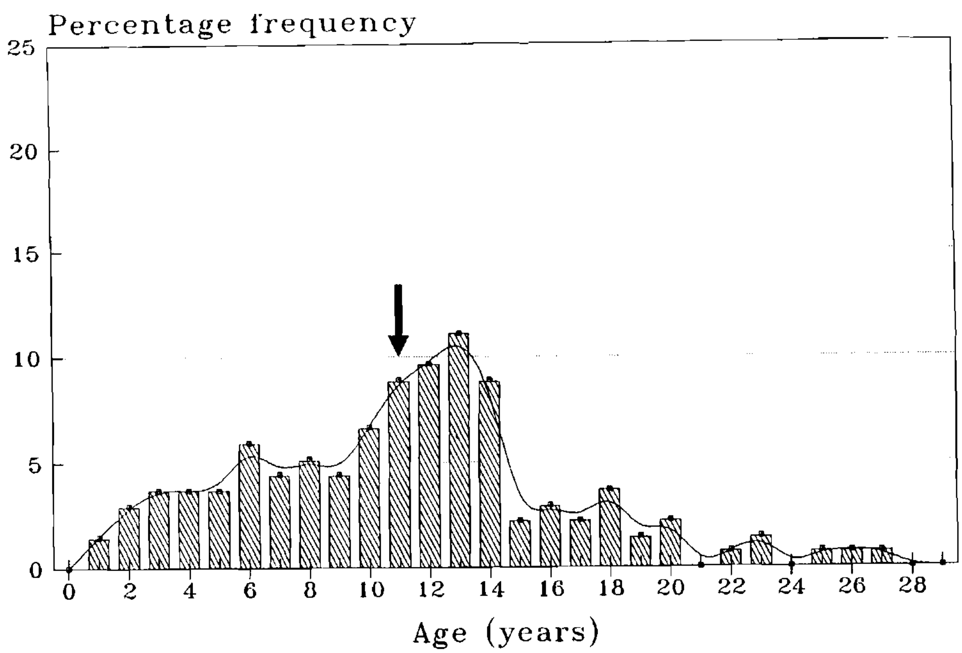

Figure 3. Age structure of the Elandsberg Private Nature Reserve geometric tortoise population as determined during 1993. Arrow indicates the effect of a wildfire which occurred in March.

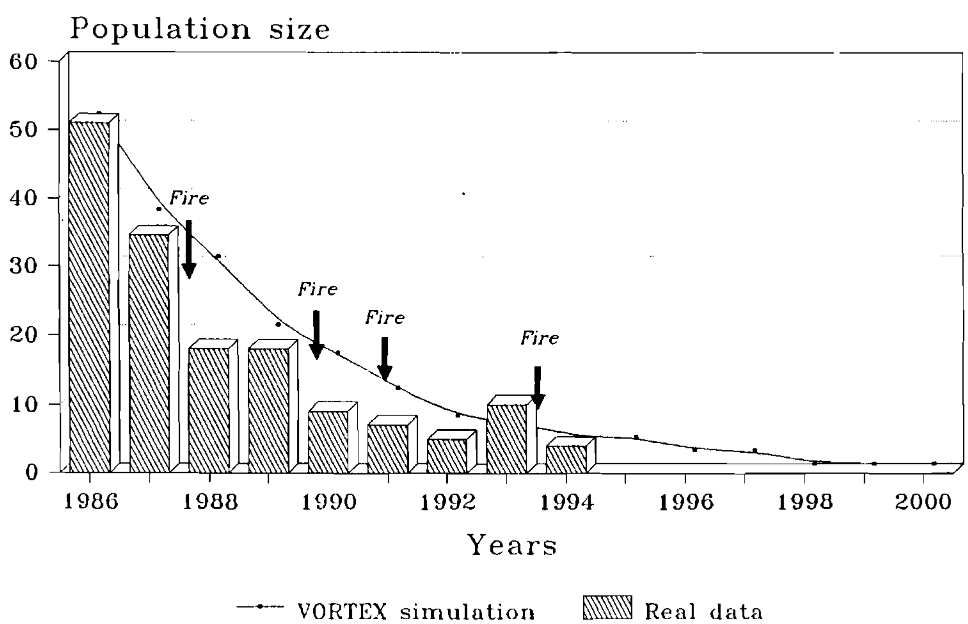

Figure 4. Graph indicating the decline of the Harmony Flats Nature Reserve geometric tortoise population during the years 1986 to 1994 following four catastrophic fires in the reserve. Modeling of the population indicate a high probability of extinction before 2000.

THE IMPORTANCE OF NUTRITION IN REARING PROGRAMS FOR GALAPAGOS LAND IGUANAS AND GIANT TORTOISES

Linda C. Cayot
Charles Darwin Research Station, Santa Cruz, Galapagos Islands, Ecuador

Olav T. Oftedal
National Zoological Park, Smithsonian Institution, Washington, D.C.

Abstract. The populations of both land iguanas (*Conolophus subcristatus*) and giant tortoises (*Geochelone elephantopus*) in the Galapagos have been decimated by human influences, including direct hunting, predation by introduced animals and habitat degradation. Breeding and rearing programs were established for populations of both species at the Charles Darwin Research Station (CDRS) on Santa Cruz Island, Galapagos with the goal of repatriating captive-reared animals to the islands from which the populations originated. By 1989 it was apparent that despite successful reproduction, juvenile mortality and morbidity were unacceptably high among land iguanas at the CDRS, threatening to interrupt the repatriation program. Digestive disorders were suspected as a cause of death. The iguanas were being fed vegetation collected from the highlands on Santa Cruz, as well as some plants grown in a garden. Nutritional analysis revealed that these plants were higher in moisture and lower in gross energy than plants consumed by iguanas in their native habitat. The levels of potassium and some other minerals were also suspect. A program of more frequent feeding was initiated, and an artificial diet was tested, leading to the development of a meal-type diet that could be locally made, using locally available grains (including quinoa) and legumes, as well as coral sand as a calcium source. Imported vitamin and mineral premixes were also included. Mortality dropped, growth rates increased and an improvement in condition was noted. The program of repatriation of captive-reared individuals to their respective islands was resumed. A similar evaluation of dietary habits and captive diets used for rearing giant tortoises is now underway.

In the Galapagos, populations of both land iguanas (*Conolophus subcristatus*) and giant tortoises (*Geochelone elephantopus*) have been decimated by human influences, including direct hunting, predation by introduced animals and habitat degradation (e.g., Macfarland, Villa and Toro 1974). The Charles Darwin Research Station (CDRS), in collaboration with the Galapagos National Park Service, established breeding and rearing programs for populations of both species on Santa Cruz island, with the goal of repatriating captive-reared animals to the islands from which the populations originated. Of necessity, these programs have been coordinated with concerted efforts to eradicate introduced predators and to preserve habitat.

By 1989 it was apparent that despite successful reproduction, juvenile mortality and morbidity were unacceptably high among land iguanas at CDRS, threatening to interrupt the repatriation program. Growth failure was coupled with digestive disorders in which animals became moribund and died with their digestive tracts filled with fibrous plant material. It was also noted that adult females remained in poor condition for prolonged periods after egg-laying. Given the suspicion that inadequate diet might underlie the problem, a collaborative study of land iguana nutrition was initiated.

In 1989, the iguanas were being fed vegetation collected from the moist highlands on Santa Cruz island, as well as some plants grown in local gardens. Samples of these food plants were collected and dried for subsequent nutritional analysis. For comparison, samples of foods that land iguanas have been observed to consume in the wild were also collected and assayed. Samples were assayed for dry matter by oven drying, for nitrogen (protein) by the Kjeldahl method, for fiber by the detergent system, for gross energy by bomb calorimetry and for minerals by atomic absorption and atomic emission spectroscopy.

Nutritional analysis revealed that the highland and garden plants were higher in moisture and lower in gross energy than plants consumed by iguanas in their native habitat. In many of the highland and garden plants the levels of potassium were very high (3-8% on a dry weight basis) and the ratios of nitrogen to potassium (N:K) were low (0.4-0.7). By contrast, plants eaten in the wild were typically found to have lower potassium (0.4-3%) and higher N:K ratios (0.7-2.7, although in *Opuntia echios* the ratio was about 0.4). Based on our analytical data, we decided to adopt the following nutritional goals: (1) to increase the available energy in the diet; (2) to increase dietary nitrogen (protein) concentration; (3) to increase dietary phosphorus concentration; and (4) to decrease dietary potassium concentration.

Management changes that were instituted include an increase in the frequency of feeding, increased selectivity in plants harvested for feeding, and segregation of dominant animals from the group pens. We also tested the effect of feeding a formulated meal-type diet that had been developed by Olav Oftedal for use with green iguanas. A study was designed in which the meal-type diet was offered to one of two groups of 15 juvenile land iguanas. The meal-type diet provided 50% of diet dry matter, the remainder being composed of vegetation; in the control group only vegetation was offered. Otherwise both groups were housed and managed similarly. In each of the three months of the trial, the land iguanas provided the green iguana diet had higher weight gains. This indicated that the land iguanas would both accept and benefit from a formulated meal-type diet that could be used to attain the nutritional goals stated above. Changes in dietary management had an immediate effect on juvenile mortality, which dropped from 25% ($n=29$) in 1988 and 17% ($n=15$) in 1989 to 2.8% ($n=2$) in 1990 and 1.4% ($n=1$) in 1991.

In 1991 we developed a diet that could be produced locally. We sampled and analyzed various grains that were available in local markets. Based on these data, a nutritionally complete diet was made from quinoa (an Andean grain consumed locally), lentils, coral sand (collected from local beaches as a calcium source), vegetable oil, and vitamin and mineral premixes. Of these ingredients only the premixes were supplied from the United States (Zeigler Bros., Gardners, Pa). The grains were first ground in a hand mill that was modified to accept a belt drive attached to an electric motor, then mixed with other ingredients in a V-mixer constructed at CDRS. The ground, mixed diet was offered so as to provide half of the dry matter intake of the iguanas, with the remainder provided by locally harvested vegetation. Introduction of this diet has led to an increase in the growth rates of the juveniles at CDRS, as compared to prior years.

Some herpetologists decry the use of artificial diets that produce rapid growth. However, in this instance increased growth has been associated with a marked reduction in mortality as well as an apparent improvement in vigor and condition, not only in juveniles but also in adults. Of even greater importance, the increased success of the captive rearing program made it possible to reinstate the repatriation of animals to the wild (Cayot and Menoscal 1992). For the first time, a large number of juveniles ($n=68$) were repatriated to the island of Baltra. The population on this island had disappeared after World War II, with only a small remnant surviving on adjacent Seymour Norte. This remnant provided the founders for the captive breeding program; it is too soon to tell whether the repatriated iguanas will become a self-sustaining population.

A similar dietary evaluation is being undertaken for the Galapagos tortoises at CDRS and at a new breeding center established on the island of Isabela. In 1994 we began collection and analysis of offered foods, and we will shortly begin tests on the effects of an artificial diet (using the land iguana diet as the experimental diet) on juvenile growth. While mortality has not been a problem in recent years, we hope that improved nutrient intakes may enhance growth, reproduction and vigor of the captive population. We are particularly interested in the effects of prior nutritional status on post-release survival, but such a study will require many years of observation.

We conclude that the previous land iguana diet comprised of vegetation from highland areas and gardens was nutritionally inadequate. Part of the problem may have been that juvenile iguanas were unable to eat and digest enough of the high-moisture, bulky food, but nutritional imbalances were likely also involved. The addition of a ground diet provided both additional energy and supplemental nutrients. It is critical when developing breeding programs for rare or endangered reptiles that the diets used be evaluated for nutritional adequacy by profesionally-trained nutritionists.

ACKNOWLEDGEMENTS

Financial support for nutritional studies has been provided by the Smithsonian Institution Research Opportunities Fund, the Smithsonian Scholarly Studies Program and the Charles Darwin Foundation. We thank the many persons at CDRS and the Galapagos National Park Service who have assisted in plant collections, care of animals and data entry.

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EFFECTS OF TEMPERATURE AND DIET COMPOSITION ON NUTRIENT UTILIZATION IN HERBIVOROUS REPTILES

David J. Baer
Allen and Baer Associates, Silver Spring, Maryland

Olav T. Oftedal
Department of Zoological Research, National Zoological Park, Smithsonian Institution, Washington D.C.

Herbivorous reptiles consume diets that contain relatively large amounts of plant fiber. Plant fiber is comprised of cellulose, hemicellulose, lignin, and other polymers. Whereas the majority of the plant cellular contents are digested through enzymatic processes, the plant fiber is fermented by symbiotic anaerobic microbes in the digestive tract of their host. The end-products of ferrnentation provide substrates for energy, and for the synthesis of amino acids, fatty acids and glucose. Most anaerobic fermentation in reptiles occurs in the hindgut of the host, after gastric digestion has occurred. The rate and degree of both gastric digestion and anaerobic fermentation can be affected by ambient temperature and diet composition. Apparent nutrient digestibility is often an appropriate measure of diet utilization and is calculated as:

$$\textit{Digestibility}\ (\%) = \frac{\textit{Intake-Fecal Output}}{\textit{Intake}}100.$$

Until recently, lack of data from controlled studies has led to confusion regarding the effect of ambient temperature on digestive function, particularly for herbivorous reptiles.

In a crossover study with 12 green iguanas (*Iguana iguana*) housed at two different ambient temperatures (28 C and 35 C), mean daily dry matter (DM) intake was 3.5 g (0.35% of body weight (BW)) for iguanas housed at 28 C and 12.7 g (1.33% of BW) for iguanas housed at 35 C. However, mean percent DM digestibility did not differ for iguanas housed at these temperatures (67.0% at 28 C and 67.2% at 35 C). Metabolizable energy intakes were different (11.4 kcal/d at 28 C and 41.75 kcal/d at 35 C) but this difference can be attributed to the difference in total diet intake and not a difference in the iguana's ability to extract energy from its diet. Furthermore, daily energy expenditure (5.48 kcal at 28 C and 14.26 kcal at 35 C) and estimated maintenance requirements were higher for iguanas housed at the higher temperature. Thus, improved rate of growth is not a consequence of improved digestive efficiency but rather a consequence of a proportionately greater increase in food intake relative to energy requirements.

Diet composition can also affect nutrient utilization and growth. For herbivorous reptiles, plant fiber is a potentially important source of energy but the dynamics of plant fiber fermentation and animal performance can be affected by diet composition. In a Latin square crossover study, 21 green iguanas were fed three diets containing 19%, 24% or 27% (DM basis) neutral detergent fiber (NDF) (designated as low-, medium- and high-fiber). There was little effect of increasing fiber level on daily DM intake (0.69% of BW, 0.76% of BW, and 0.70% of BW for low-, medium- and high-fiber diets respectively). However, increasing fiber intake decreased DM digestibility (66%, 62%, and 58% for low-, medium- and high-fiber diets, respectively) and metabolizable energy coefficients (71%, 66%, and 62% for low-, medium- and high-fiber diets, respectively). As a consequence of the decrease in energy availability from the high-fiber diet, growth rate was lower (1.42 g/d) than when iguanas were fed the medium- (2.35 g/d) and low- (2.22 g/d) fiber diets. Conversely, Barboza and Oftedal (1993) reported that growth rate did not differ when immature desert tortoises are fed diets containing 19%, 32% or 47% NDF (DM basis), and DM intake increased (0.60%, of BW, 0.83% of BW and 0.99% of BW for low-, medium- and high-fiber diets, respectively). However, the negative effect of increasing dietary fiber content on DM digestibility was similar for both green iguanas and desert tortoises (82%, 68% and 54% for low-, medium- and high-fiber diets, respectively).

It appears that the digestive strategy of these two herbivorous reptiles may be different and may be a consequence of differences in gastrointestinal tract morphology (Figure 1). The morphology of the iguana gastrointestinal tract includes a well-developed and capacious cecum where fermentation occurs (Stevens 1988). There are several mucosal folds (or semi lunar valves) in the hindgut that are thought to be important in regulating digestive flow (Iverson 1980). On the other hand, the digestive tract of the desert tortoise is relatively simply and tubiform in structure. There do not appear to be any physical mechanisms for regulating digestive flow. Whether the differences in digestive strategy represent species differences or larger taxonomic differences is not known.

For some nutrients, the response to changing diet composition is similar among different herbivorous reptilian species. For example, as dietary protein content increases, growth rate increases for juvenile *Iguana iguana* (Allen et al. 1989), *Gopherus agassizii* (Barboza 1993) and *Chelonia mydas* (Wood and Wood 1981). For all three of these species, increasing dietary protein improved growth rate (Table 1). Furthermore, mortality decreased when sea turtles were fed the higher protein diet.

Understanding the relationships between temperature and diet composition on nutrient utilization, growth and reproduction is critical to developing scientifically based diets for herbivorous reptiles. These diets are important to conservation and captive management of endangered and threatened species.

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Table 1. Growth (% of initial mass) of three species of herbivorous reptiles fed different levels of dietary crude protein.

Species	Age	Dietary crude protein content		
		11%	21%	29%
Gopherus agassizii[1]	juvenile	25	40	44
		15%	20%	25%
Iguana iguana[2]	< 1 year old	59	123	212
		25%	30%	35%
Chelonia mydas[3]	14 months	18.7	35.4	44.1
Chelonia mydas[3]	44 months	8.7	12.8	16.8

[1] Barboza and Oftedal 1993
[2] Allen et al. 1989
[3] Wood and Wood 1981

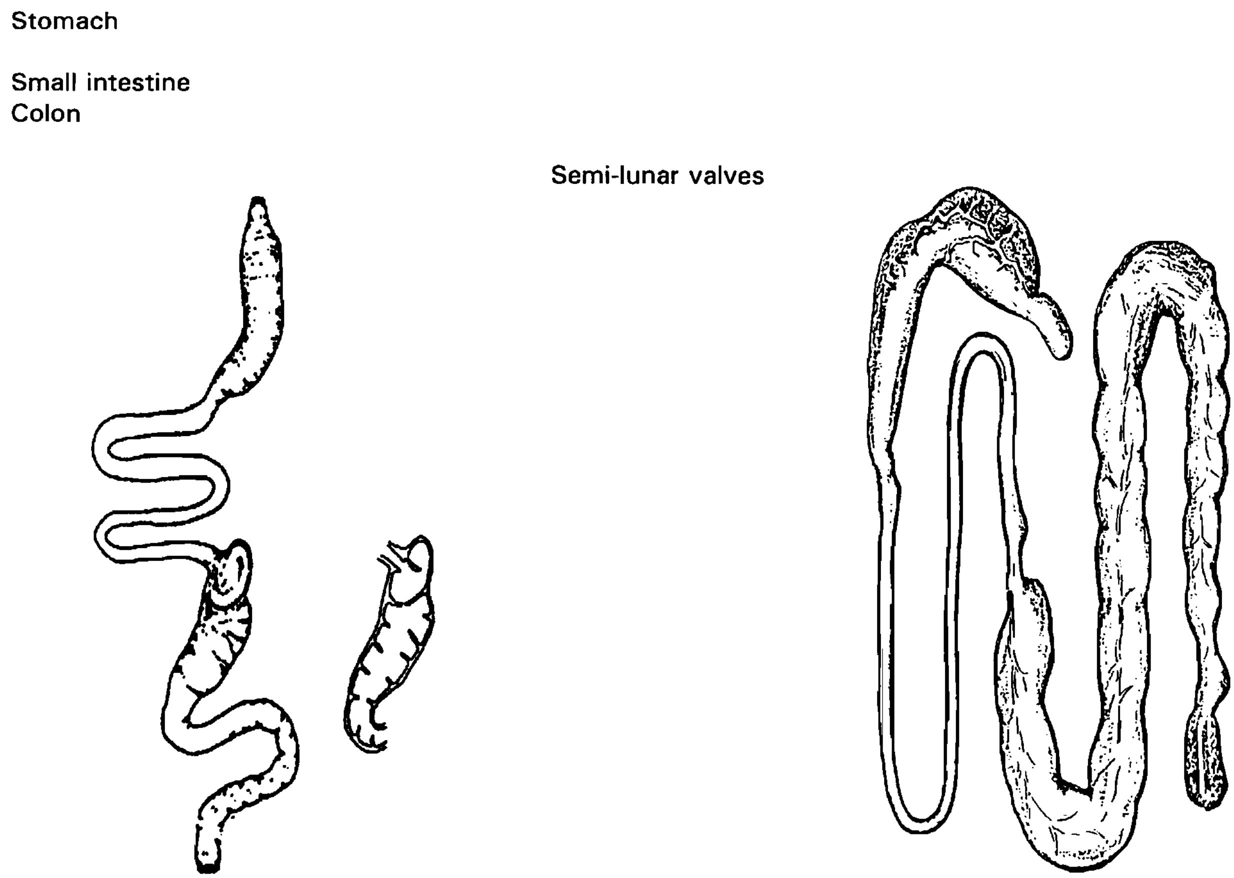

Figure 1. Schematic representation of gastrointestinal morphology tract of Iguana iguana (adapted from Stevens, 1988) and Gopherus agassizii (adapted from Barboza and Oftedal 1993).

DIETARY POTASSIUM AFFECTS FOOD CHOICE, NITROGEN RETENTION AND GROWTH OF DESERT TORTOISES

Olav T. Oftedal, Mary P. Allen
Department of Zoological Research, National Zoological Park, Washington, D.C.

Terry Christopher
Smithsonian Institution, Washington, D.C.
Desert Tortoise Conservation Center, Las Vegas, Nevada

Abstract. Reptiles that ingest excessive amounts of salts (either potassium or sodium) must excrete the salts either via a salt gland, via liquid urine or via urates; only modest amounts of salts are excreted via feces. However, desert tortoises do not have salt glands, and since they cannot produce concentrated urine, excreting salts via urine involves substantial water losses. We predicted that tortoises would be forced to produce urates to excrete excess salts, even though this means a large loss of nitrogen. Many of the potential food plants available to tortoises in the Mojave desert contain very high concentrations of potassium (3% or more on a dry matter basis [DMB]). We developed experimental diets of constant nitrogen concentration (3.2% N, equivalent to 20% protein), but varying potassium levels (0.5%, 1.6%, 2.7% and 3.8% K, DMB). In food choice studies ($n=20$ animals), tortoises were offered two of these diets in paired feeders for two weeks, and invariably preferred the lower potassium diet. When tortoises ($n=24$) were offered only one of the diets on an *ad libitum* basis, food intake was inversely proportional to dietary potassium concentration (6.8, 5.9, 3.6 and 2.7 g/kg/d on 0.5, 1.6, 2.7 and 3.8% K, respectively), suggesting that tortoises self-limited potassium loads. We examined the effects of potassium on nitrogen excretion by feeding restricted amounts of each diet, so that food intake would not differ among diets. On the low potassium diet, tortoises excreted about one-third of the nitrogen they ingested; the remaining two-thirds was retained in growing tissues. On higher potassium diets the proportion of ingested nitrogen that was excreted increased dramatically (37%, 56%, 66% and 93% on 0.5, 1.6, 2.7 and 3.8% K diets, respectively); on the 3.8% diet the proportion of N retained (7%) was not significantly different from zero. Most of the increase in N excretion was attributable to increased urate output. We conclude that desert tortoises: (1) avoid high potassium foods when possible; (2) reduce food intake when they must eat high potassium foods; (3) use nitrogen to excrete urate salts when they eat high potassium foods; and (4) have markedly reduced nitrogen retention and growth rates when they eat high potassium foods. The adverse effects of potassium appear to be exacerbated by water shortage and when foods are low in nitrogen. We predict that the foraging choices made by tortoises in the desert reflect the need to avoid potassium while maintaining water and nitrogen intakes.

INTRODUCTION

The food choices made by foraging desert tortoises have been studied at a number of sites, but the mechanisms underlying these choices are not understood. Many of the potential food plants available to tortoises in the Mojave desert contain very high concentrations of potassium (3% or more on a dry matter basis [DMB]). We suggest that potassium exerts such a negative impact on tortoises that it may be a key constituent in determining both food preferences and the benefits tortoises obtain from feeding on specific plants.

Although desert tortoises are able to tolerate some increases in circulating electrolyte levels (Minnich 1977, 1979; Nagy and Medica 1986), over the long run they must balance the intake and excretion of potassium. Many arid-adapted herbivorous reptiles, such as chuckwallas and desert iguanas, can excrete excess potassium via salt glands (Nagy 1972), but tortoises do not have salt glands. Given that the reptilian kidney is unable to produce concentrated (hyperosmotic) urine, excretion of excess potassium in liquid urine would require a large water loss which may be difficult to replace in a desert environment. We predicted that tortoises eating high potassium foods would dispose of the excess by excretion of potassium urates, even though this means a large loss of nitrogen.

We studied the ability of tortoises to discriminate between diets varying in potassium content, the effect of dietary potassium on food intake, and the pattern of nitrogen excretion when diets high in potassium were eaten. These studies were conducted with individually-housed tortoises maintained in a climate-controlled room at the Desert Tortoise Conservation Center in Las Vegas, Nevada.

METHODS

Food Choice and Intake

Twenty juvenile desert tortoises were blocked by size and received as their established or acclimated diet one of four experimental pelleted diets that varied in potassium concentration (0.5%, 1.6%, 2.7% and 3.8% potassium, DMB). The difference among diets in potassium concentration was produced by substituting a fixed mixture of potassium salts (potassium carbonate, potassium citrate and potassium chloride) for sucrose. Other ingredients (and hence nutrients) were held constant. After an acclimation period, animals were offered a choice between the acclimated diet and one of the other diets over a two-week period. Intake of each diet was monitored. In subsequent trials of the same duration, the intake of the acclimated diet was compared to that of each of the remaining diets. Regardless of the diet to which tortoises were acclimated, they ate significantly more of the diet in each pair that was lower in potassium, and in most cases the lower potassium diet accounted for 80% or more of total intake. Thus desert tortoises appear to discriminate among potassium levels, and to avoid diets of high potassium concentration.

Since we created our differences in potassium concentrations by substituting potassium salts for sucrose, an alternate explanation would be that tortoises preferred diets of higher sucrose concentration. Therefore we conducted a trial in which the 20 tortoises were offered a choice between diets of similar potassium concentration but different sucrose concentrations. However, the tortoises did not show any preference for higher sucrose concentrations, indicating that the alternate explanation was incorrect.

We also examined food intake when 24 tortoises were offered only one of the four diets on an *ad libitum* basis. Food intake was inversely proportional to dietary potassium concentration (6.8, 5.9, 3.6 and 2.7 g/kg/d on 0.5, 1.6, 2.7 and 3.8% potassium, respectively), suggesting that tortoises self-limited potassium loads.

Potassium Excretion and Nitrogen Retention

As noted above, we expected that tortoises ingesting more potassium would have to excrete the excess primarily as potassium urates and that this would entail a large loss of nitrogen. We conducted a trial in which 24 juvenile tortoises were blocked by size and assigned to one of the four diets that ranged in potassium concentration from 0.5% to 3.8% (Oftedal et al. 1994). To avoid the potential confounding effects of varying nitrogen intakes, we restricted the amount of food offered to all tortoises to an amount they would eat at the highest potassium level, so that food intake would be equal across treatment groups. Since the nitrogen concentration was the same in all diets (3.2%, equivalent to about 20% protein), nitrogen intake did not differ among the treatments. The tortoises had access to water on an *ad libitum* basis two times per week. After the animals had been acclimated to these diets, we collected, separated and analyzed all excreta produced over a three week period. Nitrogen was assayed by a macro-Kjeldahl procedure, and potassium was assayed by atomic absorption spectroscopy. Fresh urine samples were also analyzed for deuterium concentration since the tortoises had been dosed with deuterium oxide prior to the study to permit measurement of water intake by isotope dilution methods.

Tortoises fed the low potassium (0.5%) diet produced urates of low potassium concentration (5.8%, DWB) as compared to the levels of 14%, 16% and 18% potassium in the urates of tortoises fed 1.6, 2.7 and 3.8% potassium, respectively. Urinary potassium also increased, from 0.1% (fresh weight basis) on the low potassium diet to 0.6% on the highest potassium diet. The increase in urate production on the higher potassium diets had a marked effect on nitrogen excretion. On the low (0.5%) potassium diet, tortoises excreted about one-third of the nitrogen they ingested; the remaining two-thirds was retained in growing tissues. On higher potassium diets the proportion of ingested nitrogen that was excreted increased dramatically (37%, 56%, 66% and 93% on 0.5, 1.6, 2.7 and 3.8% K diets, respectively); on the 3.8% diet the proportion of nitrogen retained (7%) was not significantly different from zero. It appeared that juvenile tortoises consuming a diet containing 3.8% potassium were unable to retain sufficient nitrogen to permit growth, even though the diet was high in protein.

It should be noted that these animals had regular access to water and in fact total water intake, urine production and urinary potassium output all increased on the high potassium diets. Tortoises in the wild have limited access to water, most of which is acquired in food. Given this limitation, we predict that tortoises in the wild may be even more constrained in their ability to excrete potassium by routes other than by urate production.

CONCLUSIONS

We conclude that desert tortoises: (1) avoid high-potassium foods when possible; (2) reduce food intake when they must eat high-potassium foods; (3) use nitrogen to excrete urate salts when they eat high-potassium foods; and (4) have reduced nitrogen retention and growth rates when they eat high-potassium foods. The adverse effects of potassium are likely to be exacerbated by water shortage and when foods are low in nitrogen. We predict that the foraging choices made by tortoises in the desert reflect the need to avoid potassium while maintaining water and nitrogen intakes.

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CALCIUM, PHOSPHORUS AND VITAMIN D IN REPTILE NUTRITION

Mary E. Allen and Duane E. Ullrey
Nutritional Resources Unit, National Zoological Park,
Smithsonian Institution, Washington, D.C.

Abstract. Dietary sources of minerals are required by reptiles to maintain health and to support growth and reproductive effort, but quantitative calcium (Ca) and phosphorus (P) requirements have rarely been determined. In a depletion-repletion study with the leopard gecko (*Eublepharis macularius*), 0.85% dietary Ca (dry matter basis, DMB) was sufficient to replenish body Ca stores but 0.61% Ca was not. Dietary concentrations of 0.8 to 1.2% Ca (DMB) and 0.6 to 0.8% P (DMB) appear to be adequate for those species that have been fed nutritionally defined diets for extended periods (e.g., *Gopherus agassizii*, *Geochelone sulcata*, *Iguana iguana*, *Conolophus subcristatus*, *Eublepharis macularius, Phelsuma madagascariensis* and *Alligator mississippiensis*). However, some compounds in natural and cultivated foods may reduce the bioavailability of dietary calcium and/or phosphorus. *Opuntia* spp., alfalfa and spinach contain calcium oxalates, while the seeds of many plants may have much of the phosphorus bound as phytate. The availability of Ca and P in ingested gravel, sand or soil has not been measured, but may be low. Interactions among minerals in foods may also affect the Ca/P status of reptiles, as they do in other vertebrates.

Both captive and wild herbivorous reptiles that consume vegetative plant parts, particularly in the early growth stages, are likely to obtain sufficient Ca. However, the P content of plants varies widely and is dependent upon phenological stage and soil P content. We have found that many desert plants in the eastern Mojave contain low concentrations of P, suggesting that desert tortoise populations should be investigated for evidence of P deficiency, especially in habitats that have been altered by grazing and other human activities.

Recent studies have demonstrated that Ca and P homeostasis may be influenced by vitamin D status in captive reptiles. Vitamin D is only considered a dietary essential if exposure to sunlight is limited. It is commonly believed that a dietary supply of vitamin D can substitute for endogenous synthesis in reptiles if sunlight or artificial ultraviolet-B light is not provided, and this appears to be true in desert tortoises. However, in studies with *I. iguana* and *Varanus komodoensis*, dietary vitamin D failed to prevent deficiency signs even when fed at levels that are in excess of the requirements of domestic mammals and birds. More research is needed on phylogenetic variation in the vitamin D metabolism of reptiles.

THE INTERPLAY OF NUTRITION AND DISEASE

Laura Richman and Richard J. Montali
National Zoological Park, Smithsonian Institution, Washington, D.C.

Diseases in reptiles caused by nutritional deficiencies, derangements or imbalances is an area of growing interest and research; however many nutritional diseases in reptiles are still not fully understood. A plethora of data from domestic animal nutritional research is available and extrapolation to reptiles is the usual mode of both recognition of diseases and treatment of the nutritional disorder. Often, this is not sufficient and clinical trials are needed to determine the proper combination of nutrition, environment, and logistical settings needed for each species of reptile affected.

It is important to consider the natural food preferences of reptiles when formulating diets. Snakes are primarily carnivorous and certain species will consume small mammals, birds, fish, eggs or insects. Indigo (*Drymarchon corais*) and Garter snakes (*Thamnophis* spp.) will consume almost anything, whereas King cobras (*Ophiophagus hannah*) are almost strictly snake-eating animals. The food preferences of lizards are species-dependant, for example, green iguanas (*Iguana iguana*) seek dandelion blossoms, rose petals, vegetables and fresh fruit. Horned lizards (*Phrynosoma* spp.) prefer ants and termites. Chelonians are either carnivorous, omnivorous or herbivorous. Turtles and terrapins prefer earthworms, live whole fish and green leafy vegetables whereas tortoises thrive on fresh flower blossoms, cacti, fruit, and snails. Crocodilians are almost strictly carnivorous and usually eat fish, meat, and foul (Frye 1986).

Water requirements for reptiles are variable and the presentation is very important. Some reptiles will lick rain or dew drops off foliage to the exclusion of standing water in a container. Water within a food item often comprises a majority of a reptile's water intake.

The types of nutritional alterations associated with disease include deficiencies, toxicities, imbalances, and derangements. A majority of the recognized nutritional diseases are deficiencies, due to lack of knowledge and/or education about adequate reptile nutrient requirements and sources. The following is a synopsis of the most common nutritional disorders seen in reptiles.

Vitamin A deficiency is recognized most often in aquatic turtles. Clinically, the conjunctiva and eyelids are swollen and hyperemic and the eyes bulge from the orbits. The histopathologic changes seen include hyperkeratosis and squamous metaplasia of the lacrimal glands.

Vitamin B-1 (thiamin) is normally synthesized by intestinal bacteria and is absorbed into the bloodstream in the terminal small intestine. Thiamin deficiency is usually a result of the enzyme, thiaminase, that breaks down the vitamin. Thiaminases and/or antithiamin factors are found in post mortem tissues of some fish, clams, and certain plants. Additionally, prolonged antibiotic therapy may destroy intestinal bacteria that usually synthesize vitamin B-1. Clinical signs of deficiency manifest as central nervous system signs, including opisthotonos and vertigo; some species may appear as though they are "star gazing."

Biotin deficiency is usually associated with oviphagous (egg-eating) reptiles and a deficiency may be seen in captivity, when owners feed their animals solely raw chicken eggs. Egg whites contain avidin, a protein that has antibiotin activity. In captivity, oviphagous reptiles can be "tricked" into consuming good sources of biotin, such as mice, by smearing raw egg over the food item.

Vitamin C deficiency is rare in reptiles, since adequate levels appear to be synthesized endogenously in the intestinal tract and kidney. In the past, an association between mouth rot (stomatitis) and vitamin C deficiency was proposed; however this was never substantiated (Allen and Oftedal 1994). It is generally accepted that mouth rot is an infectious process and not caused by a nutritional deficiency.

Vitamin E deficiency has been reported in reptiles (and especially crocodilians) that consume rancid fish that are low in vitamin E. Vitamin E is an antioxidant which contributes to prevention of tissue damage from free radicals produced by solar radiation or normal cell metabolism. Fish are generally considered an adequate source of vitamin E; however improper storage, transport or thawing can destroy vitamin E. A deficiency of this vitamin causes steatitis and/or fat necrosis. On gross examination, the fat will be firm and orange-yellow, which in severe cases, is visibly evident through the skin.

Vitamin D deficiency in reptiles is currently an area of active research. Most animals are able to utilize a dietary source of vitamin D in lieu of endogenous synthesis stimulated by ultraviolet light. However, certain reptiles, such as the green iguana and komodo dragon (*Varamis komodoensis*) apparently are not able to utilize dietary vitamin D_3 (Allen et al. 1994). It has been shown that ultraviolet light in the range of 285-315 nm (UV-B spectrum) is essential for conversion of provitamin D in the skin to previtamin D (Tian et al. 1994). There are several additional steps required for the formation of active vitamin D and these steps require a functional, disease-free liver and kidney. A deficiency of vitamin D ultimately results in failure to absorb dietary calcium from the intestinal tract. Subsequently, calcium is resorbed from bone, leading to osteomalacia, pathologic fractures, and fibrous osteodystrophy (Anderson and Capen 1976a).

Metabolic bone disease is one of the most common disorders seen in pet reptiles, usually attributed to a calcium-poor diet and/or lack of UV-B light exposure. Often, uneducated owners will feed their reptiles only lettuce, which subsequently leads to the clinical signs most often associated with metabolic bone disease: lizards will have thickening of the arms, legs and mandibles due to deposition of fibrocartilaginous connective tissue around thinning bones (Anderson and Capen 1976a,b). Chelonians will develop a soft shell. Often, affected animals will be lethargic and anorexic.

Reptiles normally excrete uric acid which is voided as a white, chalky material. Uric acid is the end-product of protein and purine metabolism in reptiles. Gout is a disease caused by the deposition of uric acid crystals (gouty tophi) in abnormal locations. Recognized forms include articular gout, which is more frequently seen clinically, and visceral gout, which is usually only recognized at necropsy (Wallach and Hoessle 1967). Factors contributing to the formation of gout include: (1) dehydration; (2) an imbalance of dietary amino acids; (3) primary renal disease; and (4) hypovitaminosis A. Heavy deposition of gouty tophi in any tissue can compromise normal function.

Recognition of nutritional diseases is crucial for proper treatment of affected animals and for prevention of new cases. Extrapolation between species may or may not be possible with nutritional diseases; however it provides a starting point to which modifications can be made, if needed. Nutritional disorders may also render an animal susceptible to infectious diseases and death. Continuation of current research and support of future nutritional studies are of great importance in reptile medicine.

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DO REPTILES HAVE MINERAL APPETITES?

Jay Schulkin
National Institutes of Mental Health, Bethesda, Maryland

Minerals, such as sodium, are required to maintain both intracellular and extracellular fluid composition and stability. Both physiological and behavioral mechanisms can serve the same end point, namely the maintenance of mineral balance.

A number of mammals and birds are known to search, identify and ingest sodium sources, particularly salt licks. Salt licks, or dirt rich in minerals provide a source of minerals for a variety of animals. They are known to be ingested by herbivores, for example, when the plants and the grass that they normally ingest are diluted of sodium by excessive rainfall (Denton 1982). In a field experiment, kangaroos, for example, in Australia will ingest sodium pegs (implanted by the investigators and then videotaped by them) over non-sodium pegs when the source of sodium in their foods is diluted (Denton 1982).

On the behavioral side, in the laboratory, when deficient in sodium, in many mammalian species (Richter 1956), and several species of birds this results in the ingestion of sodium sources. For example, the very first time that the pigeon is depleted of sodium (via furosemide, an agent which activates the kidney to secrete water and sodium with or without loops of Henle) it ingests the sodium salt, over other salts that may be offered (Massi and Epstein 1990). The second time the pigeon is depleted the ingestion is actually greater than the first time.

Hormones that regulate body fluid and sodium composition at a physiological level also generate the behavior of sodium ingestion that serves the same end point; maintaining body fluid balance (Epstein 1984). For instance, when body fluids are depleted, or compromised, the hormones of sodium homeostasis are elevated (Denton 1982). They (e.g. angiotensin and aldosterone) act to conserve and redistribute sodium in the internal milieu. They also act in regions of the brain that generate behavioral homeostatic responses. Thus there are two lines of defense; the first is physiological and the second is behavioral (Schulkin 1991). They are both working toward the same endpoint; body fluid and mineral homeostasis.

The physiological mechanisms that regulate body fluid balance are also linked to cardiovascular regulation (Denton 1982). Thus hormones derived from the kidney such as angiotensin, aldosterone from the adrenal gland, vasopressin derived from the pituitary gland or atrial natriuretic factor, a hormone synthesized in the heart itself, regulate both body fluid and sodium composition as well as normal cardiovascular function.

To maintain body fluid composition hormones such as angiotensin elicit both water and sodium ingestion (Fitzsimons 1979). Angiotensin, in fact, is known to elicit water ingestion in fish, amphibia, reptiles, birds and mammals. The common green iguana, for example, is known to ingest water following infusions of intravenous or intracranial angiotensin, despite the fact that they are replete in body fluids (Fitzsimons 1979). By administering the hormone alone, which would normally be elevated at the time in which body fluid would be compromised, the iguana "thinks" it needs water, and thus ingests the water. The same reasoning and findings holds through most vertebrates that have been studied.

While it is a well established scientific fact that the hormone angiotensin will elicit sodium ingestion in several species of birds and many mammals, there is no published evidence that it will elicit a sodium appetite in reptiles, amphibia or fresh water fish (Schulkin 1991). I do not see, however, why the hormone should not increase sodium ingestion, in addition to water, in these animals (although one study did not see such effects Spigel et al. 1967). That is, since we know, for example, that extracellular depletion which elevates angiotensin results in the ingestion of water in both desert and non-desert reptiles perhaps it would also increase sodium ingestion. But that remains to be determined.

We do know that one mechanism that generates the behavior of sodium ingestion occurs when aldosterone increases brain angiotensin levels in regions of the brain that also synthesize the hormone and is linked to body fluid and cardiovascular control (Wilson et al. 1986). The brain is the organ that generates the homeostatic behaviors for mineral balance. Thus while, the kidney is drastically different in mammals and reptiles or birds (e.g. Bentley 1959), they all nonetheless have aldosterone or angiotensin which is elevated during body fluid deprivation which may result in both water and sodium ingestion.

These same hormones of body fluid and salt homeostasis are elevated when female vertebrates are noticed at salt licks during reproduction (Schulkin 1991). In fact, the evolutionary selective pressure to demonstrate a mineral appetite is in females, because of the greater mineral demands during reproduction. A wide range of vertebrates, including reptiles are noted at salt licks, or salt dirt, during reproduction (Denton 1982).

In the laboratory, both sodium and calcium are ingested to great degrees during the reproductive period in females (Richter 1956). Both ions are ingested in greater amounts even when, for instance, rhesus monkeys are virgins when compared to males. Or for instance, virgin female rats ingest more calcium salts than males, and multiparous female rats ingest even greater amounts than either virgin females or males do (Reilly et al. 1995). It would be interesting to determine whether reptiles show similar behavioral responses.

We do know that calcium deprivation which elevates the hormones of calcium homeostasis (Vitamin D, parathyroid hormone) activates a calcium appetite in birds and mammals (Rozin and Schulkin 1990). It is not known whether this holds for reptiles, although there is evidence of reptiles ingesting dirt rich in minerals, or eating bone or shells rich in calcium (Esque and Peters 1994). For instance, the desert tortoise has been observed, by a number of investigators ingesting bones and soil (Esque and Peters 1994; Allen et al. unpubl. data). Perhaps they are doing so for the calcium, and perhaps it is greater in females than males, particularly during reproduction. Moreover, it is not inconceivable that an appetite for bone may be pronounced in developing reptiles, or during seasonal demands; that is, times in which there is a greater need for calcium.

From a hormonal perspective, the same hormones which act to maintain calcium balance physiologically may also generate a calcium appetite. For instance, preliminary data suggests that the green iguana may require Vitamin D to generate calcium ingestion (Schulkin and Oftedal, unpubl. data). One hypothesis is that Vitamin D activates the brain region that produces parathyroid hormone in the brain thus resulting in the search, identification, and ingestion of calcium. This is analogous to aldosterone activating brain regions that contain angiotensin producing cells resulting in the search, identification and ingestion of sodium. Both the ingestion of sodium and calcium are reflected by the ingestion of salt licks, of which what might be salient to the mineral hungry animal is its "saltiness" (Schulkin 1991).

Finally, consider the fact that phosphorous deficiency is also known to elicit bone ingestion in cattle (Denton 1982). Phosphorous deficiency, experimentally induced, elicits phosphorous ingestion (Denton 1982). Perhaps the ingestion of bone that has been observed serves in the maintenance of both phosphorous and calcium, after all the hormones of calcium homeostasis also, to some extent, regulate phosphorous.

The search for salt and water varies with species local adaptations and physiological requirements. Nature has selected for both physiological conservation and behavioral mechanisms that serve homeostatic requirements. Hormones such as those that serve mineral metabolism also inform the brain to generate behaviors that result in the search, identification and ingestion of salts. To what extent this holds for reptiles awaits future research.

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TORTOISE BURROWS ARE NOT JUST HOLES IN THE GROUND

Ray E. Ashton, Jr.
Water and Air Research, Inc., Gainesville, Florida

Abstract. The gopher tortoise (*Gopherus polyphemus*) is known for its extensive burrows. The first reference to them was made by William Bartram in 1778, when he indicated that the tortoise burrows were so common that it was difficult to walk or ride a horse in some woodlands. Little research was done on these burrows until the 1970's when Auffenberg and Franz published their major paper on the gopher tortoise and we are now only just beginning to understand the significance of this structure. Gopher tortoise burrows can be more than 12 m long and may go down 6 m. The burrow is obviously important to the tortoise as its dwelling but it also has been shown to serve an extended ear and a way to catch a drink during storms. Excavated by one small tortoise, the burrow may be used by more than 300 species of vertebrates and invertebrates. Many species are known only from these burrows and are considered obligates to the burrow and the gopher tortoise. Many of these obligate species are considered to be declining or endangered. The recently published Rare and Endangered Biota Series volume on the invertebrates lists seven imperiled tortoise burrow species. One species of vertebrate, the Florida burrowing owl (*Speotyto cunicularia floridana*) is known to co-habitate with gopher tortoises where the two occur together. For the past five years, I have been studying this relationship and most importantly, we are looking into methods of establishing urban preserves for both owls and tortoises as well as working to determine what burrow species might be preserved as well.

SURVIVAL, MOVEMENTS, AND BURROW USE OF HATCHLING DESERT TORTOISES AT YUCCA MOUNTAIN, NEVADA

Rod G. Goodwin, James M. Mueller, and Kurt R. Rautenstrauch
EG&G Energy Measurements, Inc., Las Vegas, Nevada

Abstract. We radiomarked hatchling desert tortoises (*Gopherus agassizii*) at Yucca Mountain as they emerged from their nests and monitored them until they entered their hibernacula during 1992-1994 to determine survival rates, movement patterns, and burrow use. We located hatchlings an average of two times/week in 1992 and three times/week in 1993 and 1994. We determined location coordinates by measuring the bearing and distance to the nest or to a burrow previously used by the hatchling. Survival rates to first hibernation were 30% in 1992 ($n=20$), 74% in 1993 ($n=19$), and 75% in 1994 ($n=20$). Several hatchlings were killed by desert fire ants (*Solenopsis* spp.); no avian predation was documented. Hatchlings were located on consecutive days ($n=621$) to determine the distance moved in one day. When hatchlings moved ($n=346$), they were found an average of 9 m (range = 1-144 m) from their previous location. Hibernacula were an average of 107 m ($n=34$, SD = 117, range = 5-461 m) from the nest. Hatchlings used an average of 5.4 ($n=34$, SD = 2.6, range = 1-11) burrows, of which, 16% were excavated by the hatchlings, 49% were rodent burrows, 24% were natural cavities, 1% were excavated by other tortoises, and 10% were of unknown origin.

SURVIVORSHIP, TIME ACTIVITY BUDGETS, MICROHABITAT AND BURROW UTILIZATION OF JUVENILE DESERT TORTOISES RAISED IN A SEMI-WILD ENCLOSURE

E. Karen Spangenberg
Department of Biology, California State University - Dominguez Hills, Carson, California

Abstract. Nine juvenile desert tortoises were released into natural habitat surrounding the predator-proof enclosure where they were hatched and raised at Fort Irwin Study Site in the Central Mojave Desert. Survivorship, time activity budgets, microhabitat and burrow utilization, and movements of released juvenile tortoises were studied by radiotelemetry and compared to those of 10 juvenile tortoises maintained inside the enclosure. Released tortoises were found above ground and active more often than penned tortoises. In morning hour classes, there were more released tortoises than penned tortoises above ground 81% of the time. In afternoon and evening hour classes, the difference was only 50% but in the same direction. Released tortoises were away from their burrows and active more than penned tortoises 62% of the time during morning hour classes and 44% of the time in afternoon and evening hour classes. Released tortoises dispersed and settled into rodent burrows an average of 41.5 m (range: 10.2-195.0 m) from the point of release. Eight out of nine released juveniles were observed to use more than one burrow. Three weeks after released, seven juveniles used only one burrow, and two juveniles used multiple burrows. After nine months, 67% of the juveniles released were still alive compared to 90% of the penned tortoises. Since survivorship of juvenile desert tortoises is enhanced with predator-proof pens, rearing tortoises in their natural habitat and releasing them into that environment might serve to bolster desert tortoise populations in critical habitat.

BURROW USE BY DESERT TORTOISES AT YUCCA MOUNTAIN, NEVADA

Greg A. Brown and Kurt R. Rautenstrauch
EG&G Energy Measurements, Inc., Las Vegas, Nevada

Abstract. We evaluated burrow use by desert tortoises (*Gopherus agassizii*) at Yucca Mountain, Nevada, during 1992-1994. We defined a burrow as any underground chamber or tunnel greater than half the mid-carapace length (MCL) of the tortoise using it. Only data from tortoises located ≥50 times during an active season was used to determine number of burrows used per year. Tortoises used an average of 13.4 burrows/year ($n=214$, SD=3.9, range=5-23). Number of burrows used did not differ among sex and size classes ($P=0.32$) but did differ among years ($P < 0.01$); tortoises used an average of two fewer burrows in 1994 than in 1993. An average of 29% of the burrows used by each tortoise were >1 m deep, 55% were <1 m deep but deeper than the MCL of the tortoise, 12% were less than the MCL but deeper than half the MCL of the tortoise, and 4% were of unknown depth.

In addition, we determined the number of new burrows (i.e., burrows not used in previous years by a tortoise) used each year by adult tortoises during 1993-1994. The number of new burrows used was calculated for tortoises that had ≥75 active-season locations prior to the year being evaluated. Tortoises used an average of 6.2 new burrows/year ($n=81$, SD=3.3, range=1-17). The number of new burrows used did not differ between sexes ($P=0.58$) but tortoises used an average of 2.8 fewer burrows in 1994 than in 1993 ($P < 0.01$). Of the new burrows used, 17% were >1 m deep, 64% were <1 m deep but deeper than the MCL of the tortoise, 17% were less than the MCL but deeper than half the MCL of the tortoise, and 2% were of unknown depth.

TORTOISES AS FARMERS

Patricia S. Ashton, Ray E. Ashton, Jr., and E. Lynn Mosura-Bliss
Water and Air Research, Inc., Gainesville, Florida

Abstract. Traditionally gopher tortoises (*Gopherus polyphemus*) are considered upland sandhill species occupying communities such as long leaf pine-turkey oak, sand pine scrub, and pine flatwoods. At the turn of the century much of these uplands were turned into citrus and range land for cattle. Today, with continually shrinking uplands due to development, tortoises are frequently found in these pasture lands but virtually nothing is known about their adaptations to this habitat. Our study examines some facets of tortoise natural history in this environment including feeding behavior. Tortoises feed on a wide range of plant species in this habitat, many of which are not native to their historic Florida uplands. Gopher tortoises have two primary modes of feeding, intensive grazing areas around the burrow, and foraging forays out from their burrow for specific species. By grazing areas around their burrow frequently they alter the species composition and enhance the nutritional value of the grasses within the grazeing area over those in surrounding areas. Their forage trails out from the burrow reveal search patterns for a wide variety of selected broad leaf plants. Preliminary data shows that tortoises are quite specific as to the species that are searched out, passing over previously selected species to locate the "plant de jour" and this selectivity changes seasonally and periodically.

RESULTS OF FIVE CONSECUTIVE YEARS OF POPULATION MONITORING AT THREE SONORAN DESERT TORTOISE PLOTS

Jeffrey M. Howland and Christopher M. Klug
Nongame Branch, Arizona Game and Fish Department, Phoenix

Abstract. Five Sonoran desert tortoise population monitoring plots in Arizona have been surveyed for each of the past five years, 1990 to 1994. The Little Shipp Wash and Granite Hills plots have been 60-day plots each year, while the Eagletail Mountains plot was run as a 60-day plot in 1990 and a 35-day plot in the succeeding four years. Analysis of results using both Lincoln-Petersen and Jollyage population estimators indicates that tortoise populations at all three sites have been stable or increasing over the study period. In subadult and adult size classes, Little Shipp Wash has about 100 tortoises, Granite Hills about 65 to 70 tortoises, and Eagletail Mountains about 30 to 35 tortoises. Monitoring the same plots for several consecutive years has provided interesting information on survivorship, growth rates and health profiles. Results for juvenile and immature tortoises have been particularly enlightening because smaller tortoises have proven difficult to sample in Sonoran Desert habitats. Consecutive annual surveys have enhanced the accuracy and precision of total population estimates over what we think would be possible with less frequent sampling. We make recommendations on the future of Sonoran desert tortoise monitoring plots, including adequate rotation period for detection of population trends and consideration of alternative population monitoring techniques.

INTRODUCTION

When the desert tortoise (*Gopherus agassizii*) was emergency listed as an endangered species in 1989, it became necessary to gather information on population trends throughout the range of the species in the United States. This prompted the U.S. Fish and Wildlife Service (FWS) and Arizona Game and Fish Department (AGFD) to join the Bureau of Land Management (BLM) in a concerted effort to expand long-term monitoring studies for the Sonoran desert tortoise in Arizona (Hart et al. 1992; Shields et al. 1990; Woodman et al. 1993, 1994, 1995), an effort that had been initiated earlier by BLM (Holm 1989; Schneider 1981; Schwartzmann 1983; Shields and Woodman 1988a, b; SWCA 1990; Wirt 1988; Woodman and Shields 1988).

Among the primary objectives of the Sonoran desert tortoise monitoring project is the determination of population trends, which requires the tracking of population size through time. We also wanted information on rates of recruitment and survivorship in order to better understand the underlying mechanics of tortoise population dynamics. In this paper, we investigate the utility of the Jolly-Seber model (in Program Jolly) for estimation of population parameters as a tool in helping to reach these objectives and we compare this model with the more traditionally employed Lincoln-Petersen model. We also discuss what is known of population status and potential threats to population stability of Sonoran desert tortoises.

METHODS

AGFD and contract biologists monitored Sonoran desert tortoise populations at three sites, Little Shipp Wash, the Granite Hills, and the Eagletail Mountains, for five consecutive years from 1990 to 1994. In 1990, AGFD performed standard 60-day surveys at each site (Shields et al. 1990). The Eagletail Mountains site had been surveyed previously under a similar protocol (Shields and Woodman 1988). Little Shipp Wash and the Granite Hills had been prior study sites for tortoise projects that involved marking, but survey protocols were dissimilar (Schneider 1981; Schwartzmann 1983). These plots were selected partly based on the fact that they had been studied previously, and partly because they cover substantial portions of the geographic and habitat ranges of Sonoran desert tortoises in Arizona (Fig. 1). Little Shipp Wash is in transitional habitat between Arizona Upland and Interior Chaparral (Brown et al. 1979), while the Eagletail Mountains and Granite Hills are somewhat transitional between Arizona Upland and Lower Colorado Valley (with the Granite Hills leaning toward the former vegetation type and the Eagletails toward the latter). The Granite Hills receive summer rains more reliably than the Eagletail Mountains.

In 1991 through 1994, contract biologists resurveyed the three plots annually (Hart et al. 1992; Woodman et al. 1993, 1994, 1995). Because suitable habitat at the Eagletail Mountains site is limited and tortoise numbers are relatively small, we chose to reduce survey time there to approximately 35 person-days. Surveys at Little Shipp Wash and Granite Hills remained at the standard 60 days in all years. Site descriptions (including topography, vegetation, human impacts, and climate) and field methodology for the population surveys are thoroughly documented by Shields et al. (1990), Hart et al. (1992), and Woodman et al. (1993, 1994, 1995). These references also provide information on sex ratios, size structure, morphological anomalies, growth, reproduction, spatial distribution, and behavior.

Population estimation in desert tortoise monitoring studies has traditionally employed Lincoln-Petersen techniques (Berry 1984 and studies cited above), but we have been concerned that some of the assumptions of Lincoln-Petersen estimation (Pollock et al. 1990) are violated by desert tortoise populations, perhaps most importantly the assumption of population closure. Because its assumptions are more appropriate for the modeling of Sonoran desert tortoise populations (*e.g.*, open populations), we used the Jolly-Seber model of population estimation in Program Jolly to analyze our five consecutive years of mark-recapture data and compared these with Lincoln-Petersen estimates (using year n as the recapture period and year n-1 as the mark period).

RESULTS

Population Size and Mortality

We tested the Jolly-Seber model assumption of homogeneity of capture probability before analyzing our data. We found no differences between adults and subadults or between males and females (adults and subadults combined; Chi-square tests, $P > 0.05$ for all sampling periods). However, capture probability of juveniles differed significantly from that of adults and subadults in all years (all $P < 0.05$). We also strongly suspect that juvenile mortality differs from that of adults and subadults, which violates another assumption of the model, but juvenile sample sizes and recapture rates are so small that statistical comparison of mortality rates is not feasible at this time. Given the results of our tests of assumptions, we performed all further analyses combining all adults and subadults of both sexes.

Population density on the three study plots ranges from moderate (for Arizona) in the Eagletail Mountains (about 31 adults and subadults) to high in the Granite Hills (about 65 subadults and adults) and Little Shipp Wash (about 95 adults and subadults). Comparison of Jolly-Seber and Lincoln-Petersen population estimates for adult and subadult tortoises at the Eagletail Mountains is presented in Table 1 and Fig. 2. The two methods give very similar estimates, with confidence limits being slightly wider for Jolly-Seber estimates. For the Granite Hills (Table 2 and Fig. 3), the only substantial difference between the two methods occurred in 1993, when the Lincoln-Petersen estimate was higher. For this plot, confidence limits were similar for the two methods, although more variable for Lincoln-Petersen. For Little Shipp Wash (Table 3 and Fig. 4), the two methods provide similar estimates of population size with similar confidence limits.

At the Eagletail Mountains, 73 individual tortoises have been marked. Most (40 individuals) were adults or subadults. While total numbers of tortoises marked at the other two sites have been similar (155 tortoises at Little Shipp Wash and 163 at Granite Hills), body size distribution differs markedly. Marked adults and subadults total 105 at Little Shipp, but only 79 at Granite Hills. Granite Hills tortoises also reach smaller maximum body sizes (no tortoise exceeding 270 mm MCL has been recorded) than Little Shipp Wash (32 tortoises 270 mm or more in 1993 alone; Woodman et al. 1994) or Eagletail Mountains tortoises (11 individuals in 1993 alone; *op. cit.*).

From 1990 to 1994, we have estimates of time since death for all carcasses found within four years of death. We therefore have a minimum estimate of the number of tortoises that died between 1986 and 1994 for each of the plots. At Little Shipp Wash, we know of 16 adult mortalities over this period. Most were probable, or at least possible, mountain lion kills (based on bone breakage, claw marks, etc.), including seven of the eight carcasses found in 1993. Mountain lion predation appears to be common at Little Shipp, though 1993 may have been an aberrant year. At the Eagletail Mountains, only one adult is known to have died from 1986 to 1994, though carcasses of several younger tortoises were found. At Granite Hills, eight adult mortalities were recorded from 1986 to 1994. Carcasses found provide a minimal estimate of mortality on the plots that can be compared to survivorship estimates generated by Program Jolly. At all three sites, these minimal estimates of mortality are between one and two percent per year for adult and subadult tortoises. In comparison, adult/subadult survivorship estimates from Program Jolly ranged from 94 to 95 percent (95% confidence limits of ± four to five percentage points).

CONCLUSIONS

Both Lincoln-Peterson and Jolly-Seber estimates of population size suggest population stability or growth at all three sites over the five year study period. We are unable to make a definitive statement as to whether populations are stable as opposed to growing, but our results provide no indication that any of the three populations experienced a substantial decline over the five-year study period.

The Jolly-Seber model in Program Jolly has benefits and limitations relative to Lincoln-Petersen. The clearest reason for using Jolly-Seber, or some other open population model, is the fact that our study populations are not closed. Migration, natality, and mortality are known to occur between sampling periods. The estimation of additional population parameters by Program Jolly, including survivorship, immigration rates, and capture probabilities, is also useful. Unfortunately, any estimation of population size or survivorship requires at least three sampling periods (no population estimate can be generated for first or last period; no survivorship estimate can be calculated for the last two periods). Because our sampling period is one year, this requires a tremendous sampling effort to obtain usable estimates. For example, an absolute minimum of three sequential estimates is required to establish a meaningful trend, and this requires five years of sampling with Program Jolly. Furthermore, confidence limits on most parameters are broad, even with the high capture probabilities in this study (averaging 80% for Eagletail Mountains, 74% for Granite Hills, and 80% for Little Shipp Wash over five years). For juveniles, whose capture probabilities are much lower, the parameter estimates are so broad that they have little utility. Unfortunately, the blame for these problems lies in human ability to adequately sample tortoise populations. We are therefore forced to accept the limitations of the model, which means we must commit to a sustained and intense monitoring program.

We recommend investigation of other sampling and modeling techniques, such as those being tested by Murray (1993) using Program Capture. Perhaps the main advantage of this alternative is that population estimates can be generated with only one year of sampling. However, confidence limits in preliminary efforts were very large, so the utility of this method in long-term monitoring remains to be demonstrated.

At present, we lack sufficient data to describe population trends on a statewide basis in Arizona. We have, however, established a solid foundation for gathering such data over the next several years. We have estimates of population size from more than two years at only the three sites featured in this paper. Fortunately, these three sites represent a large portion of the geographic and habitat range of Sonoran desert tortoises in Arizona. Although these populations appear to be stable or even growing, we cannot safely extrapolate to infer stability for the Sonoran population as a whole. Potential threats to population stability, varying in nature, severity, and extent, have been identified in several areas around the state. We must therefore continue to build our monitoring program to obtain long-term data on population trends at a larger number of sites.

High levels of mortality have been documented or are suspected at several sites in Arizona. Causation remains unknown and even our suspicions differ from one site to another. Decline in the Maricopa Mountains is well established (Wirt 1988; Shields et al. 1990). Several workers suspect highly localized, long-term drought at the plot, and it is hypothesized that drought-related stress has resulted in increased mortality. Proximate causes of mortality are unknown, but may include starvation, stress-induced disease, or even consumption of toxic plants in the absence of more palatable foods. These hypotheses remain untested. Other sites having documented high levels of mortality are the Arrastra Mountains (Wirt 1988) and Bonanza (Woodman et al. 1993).

At San Pedro Valley and Hualapai Foothills, numbers of carcasses, recency of death, and size class of dead tortoises are suggestive of declines (Hart et al. 1992), but sample sizes and short time frame (no trend information) make it difficult to be certain. High mountain lion predation at Little Shipp Wash seems unlikely to be damaging to the population in the long-term, though we will continue to monitor the situation.

Although populations seem healthy at several sites (e.g. Little Shipp Wash, Granite Hills, Mineral Mountain, West Silverbell Mountains), evidence of high levels of mortality at other sites and the high frequency and widespread occurrence of disease symptoms (Dickinson 1994) are cause for concern.

To summarize monitoring sites statewide, at least 10 established plots are appropriate for inclusion in a rotating long-term monitoring program for Sonoran desert tortoises in Arizona: Little Shipp Wash, Granite Hills, Eagletail Mountains, West Silverbell Mountains, San Pedro Valley, Mineral Mountain, Hualapai Foothills, East Bajada, Harquahala Mountains, and Harcuvar Mountains. Population densities at the New Water Mountains, Wickenburg Mountains, Santan Mountains, and Mohave Mountains are so low that they may not be appropriate for continued monitoring. In spite of small population size, Bonanza, Arrastra Mountains, and Maricopa Mountains plots should be surveyed periodically to track continued mortality or recovery. It might be desirable to have as many as 12-16 plots in a long-term rotation, so inclusion of additional plots, established by other workers, such as Sugarloaf (Murray 1993), Sand Tank Mountains (E. Wirt, pers. comm.), Picacho Mountains (Barrett 1990), and Saguaro National Monument (Goldsmith and Shaw 1990) should be considered. For some, this should only occur after incompatible research uses (such as telemetry, x-rays, etc.) are completed. Alternatively, there is still some potential to establish new sites near these areas or in other areas that are known to support reasonably large tortoise populations.

We remain optimistic about the overall status of Sonoran desert tortoise populations in Arizona. While diseases such as URTD (or at least its causative agent, *Mycoplasma agassizii*) and cutaneous dyskeratosis are widespread and common (Dickinson 1994; Woodman et al. 1993, 1994, 1995), we have no evidence that disease has caused any of the known population declines in Arizona.

Perhaps the greatest threat is urban and agricultural development, which have resulted in the loss of some populations and fragmentation or isolation of others. Naturally occurring populations of tortoises have essentially disappeared from mountain preserves in the Phoenix Valley, and development along the outskirts of metropolitan Phoenix and Tucson continues to encroach upon tortoise habitat. Though agriculture, canals, and highways often do not directly impact Sonoran tortoises or their habitat, they may preclude or reduce natural migration between mountain populations, amplifying isolation in an already fragmented landscape. Evidence for genetic isolation may be provided by the high frequency of morphological anomalies (mostly consisting of unusual numbers or shapes of scutes) observed in Sonoran desert tortoises (Shields et al. 1990; Hart et al. 1992; Woodman et al. 1993, 1994, 1995).

We must investigate mortality and its causes and continue monitoring of populations at numerous sites around the state in order to allow development of sound approaches for management of Sonoran desert tortoises in Arizona. Although several local populations seem stable, we cannot conclude that the Sonoran desert tortoise population as a whole is secure. High mortality at some sites and a lack of certainty as to its causes (which probably differ among sites) leave us unable to make confident predictions on future trends or to develop conservation strategies that specifically address threats. Assuring the vitality of a robust monitoring program will entail commitment by state and federal land and resource management agencies to continue funding from existing resources and aggressively pursue supplemental support.

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Table 1. Comparison of Jolly-Seber and Lincoln-Peterson population estimations (estimate with 95% confidence limits) for adult and subadult tortoises at the Eagletail Mountains desert tortoise monitoring plot from 1990 to 1994.

Year	Jolly-Seber	Lincoln-Peterson
1990	29.08 ± 6.13	31.00 ± 5.00
1991	31.26 ± 3.72	30.00 ± 1.60
1992	34.50 ± 5.56	29.00 ± 2.20
1993	30.20 ± 5.34	30.00 ± 4.40
1994	N/A	30.00 ± 2.10

Table 2. Comparison of Jolly-Seber and Lincoln-Peterson population estimations (estimate with 95% confidence limits) for adult and subadult tortoises at the Granite Hills desert tortoise monitoring plot from 1990 to 1994.

Year	Jolly-Seber	Lincoln-Peterson
1990	N/A	68.00 ± 44.10
1991	56.05 ± 7.11	63.00 ± 13.20
1992	64.61 ± 9.48	60.00 ± 4.10
1993	69.84 ± 7.99	90.00 ± 11.60
1994	N/A	69.00 ± 3.00

Table 3. Comparison of Jolly-Seber and Lincoln-Peterson population estimations (estimate with 95% confidence limits) for adult and subadult tortoises at the Little Shipp Wash desert tortoise monitoring plot from 1990 to 1994.

Year	Jolly-Seber	Lincoln-Peterson
1990	N/A	85.00 ± 14.50
1991	82.45 ± 7.07	79.00 ± 4.00
1992	102.41 ± 10.07	107.00 ± 9.70
1993	97.53 ± 10.57	107.00 ± 6.80
1994	N/A	97.00 ± 6.40

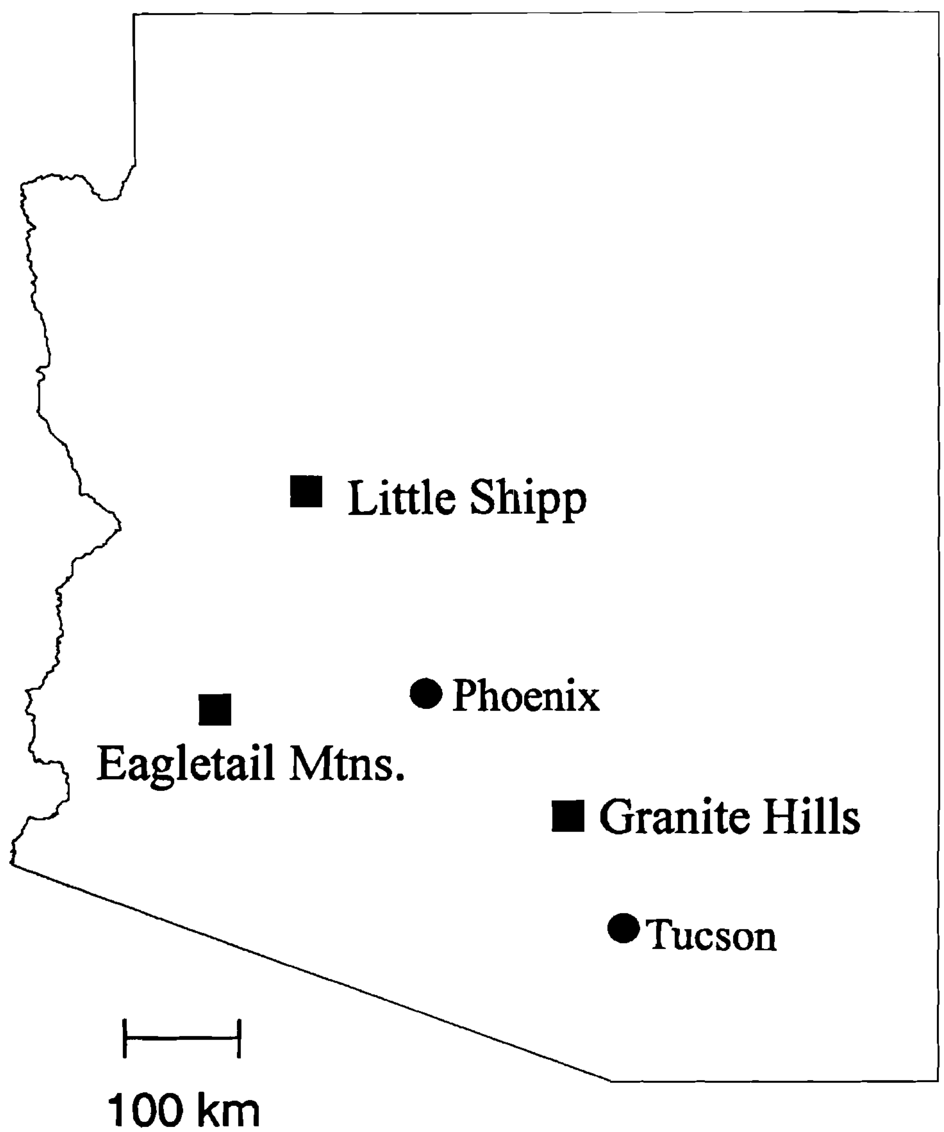

Figure 1. Locations of the three primary field sites for Sonoran desert tortoise population monitoring.

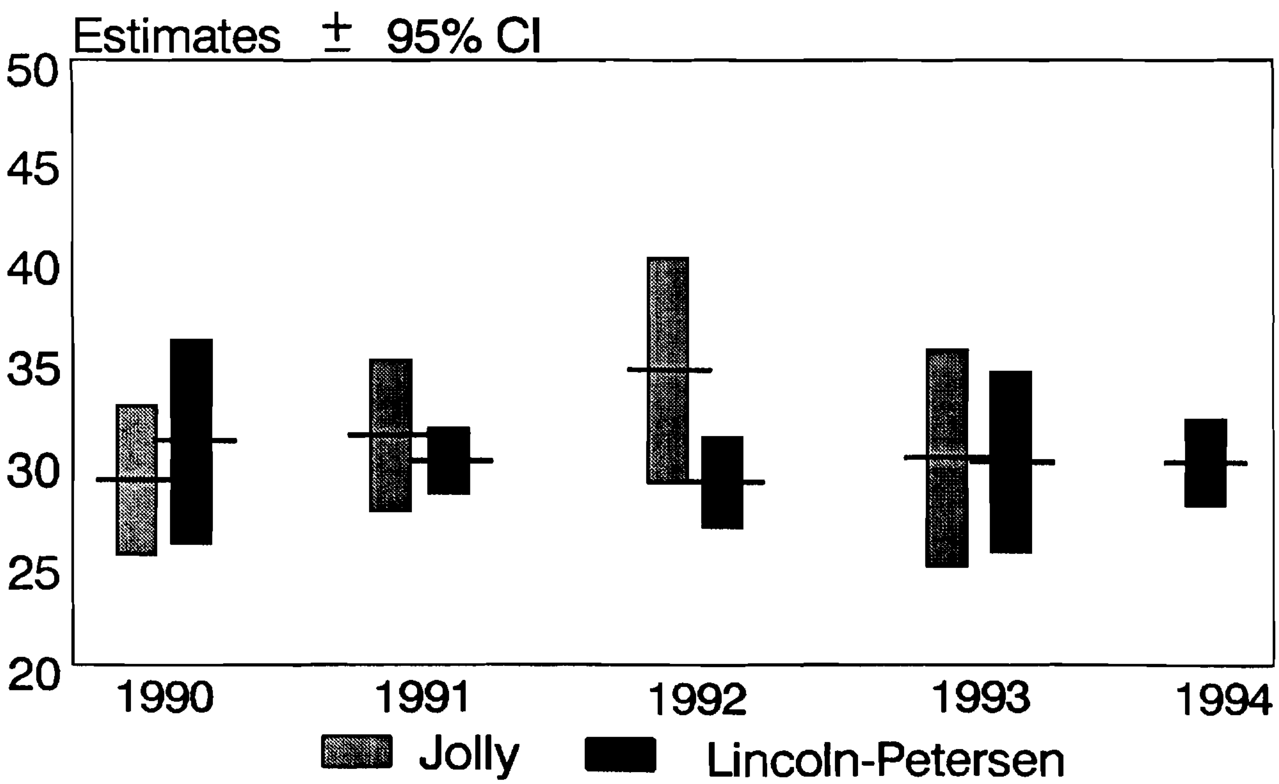

Figure 2. Comparison of Jolly-Seber and Lincoln-Petersen population estimations (estimate with 95% confidence limits) for adult and subadult tortoises at the Eagletail Mountains desert tortoise monitoring plot from 1990 to 1994.

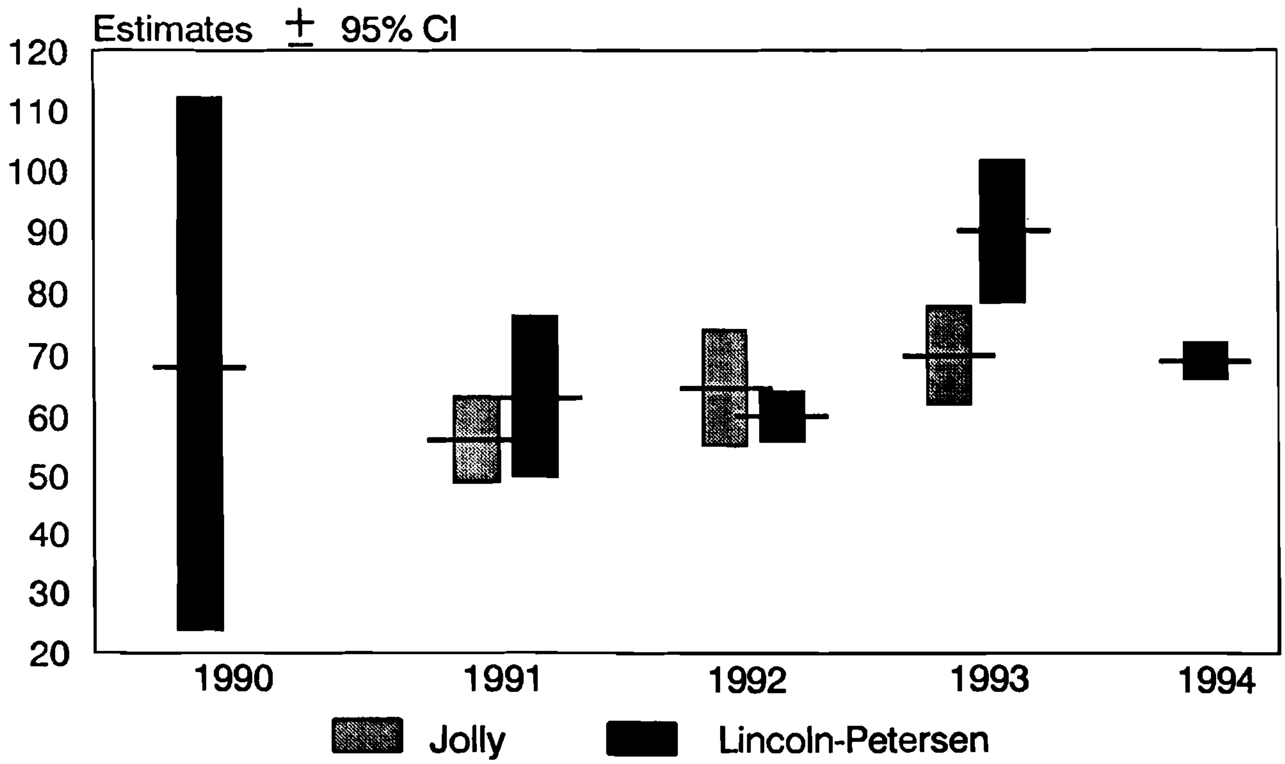

Figure 3. Comparison of Jolly-Seber and Lincoln-Petersen population estimations (estimate with 95% confidence limits) for adult and subadult tortoises at the Granite Hills desert tortoise monitoring plot from 1990 to 1994.

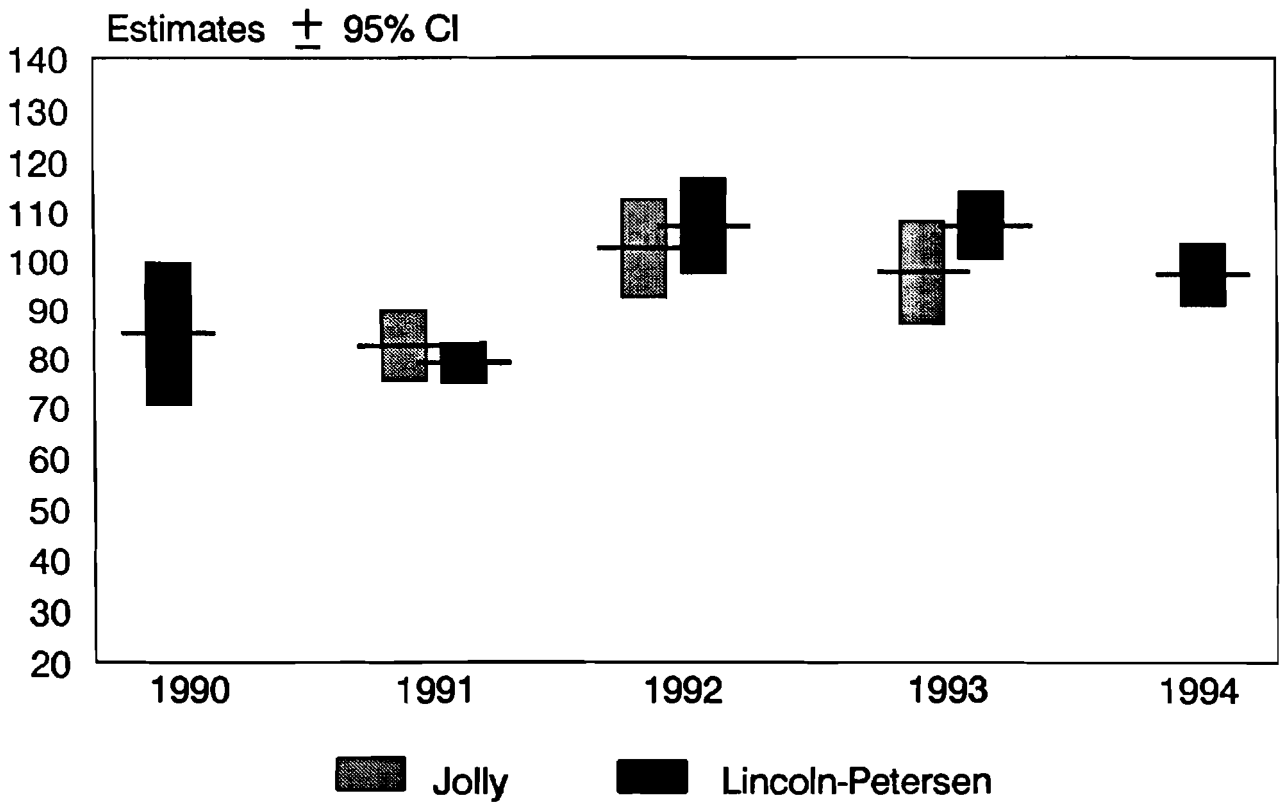

Figure 4. Comparison of Jolly-Seber and Lincoln-Petersen population estimations (estimate with 95% confidence limits) for adult and subadult tortoises at the Little Shipp Wash desert tortoise monitoring plot from 1990 to 1994.

PATTERNS OF GROWTH IN DESERT TORTOISES IN CALIFORNIA: REGIONAL COMPARISONS

Kristin H. Berry
National Biological Service
Riverside Field Station, Riverside, California

Michael Weinstein
El Morro Institute, Solvang, California

Abstract. Desert tortoises have characteristic patterns of growth which vary according to sex, size, age, rainfall patterns, and region. We evaluated data on growth from >20,000 captures of desert tortoises from six desert regions in California: Western Mojave, Southern Mojave, Northeastern Mojave, Eastern Mojave, Northern Colorado, and the Eastern Colorado. To evaluate the data base, we limited information on individual tortoises to one capture/year; capture intervals spanned a full year $\pm$ 45 days or multiples thereof. Depending on the region, numbers of tortoises contributing to the growth data base ranged from 138 to 589. For all regions, growth for tortoises follows a complex non-linear pattern with a rate of 5 mm/year for hatchlings to first year of life for very small juveniles. The rate of growth increases to about 10 mm/year (range 8-16mm) until the tortoise reaches about 150 mm in length. Thereafter, growth rates decline rapidly until they cease. The maximum annualized growth rate for wild tortoises is about 30 mm/year. At sexual maturity, growth rates of females and males diverge, with female rates dropping sharply. Differences in growth rates become more divergent with age and size.

Tortoise take from 15 to 25 years to achieve sexual maturity (assuming this occurs at 185 mm carapace length), with tortoises at most sites taking $\leq$20 years (exceptions are the western Mojave sites). Most tortoises take from 23 to 46 years to reach maximum size, the point where annualized growth is $\leq$1 mm/year. Females appear to stop growing at ages between 23-38 years, while males continue to grow until 31-46 years. The largest amount of variation in growth is due to differences between different periods of time, not differences in sex, size, or regions. Growth rates during the faster growing periods of time are almost universally higher for all tortoises and appear to be related to availability of precipitation and forage, a pattern we previously described for the Goffs site. Fast and slow growing periods of time generally are consistent from site to site and appear to correspond to periods of high and low rainfall, respectively.

THREE-YEAR MOVEMENT PATTERNS OF ADULT DESERT TORTOISES AT YUCCA MOUNTAIN

Eric A. Holt and Kurt R. Rautenstrauch
EG&G Energy Measurements, Inc., Las Vegas, Nevada

Abstract. We studied the home-range size and site fidelity of adult (>180-mm mid-carapace length [MCL]) desert tortoises (*Gopherus agassizii*) at Yucca Mountain, Nevada, during 1992-1994. Of 67 adult tortoises monitored at Yucca Mountain during this period, we evaluated the movements of 22 female and 16 male radiomarked tortoises that were located >50 times during each of the 1992, 1993, and 1994 activity seasons. By including only tortoises that were located many times in all three years, we may have biased our sample toward the resident tortoises that were easiest to locate. We used two methods to measure annual and three-year home range size: 100% minimum convex polygon (MCP) (Mohr 1947) and 95% cluster (Kenward 1987). MCP represents the maximum area a tortoise used, whereas 95% cluster represents the area a tortoise used most often. To evaluate whether tortoises used the same areas in consecutive years, we measured the shift in arithmetic-mean center of activity (Hayne 1949) and the overlap (i.e., the percent of one year's home range included in the previous year's home range) in consecutive annual home ranges (MCP only). In addition, we measured the percentage of each tortoise's three-year home range used annually (MCP only). Analysis of variance was used to test for differences ($P < 0.05$) among years and sexes for all criteria.

Males had larger ($P < 0.01$) annual MCP home ranges ($\bar{x} = 53$ ha, SD = 51) than females ($\bar{x} = 18$ ha, SD = 12). The average three-year MCP home range also differed ($P < 0.01$) between males ($\bar{x} = 93$ ha, SD = 27) and females ($\bar{x} = 27$ ha, SD = 17). MCP home ranges did not differ ($P = 0.22$) among years ($\bar{x} = 33$ ha, SD = 39).

Males also had larger ($P < 0.01$) annual cluster home ranges ($\bar{x} = 17$ ha, SD = 25) than females ($\bar{x} = 4$, SD = 6). The average three-year cluster home ranges also differed between ($P < 0.01$) males ($\bar{x} = 25$, SD = 31) and females ($\bar{x} = 7$, SD = 4). Cluster home ranges during 1994 ($\bar{x} = 5$ ha, SD = 7) were smaller ($P < 0.01$) than 1992 ($\bar{x} = 10$ ha, SD = 18) or 1993 ($\bar{x} = 14$ ha, SD = 24).

Males had larger ($P < 0.01$) shifts in arithmetic-mean center of activity between consecutive years ($\bar{x} = 151$ m, SD = 130, $n = 32$) than females ($\bar{x} = 83$ m, SD = 85, $n = 44$). There was no difference ($P = 0.56$) in shift ($\bar{x} = 112$ m, SD = 111) between consecutive year groups.

The average overlap in consecutive annual MCP home ranges was 78% (SD = 19, range = 7-100%, $n = 76$). Only one annual home range had <30% of its area in common with the previous year's home range, while 41 annual home ranges had >80% of their area in common with the previous year's home range. Overlap of 1993 on 1992 ($\bar{x} = 72\%$, SD = 21) was smaller ($P < 0.01$) than 1994 on 1993 ($\bar{x} = 83\%$, SD = 14), indicating that in 1994, as compared to 1993, tortoises used fewer areas that they did not use the previous year. There was no difference ($P = 0.78$) in percent overlap between sexes across the year groups.

Tortoises used an average of 65% of their MCP three-year home range annually (SD = 20, range = 17-100%). The percentage of the three-year home range used in 1994 ($\bar{x} = 54\%$, SD = 18) was smaller ($P < 0.01$) than in 1992 ($\bar{x} = 69\%$, SD = 19) or 1993 ($\bar{x} = 70\%$, SD = 18). This measure did not differ ($P = 0.49$) between sexes.

We conclude that males have larger home ranges than females and that tortoise movements vary annually, possibly in response to differences in rainfall. Adult tortoises at Yucca Mountain moved less during 1994, which was drier than the previous two years. Although average MCP home range size did not differ among years, tortoises had smaller cluster home ranges in 1994, indicating that they spent most of their time in smaller areas. Tortoises also used smaller portions of their three-year home range in 1994 than they did in the previous two years. In addition,

tortoises used fewer areas different from the previous year in 1994 than in 1993. We also conclude that most adult tortoises at Yucca Mountain show strong site fidelity. One reason for this conclusion is that shifts in arithmetic-mean center of activity between consecutive years were small compared to home range sizes. In addition, overlap in consecutive annual home ranges and percentage of the three-year home range used annually were relatively large. It should be noted, however, that a few tortoises we monitored at Yucca Mountain, but did not include in this analysis because we were unable to locate them often enough, moved great distances and had little site fidelity.

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INTERRELATIONSHIPS BETWEEN FLORIDA BURROWING OWLS (*ATHENE CUNICULARIA*) AND GOPHER TORTOISES (*GOPHERUS POLYPHEMUS*): HOW THESE RELATIONSHIPS ARE LEADING TO NEW, MULTI-SPECIES APPROACHES TO THE DEVELOPMENT AND MANAGEMENT OF MITIGATION PRESERVES

Ray E. Ashton Jr., E. Lynn Mosura, and Patricia S. Ashton
Water and Air Research, Inc., Gainesville, Florida

Abstract. The state, when charged with establishing mitigation programs with developers for gopher tortoises, kestrels, and other protected species, has normally approached the issues involved on a species by species basis. Also, mitigation agreements frequently involve an emphasis on maintaining or re-creating upland habitats for these species. This paper will present preliminary results of a long-term study involving a multiple species approach to on-site mitigation preserve development as well as presenting information on the interrelationships between burrowing owls and gopher tortoises.

The first four years of a long-term study into a population of burrowing owls, (*Athene cunicularia*) which are located in a future high density urban development began in 1990. This study has involved banding all resident owls, maintaining a history of all burrows used by the owls, and intensive behavioral observations as well as studies of the effectiveness of various management techniques and evaluations of their impacts. It became immediately evident that burrowing owls on site and in other regional populations are found sympatrically with gopher tortoises, (*Gopherus polyphemus*). Owls systematically use both abandoned and active burrows. Inactive burrows are frequently used to establish nesting burrows and both active and inactive burrows within the owl's nesting territory are used to rear older hatchling birds through fledging. Tortoise burrows appear to provide a microhabitat with lower mean temperatures, higher humidity and entrances that are less likely to collapse than owl-dug burrows. The study has now expanded into a study of the forage and other factors required by gopher tortoises in artificial pasture settings and to evaluate methods of increasing carrying capacity for tortoises using techniques that have been historically used in evaluating forage for cattle.

These observations have in part led to the development of multiple species mitigation preserves and foraging areas which include burrowing owls, gopher tortoises, southeastern American kestrels (*Falco sparvarius paulus*), and gopher frogs (*Rana capito*). Management of these preserves emphasize maximizing forage for all species and enhancing the environment in ways that can be undertaken by most land managers dealing with urban settings. Public education is also an important part of this effort. These management programs are providing innovative methods which may provide more effective, long-term, on-site management which will lead to greater, long-term survival of populations of all of these protected species.

A FIELD EVALUATION OF FOUR METHODS FOR ESTIMATING DESERT TORTOISE DENSITIES

Anthony J. Krzysik
U.S. Army-CERL, University of Illinois, Urbana, Illinois

A. Peter Woodman
KIVA Biological Consulting, Inyokern, California

Mark Hagan
Edwards Air Force Base, California

Abstract. Desert tortoise populations are highly patchy in both density and spatial distribution. Organisms that are spatially patchy, rare, and are distributed over landscape and regional scales pose exceptional problems in inventory sampling design and data analyses. Furthermore, desert tortoise activity levels are strongly related to seasonal and daily environmental conditions, including precipitation. Therefore, the use of traditional mark-recapture vertebrate population sampling designs to estimate tortoise densities directly are very expensive because of the extensive field time and effort required. Examples of these methods include: Peterson Estimate, Schnabel Census, Jolly-Seber Method, Zippin Maximum-likelihood Estimation. A more efficient and cost-effective strategy to estimate tortoise densities has been the use of sampling designs that survey tortoise burrows and scat, and use these estimated densities as surrogates or calibrational indices of "actual tortoise densities," generally in conjunction with calibration plots where tortoise densities have been estimated directly by an intensive mark-recapture study.

In this research four tortoise survey methods were conducted simultaneously at three study plots in the western Mojave Desert. Two were located on Edwards Air Force Base and the other was located along State Highway 58, outside the air base. The methods were Zippin, 2.4 km triangular strip transects, nested square strip transects, and Line Transect Distance Sampling Modeling (LTDSM). The latter method has a firm foundation in statistical theory, and has been adapted by the senior author for broad applications in ecological and biodiversity assessment and monitoring. LTDSM inherently possesses several important features: (1) It models and develops a detectability function for each specific sampling element. Therefore, tortoise burrows and scats are "equally detectable," (2) density estimates are independent of surveyor observational abilities or experience, (3) habitat bias on density estimates is eliminated, and (4) it provides statistically valid confidence intervals for estimated densities.

The number of tortoises found in these surveys were insufficient to directly estimate tortoise densities. Comparisons of the other three methods revealed that the LTDSM method gave the most consistent and reliable estimates of burrow and scat densities. This was the only method that accurately and consistently estimated scat densities. This was the only method that accurately and consistently estimated scat densities, and was particularly effective in climbing surveyor and habitat bias.

CORRELATION OF DESERT TORTOISE HABITAT CONDITION AND POPULATION TRENDS THROUGH REMOTELY SENSED DATA AND GIS

Steve Ahmann, Mickey Quillman, Carolyn Lackey, Katie Edson
Natural Resources, Fort Irwin, California

Roy Dokka
Louisiana State University, Baton Rouge, Louisiana

Joe Watts
U.S. Army Topographic Engineering Center, Alexandria, Virginia

Abstract. The purpose of this work is to delineate the relationship between remotely sensed disturbance patterns in desert tortoise habitat to estimates of population size. Since 1984 is the earliest year for which both remotely sensed telemetry and desert tortoise survey results are available on the National Training Center it has been designated as baseline. This early work is compared to 1994 telemetry through digitization and analysis to establish patterns in habitat condition and predict population size and distribution. Finally, following spring, 1995 monitoring, an evaluation is made of the effectiveness and recommendations suggested for future research.

DESERT TORTOISE EDUCATION: IMPLICATIONS FOR ENDANGERED SPECIES MANAGEMENT

Wanda S. Deal, Mark Hagan, and Veronique Anderson
Environmental Management, Edwards Air Force Base, California

Abstract. The Air Force Flight Test Center, Edwards Air Force Base (AFB), conducts many military operations and a variety of support activities. Testing of new aircraft, avionics, weapon delivery systems, and static testing of large solid and liquid propellant rocket motors are just a few examples of military operations that are routinely conducted. Construction of new facilities, utility corridors, roads, residential housing areas, and shopping centers illustrate some of the activities which support military operations. Edwards AFB encompasses approximately 301,000 acres in the western Mojave desert. Edwards AFB consists of five different plant communities; halophytic phase saltbush, xerophytic phase saltbush, creosote bush scrub, Joshua tree woodland, and mesquite woodland. Desert tortoises (*Gopherus agassizii*) occur throughout 2/3 of the installation. The other third consists of playa lakes and concentrated development. The Desert Tortoise Education Program is one element of natural resources management at the installation. The Education Program consists of developing video tapes, brochures, decals, fact sheets, and briefings. Coordination with other federal, state, and local agencies and private organizations is an integral part of the program. All base personnel and contractors are briefed on requirements to protect the desert tortoise. Presentations are also given to school children both on and off the installation. Collection of desert tortoises for pets had decreased dramatically over the last three years. Reports of observations by base personnel has increased over the same time period. Natural resource personnel now respond to the reports and desert tortoises have been left in their natural environment. The Education Program has proven to be invaluable in the management of the desert tortoise. Edwards AFB plans to continue and expand this program as an important part of desert tortoise and natural resources management. Future plans are to incorporate desert ecosystem education kits with teaching curriculums into the program to provide more hands on experience and learning.

INTRODUCTION

The primary mission of the Air Force Flight Test Center at Edwards Air Force Base (AFB) is research and development of aircraft, avionics, and weapons systems. Edwards AFB tests some of the newest aircraft in the inventory, does static testing of rocket motors and serves as a landing site for the shuttle. To accomplish this, many support operations, such as the construction of facilities, roads, and utility corridors also occur. Edwards AFB has everything you typically expect in a small town, housing, recreation, schools, hospital, shopping, gas station, landfill, etc.

METHODS

Edwards AFB is located 1½ hours northeast of Los Angeles, CA and 45 minutes west of Barstow, CA. Edwards AFB encompasses approximately 301K acres or 470 square miles in the western Mojave Desert. One third of Edwards AFB is comprised of playa lakes and concentrated development. The other 2/3 consists of five different plant communities: creosote bush scrub (*Larrea tridentata*), xerophytic phase saltbush (*Atriplex* sp.), halophytic phase saltbush, and mesquite woodland (*Prosopis glandulosa torreyana*). Common species on Edwards AFB consists of typical desert animals, such as, coyotes (*Canis latrans*), desert kit fox (*Vulpes macrotis*), antelope ground squirrel (*Ammospermophilus lecurus*), blacktailed jackrabbit (*Lepus californicus*), etc. Less common species on Edwards AFB consists of mohave ground squirrel (*Citellus mohavensis*), bobcat

(*Felis rufus*), burrowing owl (*Athene cunicularia*), desert cymopterus (*Cymopterus deserticola*), alkali mariposa lily (*Calochortus striatus*), Barstow woolly sunflower (*Eriophllum mohavense*), and the desert tortoise (*Gopherus agassizi*).

The Desert Tortoise Education Program is an important element of natural resource management at the installation. The program is carried out through a series of briefings, trainings, tours, field trips, open houses, poppy festival, etc. This program takes advantage of a joint National Aeronautical Space Administration (NASA)/Air Force video, brochures, stickers, cards, and terms and conditions of the appropriate biological opinion. Coordination with other federal, state, local, and private organizations is an integral part of the program. All personnel living and working on Edwards AFB, military, civilians, contractors and children are focused on for training. The level of training is adapted to the level of likelihood they will come in contact with a desert tortoise or affect the species' habitat.

RESULTS

In 1990, a desert tortoise was picked up on the flightline, held for several days and ended up as a pet tortoise. From 1990 to 1993 several desert tortoises were removed from roads on Edwards AFB. Since 1994 over 2,000 individuals have been trained causing different outcomes during encounters with desert tortoises.

Since 1994 multiple sightings of desert tortoises have been reported, up to seven desert tortoises were reported in one day - none of them were handled. One desert tortoise was sighted on a dirt road upside down. The individuals which observed it, righted the tortoise, left it where it was, and then led us to where the tortoise was found. One week later a desert tortoise was sighted on the taxiway parking apron. The individual observing it called us to report the tortoise. We responded, assessed the situation, and after consultation with the U.S. Fish and Wildlife Service it was decided to relocate the animal to the nearest habitat known to support tortoises.

In all cases the individuals pointed to the desert tortoise education program they had received which guided them in how to handle the situation.

DISCUSSION

Education often lacks the emphasis which is needed. These results seem to indicate education may be an important part of endangered species management.

We will continue to work on fine tuning and enhancing our training. We plan to incorporate the use of desert ecosystem education kits for more hands on training for children, and develop posters and displays. These are being accomplished through cooperative efforts with local, public, and private agencies.

COMMON RAVEN USE OF ANTHROPOGENIC RESOURCES AT EDWARDS AIR FORCE BASE: SUMMER 1994

William I. Boarman
National Biological Service, Riverside, California

Richard J. Camp
Colorado State University, Fort Collins, Colorado

Mark Hagan and Wanda S. Deal
Edwards Air Force Base, California

Abstract. Common ravens (*Corvus corax*), which sometimes prey on juvenile desert tortoises (*Gopherus agassizii*), are increasing in numbers in the Mojave Desert and elsewhere in the southwestern United States. The increases are likely caused by ravens' use of human-based resources, such as garbage for food, sewage for water, and power transmission towers as nest sites. During July 1994, we compared raven use of various resource types by surveying for ravens at landfills, sewage ponds, golf courses, city streets, and desert reference site as a control. Replicate sites were visited at Edwards Air Force Base (EAFB), Mojave, and Boron in Kern County, California. We determined patterns of raven use of a landfill by censusing wing-tagged and unmarked ravens at sunrise, midday, and sunset at the landfill at EAFB to obtain population estimates for tracking population trends as a result of changes in landfill management methods. Finally, we determined patterns of movements of ravens with respect to various resource sites by searching for 36 wing-tagged and 7 radio-tagged ravens in and near EAFB. The birds were caught at marked at the EAFB landfill.

We found significantly more ravens at landfills than at the other four resource types ($F=7.27$, $df=4$, $P=0.01$). Significantly more ravens were observed at midday than sunrise or sunset at the EAFB landfill ($F=17.28$, $df=2$, $P=0.0001$). The majority ($n=90$) of re-sightings of tagged ravens were at the landfill; fewer ($n=50$) were in the base housing and operations area, within 4.5 km of the landfill; and a few ($n=8$) were found off base, as far as 27 km from the landfill. The results indicate that landfills are heavily used by ravens and that there is considerable movement of ravens between various anthropogenic resource sites. Limiting raven access to garbage at landfills may help to slow increases in raven populations. We are continuing our research at EAFB and are beginning similar work at the National Training Center, Fort Irwin, California, to determine if the patterns reported herein vary with season and location.

DESERT TORTOISES ADJUST METABOLIC RATES AND WATER FLUXES TO LOCAL AND GLOBAL CLIMATIC CONDITIONS

Brian T. Henen, Kenneth A. Nagy, Charles C. Peterson, Ian R. Wallis, Byron S. Wilson, Mark A. Wilson, and Isabella A. Girard
Department of Biology and Division of Environmental Biology
University of California - Los Angeles, Los Angeles, California

Abstract. We used the doubly labeled water technique to study the energy and water relations of adult desert tortoises in the Eastern Mojave Desert (Goffs and Ivanpah, California) and Western Mojave Desert (Desert Tortoise Natural Area, California City, California) from May 1989 to October 1992. Field metabolic rates (FMR; 1 CO_2/kg x d), water influx rates (WIR; ml H_2O/kg x d) and water economy indices (WEI; ml of H_2O in/kJ of FMR) differed between seasons and years but were similar between sites for most time intervals. FMR, WIR, and WEI were low in winter, high during late spring or early summer periods, and generally at intermediate levels during other periods. The peak (late spring to early summer) FMR, WIR, and WEI were lower in drought years than in wetter years. Seasonal differences within each site were associated with food availability, rainfall, or temperature variation. Tortoises in the Eastern and Western portions of the Mojave Desert responded similarly to rain, food, and temperature variation. This suggests that differences in responses between populations were associated primarily with local rains, rather than with other site characteristics.

Except during winter, tortoises in all three populations exploit food and water when available. However, they become conservative during drought conditions, reducing metabolic rates and water fluxes to 10% or less of peak (late spring) levels. The ability to relax or abandon homeostasis probably enhances survivorship and reproductive success. Global climatic patterns like El Niño events may determine long term demographic patterns in desert tortoises.

DOES WATER AVAILABILITY EVER LIMIT DESERT TORTOISES?

Brian T. Henen
Department of Biology and Division of Environmental Biology
University of California - Los Angeles, Los Angeles, California

Abstract. Female desert tortoises use a relaxed homeostasis to tolerate large deficits and surpluses in their water budgets. This ability helps them survive in the desert where the availability of dietary and drinking water is extremely unpredictable. Female tortoises may store water surpluses during one season or year and use these reserves to support egg production or digestion during other seasons or years. The relative contributions of dietary or drinking water influx to total water influx vary with the availability of these water sources.

Small body water reserves can limit digestion and lipid storage when tortoises consume dry annual plants and can limit egg production during drought years. Females were in negative water balance only during spring, when egg laying occurs, and had an annual water deficit only during the drought year of my study. During drought years, females may face a tradeoff between reproduction and body condition. Females with large values of total body water (TBW; ml) forfeited body water to produce eggs and females with small TBW forfeited egg production and increased their TBW.

Providing drinking water or succulent food to relocated tortoises or tortoises in disturbed habitat may help them increase TBW, egg production, lipid storage for winter, body protein reserves, or a combination of these traits. Changes in body mass are often primarily due to changes in TBW. Thus, large changes in body mass may sometimes simply represent a relaxed homeostasis towards water balance.

MUSTERING THE ENERGY TO REPRODUCE: ENERGY BUDGETS OF FEMALE DESERT TORTOISES

Brian T. Henen
Department of Biology and Division of Environmental Biology
University of California - Los Angeles, Los Angeles, California

Abstract. Female desert tortoises used a relaxed homeostasis to tolerate large deficits and surpluses in their seasonal and annual energy budgets. They can anabolize nonlipid body reserves (probably protein) during one season and use these reserves to fuel winter metabolism or to produce eggs during spring. Females can even tolerate large (>10%) declines in their nonlipid energy content on an annual basis. These tortoises decreased metabolic rates and food requirements in response to low food availability but they still managed to produce eggs.

Body protein, but not body energy, appears to be a primary limiting resource for egg production. However, lipid and nonlipid energy reserves were critical for supporting winter metabolism. Females increased their nonlipid reserves when consuming succulent annual plants (e.g., *Pectocarya recurvata* and *Cryptantha angustifolia*) and rapidly stored lipids when eating dry annual plants (e.g., *Schismus barbatus*).

Supplemental feeding programs may be critical to successfully relocating tortoises or managing disturbed tortoise habitat. We can select diets that foster egg production, lipid storage for winter dormancy, or both egg production and lipid storage. Additionally, assessments of the general health of desert tortoises must incorporate the desert tortoise's ability to tolerate extremely variable conditions.

PCR-RFLP DETECTION OF A NEW MYCOPLASMA ISOLATED FROM THE UPPER RESPIRATORY TRACT OF DESERT TORTOISES

Dan R. Brown, Barbara C. Crenshaw, Grace S. McLaughlin, Isabella M. Schumacher, Catherine E. McKenna, Paul A. Klein, Elliott R. Jacobson, and Mary B. Brown
Dept. of Infectious Diseases, College of Veterinary Medicine
University of Florida, Gainesville, Florida

Abstract. A chronic infectious disease, upper respiratory tract disease (URTD), of desert tortoises leads to degeneration of airway epithelium and severe occlusion of the upper airway with mucus. A newly recognized bacterium, *Mycoplasma agassizii*, was previously isolated from affected tortoises and shown by transmission studies to be an etiologic agent of URTD. Because *M. agassizii* is difficult to culture, a polymerase chain reaction (PCR) test was developed to determine current infection status of tortoises. The test detected the 16S rRNA gene of mycoplasmas. Phylogenetic analyses predicted *M. agassizii*-specific PCR products would include a unique restriction endonuclease AgeI recognition sequence (RFLP). Mycoplasmas cultured from the respiratory tracts of 30 desert tortoises, seropositive in an enzyme-linked immunosorbent assay (ELISA) for *M. agassizii*-specific antibodies, were characterized retrospectively by the PCR-RFLP test. The PCR products from 10 isolates differed from the *M. agassizii* AgeI RFLP pattern. The 16S rRNA gene nucleotide sequence of one of these did not match that known for any other mycoplasma, suggesting it was a new species. The sequence predicted a unique restriction endonuclease NciI RFLP which was common to each of the 10 isolates. Alternative interpretations of these results are: (1) tortoises seroconverted after previous exposure to *M. agassizii*, but were infected only with the new species of mycoplasma when sampled; (2) tortoises seroconverted after co-infection but the new species overgrew *M. agassizii* in culture; and (3) antibodies to the new species cross-react in the *M. agassizii* ELISA. Potential pathogenicity of the new mycoplasma species remains to be investigated.

MYCOPLASMA AGASSIZII IS THE ETIOLOGIC AGENT OF UPPER RESPIRATORY TRACT DISEASE IN THE GOPHER TORTOISE *(GOPHERUS POLYPHEMUS)*

Mary B. Brown, Grace S. McLaughlin, Dan R. Brown, Barbara C. Crenshaw, Alyssa D. Whitemarsh, Paul A. Klein, Catherine E. McKenna, Isabella M. Schumacher, and Elliott R. Jacobson
Department of Infectious Diseases, College of Veterinary Medicine
University of Florida, Gainesville, Florida

Abstract. *Mycoplasma agassizii* was first isolated from the respiratory tract of desert tortoises (*Gopherus agassizii*) with clinical signs of upper respiratory tract disease (URTD). Subsequent experimental infections demonstrated that *M. agassizii* could induce both the clinical signs and pathological lesions found in the natural disease. *M. agassizii* also has been isolated from the Florida gopher tortoise. Although the habitats of these two tortoise species are dramatically different, a similar upper respiratory infection characterized by nasal exudate and eventual wasting has been observed. The objective of the present study was to determine if *M. agassizii* strain 723, isolated from a clinically ill gopher tortoise, could cause URTD. Clinically healthy, seronegative gopher tortoises were transported to the University of Florida, housed in individual pens, and allowed to acclimate to their new environment. Prior to infection, an overall health assessment was performed. Animals were anesthetized, and a nasal flush and blood sample were obtained. At the time of infection, nine tortoises received 10^7 CFU of *M. agassizii* strain 723 by intranasal inoculation (0.1 ml/nare). Seven tortoises served as controls and received sterile SP4 broth. Three additional tortoises served as sentinel animals and received no treatment. Tortoises were observed a minimum of twice weekly. At 4, 8, 12, 14, and 16 weeks post-infection (PI) nasal flushes and blood samples were obtained from all tortoises. Nasal flushes were cultured for *M. agassizii* and were tested by polymerase chain reaction (PCR). Serum samples were tested for specific antibody to *M. agassizii* by enzyme-linked immunosorbent assay (ELISA). Clinical signs of nasal and ocular discharge, palpebral edema, and conjunctivitis were scored from 0 to 3 on the basis of severity, with 3 being the most severe. No control tortoise developed clinical signs; however one sentinel tortoise did develop signs of infection and seroconverted during the study. The results of the study are summarized in Table 1.

All clinical signs were significantly higher in infected tortoises than from controls in all weeks post-infection (Mann-Whitney U nonparametric test. $P < 0.05$) than from controls with two exceptions. At week eight PI, clinical scores for both ocular discharge and palpebral edema were not different from controls. By week four PI, 30% of infected tortoises had developed specific antibody as detected by ELISA; by week eight PI all infected tortoises had seroconverted. Detection of *M. agassizii* by PCR was most effective at 8 and 12 week PI, which corresponded to the peak period of nasal discharge. *M. agassizii* was isolated by culture in >50% of all infected animals throughout the study but the numbers of *M. agassizii* recovered were in most instances quite low. The result of this study demonstrated that *M. agassizii* causes URTD in the gopher tortoise. Documentation of ocular involvement during the early course of the disease may provide valuable information for field workers in assessing the heath status of tortoises in the absence of nasal discharge. Further, the study confirms the reliability of ELISA to determine exposure in high dose infections.

Table 1. Mean clinical lesion score in experimentally infected gopher tortoises ($n = 9$). All values are expressed as the mean clinical score $\pm$ standard error.

	Weeks post-infection				
Clinical Sign	0	4	8	12	16
Nasal discharge	0 ± 0	1.11 ± .26	1.67 ± .44	2.00 ± .41	1.56 ± .25
Ocular discharge	0 ± 0	1.00 ± .33	.89 ± .39	1.12 ± .35	1.25 ± .34
Palperbral edema	0 ± 0	1.00 ± .33	.89 ± .39	1.3 ± .37	1.33 ± .24
Conjunctivitis	0 ± 0	.78 ± .28	1.22 ± .23	.89 ± .31	.89 ± .31

CHALLENGE OF PREVIOUSLY EXPOSED GOPHER TORTOISES (*GOPHERUS POLYPHEMUS*) WITH *MYCOPLASMA AGASSIZII*

Grace S. McLaughlin, Mart B. Brown, Dan R. Brown, Barbara C. Crenshaw, Alyssa D. Whitemarsh, Paul K. Klein, Catherine E. McKenna, Isabella M. Schumacher, and Elliott R. Jacobson
Department of Infectious Diseases, College of Veterinary Medicine
University of Florida, Gainesville, Florida

Abstract. *Mycoplasma agassizii* causes respiratory disease of tortoises, with clinical signs including nasal and ocular discharge, palpebral edema, and conjunctivitis. Eighteen adult gopher tortoises (*Gopherus polyphemus*) of both sexes and various weights were inoculated intranasally with an SP4 broth culture of *M. agassizii*. Seven tortoises were antibody-positive (challenge group) and 11 were antibody-negative (naive group) before experimental infection. Six additional tortoises served as controls, and were inoculated intranasally with sterile SP4 broth. Tortoises were examined at 2-week intervals until eight weeks post-infection (PI). The four clinical signs were evaluated on separate scales of 0-3, with 0 being none and 3 being severe. Nasal flush and swab samples were collected at the same time. Flushes were diluted serially 10-fold in SP4 broth and quantitatively cultured on SP4 agar. Swabs were plated on SP4 agar. Broth cultures were maintained at 30 C and ambient air; agar plates were maintained at 30 C and 5% carbon dioxide. All cultures were examined regularly for up to six weeks to detect the growth of mycoplasma. No control tortoises developed clinical signs, nor did two naive tortoises; all other infected animals exhibited mild to severe signs during the experimental period. At two weeks PI, clinical sign scores for nasal discharge, palpebral edema, and conjunctivitis were significantly higher in the challenge group than the naive group (Wilcoxon 2-sample test; all $P < 0.05$). By four weeks PI, the naive group scores had increased to the same level as the challenge group scores, and were significantly higher than the 2-week naive group scores. Both group scores stayed high throughout the remaining experimental period. *M. agassizii* was recovered from the nasal samples of all infected tortoises on at least two sampling occasions. Antibodies against *M. agassizii* did not seem to confer any protection against further exposure.

EFFECTS OF UPPER RESPIRATORY TRACT DISEASE ON REPRODUCTION AND STEROID HORMONE LEVELS IN MALE AND FEMALE DESERT TORTOISES

Valentine A. Lance
Center for Reproduction of Endangered Species
Zoological Society of San Diego, California

David C. Rostal, Janice S. Grumbles
Department of Biology
Georgia Southern University
Statesboro, Georgia

Isabella Schumacher
Department of Infectious Disease
College of Veterinary Medicine
University of Florida, Gainesville, Florida

Abstract. Fifty tortoises (maintained in 10 groups of 2 males and 3 females) were sampled at the Desert Tortoise Conservation Center, Nevada from August 1991 to July 1993. Blood sampled (3-5 ml) drawn via the jugular vein, were assayed for testosterone, estradiol, progesterone, and corticosterone by radioimmunoassay. Plasma calcium and magnesium were assayed to assess vitellogenesis in females. Each blood sample was assayed for the presence of antibodies by *Mycoplasma agassizii* using an enzyme-linked immunosorbent assay technique and each animal was examined for clinical signs of upper respiratory tract disease (URTD). The reproductive status and egg production of female tortoises was monitored using ultrasonography. Clutch size, egg size, hatching success, and hatchling size were compared between infected and healthy tortoises. Plasma testosterone was significantly lower in URTD males than in healthy males. Plasma estradiol was significantly lower in URTD females than in healthy females. A negative correlation was observed between infection (positive ELISA) and percent of reproducing females (54% vs 100%). URTD may be negatively affecting reproduction in wild tortoise populations.

NECROPSIES OF 14 DESERT TORTOISES FROM THE MOJAVE AND COLORADO DESERTS OF CALIFORNIA AND THE SONORAN DESERT OF ARIZONA

Bruce L. Homer[1], Kristin H. Berry[2], Mary M. Christopher[3],
Mary B. Brown[4], Ellis C. Greiner[5], Elliott R. Jacobson[6]
[1]Departments of Pathobiology, [4,5]Infectious Diseases, and [6]Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, Florida
[2]National Biological Service, Riverside Field Station, Riverside, California
[3]Department of Clinical Pathology, School of Veterinary Medicine, University of California, Davis, California

Abstract. Fourteen desert tortoises, *Gopherus agassizii*, were received over a period of 19 months (from March 1992 through October 1993) for complete necropsies from the Mojave and Colorado Deserts of California (12) and the Sonoran Desert of Arizona (2). The purpose was to determine the cause of illness and/or death of the tortoises. Complete necropsy examinations included identification of gross and microscopic lesions, hematologic and biochemical profiles, *Mycoplasma* spp. serology and culture from the choanae and nasal cavities, urinalysis, bacterial culture and isolation from the nasopharynx and colon, identification of intestinal parasites, and analysis of plasma, liver, and kidney for heavy metals and organic compounds. Seven tortoises had shell lesions typical of cutaneous dyskeratosis. Gross lesions consisted of areas of grey-white, flaky, roughened shell with foci of pitting, chipping and loss of scute. Microscopically, the stratum corneum of the affected shell often had fissures or was fragmented. There often was increased remodeling of dermal bone and in the most severe lesions, there was osteoclastic resorption of trabecular bone. Tortoises with the most severe shell lesions had the lowest ratio of plasma calcium to phosphorus. Another tortoise had a bilaterally symmetrical loss of the anterior scutes of the carapace and plastron subtended by necrotic bone, which was colonized by a mixed population of fungi and bacteria. Shell necrosis in this tortoise was due to a mixed microbial infection. Concentrations of lead in the liver and kidney of this tortoise were mildly elevated. Two tortoises had respiratory tract diseases. One of these tortoises had fungal pneumonia. Concentrations of cadmium in the liver and kidney of this tortoise were elevated. The other tortoise had lesions (chronic proliferative rhinitis), titer (1:10), and culture results consistent with mycoplasmosis. Three tortoises had lesions associated with trauma or entombment. One of the tortoises had been severely injured by a predator and had an acute bacterial-induced bronchopneumonia. Another tortoise had septicemia and a cutaneous fungal infection secondary to being entombed within its burrow. The third tortoise had plasma biochemical changes (leukopenia, hypoproteinemia, hypoglobulinemia) and lesions (black discoloration of shell, burn wound of left front leg, transmural necrotizing inflammation of the small and large intestine) associated with burn injury. This tortoise also had a low serum titer against *Mycoplasma*, but had no lesions of mycoplasmosis, and culture for *Mycoplasma* spp. was negative. The fourteenth tortoise had mild palpebral edema and biochemical and morphologic changes suggestive of liver disease.

PROGRESSION OF ABNORMAL LABORATORY DATA AND CLINICAL SIGNS OF DISEASE IN 36 TORTOISES IN THE MOJAVE DESERT FROM 1990-1993

Mary M. Christopher
Department of Veterinary Pathology, Microbiology, and Immunology
at the University of California, Davis, California

Kristin H. Berry
National Biological Service, Riverside, California

Kenneth A. Nagy, Brian T. Henen, Charles C. Peterson, Ian R. Wallis,
Byron S. Wilson, and Isabella A. Girard
Department of Biology and Division of Environmental Biology
University of California - Los Angeles, Los Angeles, California

Abstract. The Desert Tortoise Health Profiles program coordinated by the National Biological Service has developed well-defined laboratory and field guidelines for the health evaluation of desert tortoises in the eastern and western Mojave Desert of California. Although the primary purpose of this longitudinal study was to develop baseline normal values for three populations of desert tortoises, the identification of ill tortoises has become increasingly important due to the epidemic spread of mycoplasmosis (upper respiratory tract disease) and the increasing incidence of shell disease and necrosis. A small cohort of tortoises in our study have shown signs of upper respiratory tract disease and/or abnormal laboratory data over multiple years of the study; all known mortalities in 1993 occurred in this group of tortoises. We evaluated the progression of disease in this population of tortoises in order to better understand how to identify and manage endemic disease in tortoise populations.

Eleven tortoises each from the Desert Tortoise Natural Area (DTNA) and Goffs, and 14 tortoises from the Ivanpah Valley were evaluated individually and as a group. Tortoises with multiple years of even mild abnormalities were more likely to develop overt disease or positive titers to *Mycoplasma agassizii* than tortoises with transient abnormalities. This group of tortoises tended to have lower packed cell volume and glucose values than other tortoises. Progression of disease differed by site. Both DTNA tortoises and Goffs tortoises showed a decline in disease signs and abnormal laboratory data in 1992 compared with 1990-91 and 1993. Two tortoises at Goffs have shown multiple signs of illness since 1990 but remain seronegative for *M. agassizii* (although one had a positive mycoplasma culture). Several tortoises at both Goffs and Ivanpah developed oral ulcers in 1993. Ivanpah tortoises had persistent and increasing signs of disease and laboratory abnormalities for all three years. Ivanpah tortoises initially developed leukocytosis, heterophilia and/or basophilia and subsequently developed additional laboratory abnormalities, clinical signs of respiratory disease, and positive titers by 1993.

EFFECTS OF PROTECTION FROM ANTHROPOGENIC DISTURBANCES ON BIRDS, LIZARDS, AND JACKRABBITS AT THE DESERT TORTOISE RESEARCH NATURAL AREA, CALIFORNIA

Matthew Brooks
University of California, Riverside, and
Desert Tortoise Preserve Committee, San Bernardino, California

Abstract. I previously showed that both plant and nocturnal rodent communities inside of the Desert Tortoise Research Natural Area (DTRNA) can benefit from protection from off-highway vehicles and sheep grazing (Brooks 1995). Both groups of taxa variously displayed higher biomass, density, and diversity inside compared to outside of the fenced DTRNA. In the present study I predicted that bird and lizard communities and black-tailed jackrabbit population should respond to protection in the same manner. Specifically, I hypothesized that the bird and lizard communities and jackrabbit population are more abundant and diverse inside compared to outside of the DTRNA.

I employed indices of abundance and did not attempt to determine densities. Sampling was focused on two disparate parts of the DTRNA: the northeast region located at 850 m on shallow, rocky residual soils; and the southern region located at 700 m on deeper, sandier alluvial soils. Birds were sampled at the middle (early May) and end (early July) of the breeding season and in December 1994. Trends suggest greater abundances of birds inside compared to outside of the DTRNA, but significant differences were only detected for all species combined ($P<0.10$) and species richness ($P<0.05$) on the south plot in May. Lizards were sampled once in early July 1994. Trends suggest greater abundances inside compared to outside of the DTRNA, but no significant differences were observed.

The abundance of black-tailed jackrabbits was determined concurrently with bird surveys in May and June 1994. Fecal pellet counts were also collected in April 1994. Measurements suggest greater jackrabbit abundance inside compared to outside of the DTRNA. Significant differences were observed in May on the northeast ($P<0.05$) and the south plots ($P<0.10$), in July on the south plot ($p<0.05$), and in April from fecal counts on the northeast plot ($P<0.05$).

Annual plant productivity was only about 15 kg/ha at the DTRNA in spring 1994. This represents the lowest amount at this location since spring 1989. Due to the minimal productivity in spring 1994, and the scant winter rainfall which preceded it, I plan to repeat the bird, lizard, and jackrabbit surveys during 1995. The experimental design and timing of sampling will remain unchanged from 1994, except that lizards will be additionally sampled in May.

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REDUCTION IN MORTALITIES OF DESERT TORTOISES AND OTHER VERTEBRATES ALONG A FENCED HIGHWAY

William I. Boarman
National Biological Service, Riverside Field Station, Riverside, California

Marc Sazaki
California Energy Commission, Sacramento, California

Glenn C. Goodlett and Tracy Goodlett
EnviroPlus Consulting, Ridgecrest, California

Abstract. Vehicle traffic on highways is an important cause of mortality for desert tortoises (*Gopherus agassizii*). The effect is measurable as road kills and lower densities of tortoises along versus away from highway edges. Barrier fences, coupled with culverts designed to facilitate movements beneath the highway, may help reduce tortoise mortalities caused by highway traffic. In 1991, we began a study of tortoise populations along California State Highways 58 and 395 in the western Mojave Desert to determine the impact a barrier fence and culverts have on the tortoise populations. We found that tortoise mortality along a 24 km section of fenced highway was 97% less than along a 24 km section of unfenced highway (1 vs. 34). We also found a 1170% increase in mortalities of several other species of vertebrates along the unfenced section of highway. We conclude that barriers are an effective way of reducing highway-related population losses in many small vertebrates. Only one tortoise is known to have passed through a culvert during two years of investigation, thus we do not yet know if culverts reduce population fragmentation caused by the highway and fence.

IMPLEMENTATION OF MITIGATION REQUIREMENTS FOR LUZ ENERGY FACILITY IN WESTERN MOJAVE DESERT

Roger Dale
Desert Tortoise Preserve Committee, Inc., San Bernardino, California

Abstract. In March 1989, the California Energy Commission (Commission) granted certification of a solar electric generating facility near Harper Dry Lake in the western Mojave Desert to Luz Finance and Development Corporation. In order to prevent vehicular mortalities to desert tortoises along Harper Lake Road, the only access to the facility, the Commission Decision required the construction of a tortoise-proof fence along the road. The Bureau of Land Management (BLM) granted a permit to Luz for its transmission line route over federal lands. The BLM's permit included the same requirement for a tortoise-proof fence along Harper Lake Road.

In July 1993, Harper Lake Companies (HLC), the successor-in-bankruptcy to Luz for the operation of the facility, filed with the Commission a request to amend the original mitigation requirement of a tortoise-proof fence. In particular, HLC proposed substituting long-term roadway monitoring for the as-yet unbuilt fence. HLC's request alleged that previously unknown private property ownership along Harper Lake Road prevented acquisition of sufficient easements to construct the fence.

The Commission conducted hearings in February 1994 to receive testimony from HLC in support of amending the fence requirement and from advocates for the retention of the fence requirement. The Desert Tortoise Preserve Committee (Preserve Committee), along with the BLM, the U.S. Fish and Wildlife Service, and the California Department of Fish and Game strongly supported the retention of the requirement for a tortoise-proof fence. The Preserve Committee based its position on the belief that the fence was the only effective means of directly mitigating the actual impacts on the desert tortoise caused by the project, and that HLC had not made a good faith effort to acquire the necessary easements.

The Commission ultimately supported that Preserve Committee's position and retained the fence requirement. As a result of the Commission hearings and subsequent negotiations with HLC, the Preserve Committee was designated as a third-party agent for the implementation of the requirement. Specifically, pursuant to the Commission's decision, HLC reached an agreement with the Preserve Committee whereby HLC would deposit $489,300 into an account to be used by the Preserve Committee to acquire the easements, construct the tortoise-proof fence, and conduct interim roadway monitoring. The agreement has recently been implemented and funded, and the Preserve Committee is now pursuing acquisition of the easements necessary to complete the fence.

LUZ BANKRUPTCY EFFECT ON MITIGATION EFFORTS: STREAMLINING THE ACQUISITION OF HABITAT TO INCREASE THE RATE OF CONSOLIDATION

Robert V. Keeran and Pete D. Westman
R V Realty, Helendale, California

Abstract. Our company has transferred tens of thousands of acres of raw land in the Mojave Desert area over the last 15 years. Our reputation for moving large parcels throughout the Desert area was instrumental in our company being chosen by the Federal Bankruptcy Court to dispose of land holdings in the Luz Development and Finance Corporation's bankruptcy Estate, (LDF). LDF was the Developer of the worlds largest Solar Electric Generating Stations (SEGS), when it filed Chapter 11 Bankruptcy in 1991. LDF had in its possession at the time of filing approximately 2,600 ha in the Kramer Corners and Harper Lake areas of California, rnost of which was in Category 1 Habitat with some additional land in critical wetlands and other multi-species Desert Habitats.

Most of the land was approved for transfer to the California State Department of Fish and Game as consideration for the operating permits to run the solar plants. The permits were given prior to the land being deeded to the State so when the bankruptcy was filed, legal title transferred to a Federal Court appointed Trustee, Sam Biggs of the accounting firm Biggs and Co., in Santa Monica, California. Much of the raw land was purchased by LDF for mitigation of SEGS construction impacts on the prime desert tortoise habitat where the plants were built. The transfer of title to a bankruptcy trustee means the State didn't receive the land even though the operation permits were given. We suggest this could have been averted by closer attention to the developing situation of the pending bankruptcy. We suggest policies for habitat acquisition be streamlined in the future, ultimately resulting in more land being acquired sooner, and conceivably averting a breakdown of the process such as the LDF bankruptcy. We offer the group a walk through of the LDF problem and suggest ways to avert the same situations in the future.

One never knows what the future will bring. The current process of attempting to acquire only the best of Zone "A" is incorrect. Lands in the new Zone "A" management areas include several different sub-habitats or strata categorized by topographical characteristics. Not all currently having the highest population. However, the Federal Register 50 CFR Part 17 dated February 8, 1994, states in issue 4, "Areas suggested for deletion because of poor habitat were re-examined in terms of value to tortoises. In some key areas, habitat currently in poor condition was retained because of its important location and high potential for contribution to recovery."

We suggest all lands that are included within the newly classified management areas, known as Zone "A" desert tortoise habitat, are valuable to the desert tortoise recovery and should be acquired aggressively. It all matters. There is reason to have all land within the area consolidated into Federal or State Government ownership for the protection of the desert tortoise and other species, and the policy should be to get as much of the land as possible while favorable laws exist.

OFF-HIGHWAY VEHICLE MANAGEMENT IN THE RAND MOUNTAIN-FREMONT VALLEY MANAGEMENT AREA

Jim Keeler
U.S. Department of the Interior, Bureau of Land Management,
Ridgecrest Resource Area, Ridgecrest, California

Abstract. The Rand Mountains-Fremont Valley Management Plan (Rand Plan), signed in August 1993, forms a management foundation for administering multiple-use activities in an area of critical habitat for the California desert tortoise (*Gopherus agassizii*).

The planning area is on Public Land, in the Bureau of Land Management (BLM) Ridgecrest Resource Area, California Desert District. It encompasses an area of 26,000 ha in eastern Kern County, in the valley and mountain areas east of the Desert Tortoise Natural Area (DTNA), and west of U.S. Highway 395.

The area is rich with resources that have been tapped for over a century. The Rand Mining District has provided large quantities of gold, silver, flagstone, and other minerals; Koehn dry lake has been harvested for salt. The area has a long history of cattle and sheep grazing; large areas were developed for agriculture, primarily hay production.

While the mining and agriculture continues, since World War II, the expanding growth in Southern California has affected the area as well, primarily by recreational activities. The Rand Fremont area has been utilized for human activities including prospecting, mining, sheep grazing, recreational rockhounding, upland game bird hunting, sightseeing, and off-highway-vehicle (OHV) use.

Some of these activities originate from the local small urban areas including Ridgecrest, California City, and Mojave areas. Utilizing freeways, more than 20 million people live within three hours of the Rand area, both from the Los Angeles, and San Bernardino-Riverside areas and from central valley locations like Bakersfield and Fresno. Motor homes, house trailers, and air conditioning have transformed the west Mojave desert into a weekend destination for thousands of recreationists.

Over the last three decades biologists became increasingly concerned about declines in tortoise populations in the area. The Desert Tortoise Natural Area (DTNA) was designated in 1973 and about 25,000 acres have now been set aside as a preserve. When BLM's California Desert Conservation Area Plan was signed in 1980, portions of the Fremont Valley and Western Rand Mountain were designated as an Area of Critical Environmental Concern (ACEC).

As more data became available to confirm the decline in tortoise population, the BLM Ridgecrest staff initiated development of a management plan for the entire area. The tortoise received final federal listing as threatened in late 1990. The majority of the planning area was closed to human activities from late 1989 until early 1991.

Although the final consultation with U. S. Fish and Wildlife Service and final draft of the Rand Plan was not signed until late 1993, many of the implementation efforts for the plan were initiated before the quarantine was lifted in November 1991. Early implementation was intended to provide some of the habitat protection offered by proposed actions in the plan. Some actions that were started and are ongoing include:

- Sheep grazing has not been permitted on public land in the management area since 1988. This management plan proposed action implements the Rangewide Biological Opinion for sheep grazing in Critical Tortoise Habitat.

- Hunting in the project area has been restricted to shotguns only during upland game season. Target shooting and "plinking" are not permitted.

- Camping has been restricted to a few designated sites in the less suitable tortoise habitat.

- Competitive OHV events are not permitted in the management area.

- Vehicle access has been restricted to a designated network of roads and trails, as required in the Desert Tortoise Recovery Plan. This constitutes almost a 90% reduction from the network of existing routes.

- Patrol of the area has been intensified, both by BLM (Law Enforcement) Rangers, and by visitor services park rangers. On intensive weekends, they have been monitoring activity and preparing compliance maps.

- OHV volunteers are performing a majority of the route signing and assisting with visitor contact.

- Eleven information kiosks have been placed in key access spots throughout the area, providing area maps, visitor handouts and other information

- A 29 km boundary fence, with 12 portals for the designated routes, is being constructed along the southern border of the management area. Over 21 km has been completed. This fence is being constructed using OHV registration funds from the OHV Commission (Green Sticker) funds with active user support.

Two additional activities are in the planning stage and will be started this year:

- A more formal use and habitat condition monitoring plan has been finalized. This will include annual aerial photographs of the area, installation of three permanent traffic counters, and the establishment of permanent repeatable monitoring transects.

- We will start to maintain designated roads and trails, and begin to reclaim unauthorized routes, later this year. We have proposed an interdisciplinary team study to establish rehab priorities and appropriate, cost effective techniques for the differing site conditions and habitat needs.

This type of OHV management has never been attempted in the California desert to this scale and with this level of intensity. The ultimate outcome has yet to be determined, but we have been pleased with the level of support and volunteer effort that the OHV enthusiast groups have provided.

On President's Day weekend (Feb. 18-20, 1995) approximately 300 OHV enthusiasts camped near the Rand-Fremont area, mostly on private land adjacent to the management area. By current standards, this is a busy weekend, accounting for an estimated 1000 visitor days. The compliance on this weekend was markedly improved from previous comparable periods.

In the Desert Tortoise (Mojave Population) Recovery Plan (U.S. Fish and Wildlife Service 1994) 2.6 million ha were designated as critical habitat for the desert tortoise. Implementation efforts for the Rand Plan can provide a model for management of human impacts, particularly OHV activities in tortoise habitat.

STATUS AND DETERMINANTS OF ENDANGERMENT IN TURTLES OF THE UNITED STATES

Jeff Lovich
National Biological Service, Palm Springs Field Station
North Palm Springs, California

Abstract. There are 54 native species of turtles, or approximately 20% of the world's total, in the United States and its offshore waters. Of these, 25 (46%) require conservation action under CITES, the Red Data Book, the Action Plan Rating of the IUCN/SSC for tortoises and freshwater turtles, or the Endangered Species Act (ESA) of the United States. Included are 21 species (39%) that are protected, or are candidates for protection, under the ESA. After considering the plight of turtles in general I was interested in identifying factors that may predispose a particular turtle species to endangerment. Variables and categories considered to be potentially useful in classifying turtles as "imperiled" or "safe" included habitat, degree of endemicity, trophic status, degree of dietary specialization, typical clutch size, male size, female size, and a measure of sexual size dimorphism. Correlation analysis, logistic regression and multivariate analysis showed habitat, clutch size and body size to be significant correlates and predictors of status, with marine, estuarine, and terrestrial species at greatest risk. The results are surprising in light of the fact that attributes such as large body size, large clutch size and occupation of vast marine ecosystems--characteristics that would seem to "protect" a species--are no hedge against endangerment. The various models developed may prove useful in identifying species at risk of future endangerment.

THE DESERT TORTOISE CONSERVATION PROGRAM AT THE NEVADA TEST SITE

Dan C. Steen and Tim A. Lindemann
EG&G Energy Measurements
Las Vegas, Nevada

Abstract. In May 1992, the U.S. Fish and Wildlife Service issued a non-jeopardy Biological Opinion and an incidental take permit to the U.S. Department of Energy (DOE) for Nevada Test Site (NTS) activities. To comply with the terms and conditions of this opinion DOE/NV established a desert tortoise conservation program.

Desert tortoise training for all NTS employees was developed as the program's foundation. Training consists of an 11min video presentation describing tortoise populations, the threatened status of this species, laws protecting the tortoise, and actions to take when sighting a tortoise. DOE developed a compliance checklist given to all trained NTS contractors. Each contractor ensures that they follow the checklist during construction activities in tortoise habitat. All trained NTS employees are required to report sightings of tortoises. Records of these sightings are used to identify sections of roads where tortoises are often seen and additional mitigation measures such as where signs are needed. A news release is also issued every spring reminding employees to watch for tortoises.

Since the inception of the DOE education program in 1992, 7,087 NTS employees have been trained; contractors have used the compliance checklist during 50 construction projects; no desert tortoises have been killed, injured, or removed from construction sites; employees have reported 155 sightings of desert tortoises on or near roads; and one tortoise has been killed along a road.

GENETICS, MORPHOLOGY AND BEHAVIOR OF THE DESERT TORTOISE IN THE BLACK MOUNTAINS, MOHAVE COUNTY, ARIZONA

Ann McLuckie
Bureau of Land Management, Kingman, Arizona

Cecil Schwalbe
National Park Service, University of Arizona, Tucson, Arizona

Trip Lamb
Department of Biology, Eastern Carolina University, Greenville, North Carolina

Bob Hall
Bureau of Land Management, Kingman Resource Area, Kingman, Arizona

Abstract. Desert tortoises (*Gopherus agassizii*) occurring east and south of the Colorado River form the "Sonoran population", a regulatory designation of the U.S. Fish and Wildlife Service, whereas tortoises west and north of the river constitute the "Mojave population". This distinction is based on significant genetic, morphometric, and ecological differences. However, many tortoises from the eastern bajada of the Black Mountains (about 40 km east of the Colorado River) exhibit Mojave tortoise behavior, inhabiting sparsely vegetated creosote bush flats and gentle slopes, in contrast to the heavily vegetated steep rocky slopes used by most Sonoran tortoises. Mitochondrial DNA analysis, morphology, and ecological data from a Black Mountain subpopulation identify the evolutionary affinities of those tortoises as Mojavean: 10 of 11 Black Mountain tortoises possessed the Mojave genotype, tortoises predominately expressed the Mojave phenotype and were clearly similar to Mojave populations in macrohabitat selection. Some ecological and behavioral attributes such as home range size and hibernaculum selection did not differ among Mojave, Sonoran, and Black Mountain tortoise populations. Several hypotheses on how the Mojave traits became established in the Black Mountain tortoise population are discussed.

A SYNOPTIC AND INDEXED BIBLIOGRAPHIC DATABASE OF CHELONIAN SCIENTIFIC LITERATURE FROM PRE-LINEAR TO CURRENT REFERENCES INCLUDING CITATIONS FOR ALL LIVING AND EXTINCT TURTLES (ORDER: TESTUDINES)

Anders G.J. Rhodin
Chelonian Research Foundation, Lunenburg, Massachusetts

Kent R. Beaman
Tierra Madre Consultants, Riverside, California

Lori A. DeConza
Yale School of Medicine, New Haven, Connecticut

Abstract. A comprehensive database of chelonian literature, encompassing references to tortoises, freshwater turtles, marine turtles, and turtle paleontology, has been established by Chelonian Research Foundation (CRF). All references are entered into a computerized searchable database, utilizing ProCite by Personal Bibliographic Software, Inc. In addition to the basic bibliographic information (author, date, title, citation), specific fields have also been created for cross-indexing of content matter, including: taxonomic (family), taxonomic (species), geographic area, subject (currently over 100 separate subject headings utilized), language, and remarks.

The bibliographic database includes all scientifically relevant turtle references from the very beginnings of natural history literature in the pre-Linnaean era up through the present. The current database stands at approximately 25,000 references. The database is being continuously updated as new literature appears and as older overlooked references are recorded and entered. It currently contains over 1200 references to *Gopherus* and over 5300 references to Testudinidae. Plans for publication include hard-copy bound volumes of the alphabetically-sorted basic bibliographic data (author, date, title, citation) and a separate indexed listing, with available disks containing the searchable database with full bibliographic data including all cross-indexed content fields. The data base will hopefully be published during 1995, but is already available for literature searches on behalf of interested researchers, who may contact CRF for assistance.