POPULATION AND HABITAT VIABILITY ASSESSMENT
for the
DESERT BIGHORN SHEEP OF NEW MEXICO

(Ovis canadensis)

Sunrise Springs
Santa Fe, New Mexico
27-30 July 1999

Final Report

November 1999

Sponsored By:
The Turner Endangered Species Fund
New Mexico Department of Game and Fish

In Collaboration With:
Conservation Breeding Specialist Group (SSC/IUCN)

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A contribution of the IUCN/SSC Conservation Breeding Specialist Group in collaboration with the Turner Endangered Species Fund and the New Mexico Department of Game and Fish.

Fisher, A, E. Rominger, P. Miller and O. Byers. 1999. *Population and Habitat Viability Assessment Workshop for the Desert Bighorn Sheep of New Mexico (*Ovis canadensis*): Final Report*. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Additional copies of *Population and Habitat Viability Assessment Workshop for the Desert Bighorn Sheep of New Mexico (*Ovis canadensis*): Final Report* can be ordered through the IUCN/SSC Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124.

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Section 1
Executive Summary

Desert Bighorn Sheep
Population and Habitat Viability Assessment
Executive Summary

Introduction

Historically, desert bighorn *(Ovis canadensis mexicana)* probably occurred in most of the arid mountain ranges in southern and central New Mexico. By the early 1900's, most populations were extinct due to indiscriminate hunting and competition and diseases introduced by domestic livestock. By 1955, only 2 populations remained. In 1980, desert bighorn were classified as state endangered in New Mexico under the state's Wildlife Conservation Act. The captive Red Rock herd was exempted from the listing to facilitate management activities and the Peloncillo Mountain population was delisted in 1988.

In 1989, 130 bighorn were estimated within 4 free-ranging populations. Between 1989 and 1999, 130 bighorn were removed from Red Rock to establish new herds and supplement existing herds. By 1999, only 220 bighorn were estimated within 7 populations with another 100 bighorn in Red Rock. Clearly, most of the populations were not self-sustaining and partly dependent upon Red Rock supplementation. In *New Mexico's Long-range Plan for Desert Bighorn Sheep (Fisher 1995),* desert bighorn were considered vulnerable to extinction because all populations numbered less than 100 individuals and only 1 metapopulation occurred in the state. Competing public interests and increasing human pressure in desert environments were identified as the most important threats. These problems remain to date.

Over the last few years, new problems arose: recruitment of females at Red Rock dropped dramatically as lamb crops became heavily skewed towards males, and mortality from mountain lion predation increased significantly in most of the free-ranging populations (Logan et al., 1996; Evans, 1986).

Initiation of the PHVA Process for Desert Bighorn Sheep

Turner Endangered Species Fund recognized the significance of the problems facing desert bighorn in New Mexico and generously offered to sponsor a PHVA Workshop to assist the recovery of New Mexico's desert bighorn sheep. In February 1999, a planning meeting between the New Mexico Department of Game and Fish (NMGF) and the Conservation Breeding Specialist Group (CBSG) of the IUCN-World Conservation Union's Species Survival Commission was held in Santa Fe, New Mexico. In May 1999, NMGF mailed invitations to 114 people with interest and expertise in bighorn sheep, lion predation, genetics and landowner relations.

The PHVA Workshop for Desert Bighorn Sheep of New Mexico, a collaborative endeavor between the NMGF and CBSG, was held from 27 -30 July 1999 at Sunrise Springs, Santa Fe.

Sunrise Springs was chosen for its attractiveness and isolation, which encouraged productivity. The 30 participants came from 7 western states and the Republic of Mexico. The diverse group included biologists, researchers and faculty from 15 state and federal agencies, private conservation groups, and universities. A large number of private landowners in bighorn country were invited (see section 2), but were unable to attend the PHVA due to ranching obligations. Representatives from sportsman and livestock groups were unable to attend for similar reasons. This was unfortunate because these stakeholders have been actively involved in the desert bighorn program through their involvement in the Bighorn Advisory Boards, which meet regularly to review program objectives and achievements.

The meeting was opened with welcoming comments by Dr. Ulysses Seal, Chair of CBSG and workshop facilitator, and Amy Fisher, Assistant Chief, Conservation Services Division, NMGF, who coordinated arrangements for the workshop. Dr. Eric Rominger, Bighorn Sheep Contractor for NMGF, presented a background report that summarized the history and current status of desert bighorn in the state (see appendix II).

The PHVA Process

Effective conservation action is best built upon critical examination and use of available biological information, but also very much depends upon the actions of humans living within the range of the threatened species. Motivation for organising and participating in a PHVA comes from fear of loss as well as a hope for the recovery of a particular species.

At the beginning of each PHVA workshop, there is agreement among the participants that the general desired outcome is to prevent the extinction of the species and to maintain a viable population(s). The workshop process takes an in-depth look at the species' life history, population history, status, and dynamics, and assesses the threats putting the species at risk.

One crucial by-product of a PHVA workshop is that an enormous amount of information can be gathered and considered that, to date, has not been published. This information can be from many sources; the contributions of <u>all</u> people with a stake in the future of the species are considered. Information contributed by farmers, ranchers, game wardens, scientists, field biologists, and zoo managers all carry equal importance.

To obtain the entire picture concerning a species, all the information that can be gathered is discussed by the workshop participants with the aim of first reaching agreement on the state of current information. These data then are incorporated into a computer simulation model to determine: (1) risk of extinction under current conditions; (2) those factors that make the species vulnerable to extinction; and (3) which factors, if changed or manipulated, may have the greatest effect on preventing extinction. In essence, these computer-modelling activities provide a neutral way to examine the current situation and what needs to be changed to prevent extinction.

Complimentary to the modelling process is a communication process, or deliberation, that takes place during a PHVA. Workshop participants work together to identify the key issues affecting the conservation of the species. During the PHVA process, participants work in small groups to discuss key identified issues. Each working group produces a report on their topic, which is included in the PHVA document resulting from the meeting. A successful PHVA workshop depends on determining an outcome where all participants, coming to the workshop with different interests and needs, "win" in developing a management strategy for the species in question. Local solutions take priority. Workshop report recommendations are developed by, and are the property of, the local participants.

At the beginning of the workshop, the participants worked together in plenary to identify the major issues and concerns affecting the conservation of Desert Bighorn Sheep. These identified issues centred around three main topics, which then became the focus of the working groups: Management; Threats; and Modelling/Life History.

Each working group was asked to:

- Examine the list of problems and issues affecting the conservation of the species as they fell out under each working group topic, and expand upon that list, if needed.
- Identify and amplify the most important issues.
- Developed recommendations to address the key issues.
- Specify the action steps necessary to implement each of the recommendations
- Identify the responsible party, timeline and resource needs associated with implementation of these actions.

Each group presented the results of their work in daily plenary sessions to make sure that everyone had an opportunity to contribute to the work of the other groups and to assure that issues were carefully reviewed and discussed by all workshop participants. The recommendations coming from the workshop were accepted by all participants, thus representing a consensus. Working group reports can be found in sections 3-5 of this document.

Working Group Summaries

Life History and Modeling

- Under current conditions, both the component populations and the aggregate metapopulations, with the exception of a proposed reintroduction into the San Andres mountains, show significant risks of extinction over a 100-year timeframe. This is most likely due to significant levels of lion-caused mortality.

- The addition of as little as 5% mortality among all age/sex classes to the “baseline” levels drives most populations towards relatively rapid extinction.

- If supplementation of existing (or proposed) populations is to be effective at expanding the total numbers of individuals in each metapopulation unit, mortality must be reduced. If this cannot occur, supplementation must be essentially continuous and substantial if long-term persistence is to be realized.

- It appears from simulations that a captive population similar to that at Red Rock may not be viable in the long-term if the highly male-biased sex ratio among lambs persists.

Threats

The Threats Working Group identified 6 major categories of concern related to their working group topic (in order of priority): predation, disease, genetics and demographics, science issues, competition of exotics and livestock (non-disease issues) and environmental issues. Each of these categories was discussed and the following goals were identified to address the concerns. Specific action steps were outlined for each goal (see section 4).

Predation

1. Manage predators/prey interactions based on science by obtaining reliable knowledge of the effectiveness of predator control methods to enhance bighorn sheep populations.
2. Determine predator/prey dynamics in multiple prey systems.
3. Develop public understanding and support for NMDGF management of bighorn and predators on bighorn ranges.

Disease

1. Evaluate options that minimize scabies as a management issue in the San Andres Mountains.
2. Minimize fitness implications of presence of bluetongue.
3. Gather additional scientific information to determine whether Elaeophora is an important pathogen.
4. Minimize potential interaction between domestic sheep and cattle and bighorn sheep.
5. Identify and focus research efforts on diseases that have negative population impacts.
6. Manage translocations, supplementations, and movement corridors to minimize disease impacts.
7. Ensure availability of source stock by minimizing consequences of disease in captive and free-ranging populations.

Genetics and Demographics

1. Conserve and enhance genetic diversity/variation in desert bighorn.
2. Acknowledge habitat limitations on demographics.

Science issues

1. Identify important problems and conduct appropriate research to determine level of impact.
2. Collaborate with other desert bighorn states in scientific research projects.
3. Ensure good communication between scientific community and managers.

Competition of exotics and livestock (non-disease issues)

Evaluate the potential benefits to bighorn populations of removing all exotic (feral and non-feral) ungulates from bighorn ranges in New Mexico.

Environmental issues

Focus on the desired ecological state to manage for and use models to predict change over time.

Management
The Management Working Group identified 4 categories of concern to bighorn sheep managers: population issues, habitat issues, public issues and broad issues. Within these prioritized categories, a series of issues were discussed and general goals were derived for each. The working group report (see section 5) contains the detailed steps for implementation of these goals.

Population Monitoring and Measurement

1. For each population, annually measure the number of sheep, population trends, age and sex structure, recruitment, and mortality (with confidence interval).
2. Monitor inter-mountain movements of bighorn sheep within metapopulations.

Management of captive populations; Red Rock production inadequate

1. Increase production of captive bighorn sheep to meet management goals established here.
2. Maximize post-release success of sheep from Red Rock or other captive facilities.

Release/Reintroduction/Augmentation strategies and post-release strategies are uncertain for Bighorn Sheep in New Mexico.

1. Design transplants for optimum production.
2. Determine reintroduction versus augmentation balance.

Identification of sources of mortality

Determine, or estimate, causes of death for each individual mortality in all age classes for each metapopulation (or population).

Habitat loss and protection, minimizing and avoiding fragmentation

Allow no net loss of bighorn sheep habitat.

Habitat management

Optimize BHS habitat.

Habitat evaluation of all potential sites to maximize transplant success

Evaluate habitat and corridors of all potential sites to maximize transplant success.

Re-evaluate and prioritize existing sites and potential sites for augmentation and reintroduction.

Evaluate success of reintroductions to date and evaluate prior models used to evaluate sites.

Management response to periodic drought

Ensure adequate water source for BHS.

Funding for Management

Ensure adequate funding for all agencies to accomplish goals of the management plans.

Human Disturbance

Minimize human disturbance to BHS populations.

Determination of public opinion (support/acceptance/opposition) to management activities

Determine level of public support/acceptance/opposition to management activities for each issue.

Promote and Maintain Support for BHS management activities

1. Develop and maintain effective mechanisms for inter-agency communication and support.
2. Garner broad public support for BHS program.

Public support for predator control

1. Develop an effective decision tree to determine when predator control is appropriate.
2. Properly identify and involve the interests of all stakeholders and various publics.

Poaching

Reduce the unlawful take of any bighorn sheep.

Lack of Experimental Management

Goal: Incorporate experimental design into management plans to provide reliable data for effective, adaptive management.

Need for Program Manager (FTE) to administer BHS program

Dedicate a person to administer program.

Workshop participants agreed that, given the limits of the habitat's small patch sizes and fragmented condition and its consequent impact on demographic and genetic viability, maintenance of bighorn sheep populations in NM will require ongoing proactive management in the form of continuing augmentations and chronic predator control.

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Section 2
Workshop Invitation and Invitation List

STATE OF NEW MEXICO
DEPARTMENT OF GAME & FISH

Villagra Building, P.O. Box 25112, Santa Fe, NM 87504

http://www.gmfsh.state.nm.us
For general information: 1-800-862-9310

25 May 1999

Dear Bighorn Sheep Colleague:

We invite you to participate in a Population and Habitat Viability Assessment (PHVA) workshop for desert bighorn sheep (*Ovis canadensis*) sponsored by the Turner Endangered Species Fund and the New Mexico Department of Game and Fish. The focus would be on New Mexico's populations which currently number about 300 bighorn. All but one population is on the state endangered list. The workshop will be held 27-30 July at Sunrise Springs, near Santa Fe, New Mexico.

The goal of the PHVA is to assist the recovery of New Mexico's desert bighorn sheep. Agency representatives, researchers, sportsmen, landowners and other interested parties are invited to collaboratively analyze the available information (much of which will be gathered before the workshop) and develop practical conservation strategies. The objectives of the workshop are to

- Identify key issues affecting the conservation of the species.
- Evaluate the interactions of genetic, demographic, and environmental factors on the dynamics and extinction risks of New Mexico's populations with VORTEX, a simulation model.
- Draft a PHVA report to be published following the workshop.
- Increase collaboration and consensus among interested parties.
- Distribute the PHVA tools to members of the conservation community from other states.

Dr. Ulysses Seal and his colleagues at the Conservation Breeding Specialist Group (CBSG) will facilitate the PHVA. CBSG is an internationally recognized organization that has conducted more than 150 PHVAs worldwide. Species investigated with PHVAs include the black-footed ferret, Florida panther, Peary Caribou, and mountain gorilla.

This will be the CBSG's first workshop on bighorn sheep--a unique opportunity to better understand the species in New Mexico and learn tools applicable to bighorn management and conservation in other states. More information on the workshop follows. **The deadline to register is 12 July 1999.** We hope you can attend.

Best Regards,

Amy Fisher
Assistant Chief, Conservation Services Division

505-827-9913 (phone); 505-827-7801 (fax)

DESERT BIGHORN PHVA WORKSHOP INVITEES

Last Name	First Name	Organization Name	Address	City	State	Zip
		Hurt Cattle Company	PO Box 189	Deming	NM	
		New Mexico Cattle Growers	PO Box 7517	Albuquerque	NM	
		New Mexico Wool Growers, Inc.	2901 Candeleria NW	Albuquerque	NM	
Allen	Jack	San Diego Wild Animal Park	15500 San Pasqual Valley	Escondido	CA	
Antonio	John	Bureau of Indian Affairs-Nat. Resources	PO Box 26567	Albuquerque	NM	
Arthur	Steve	Alaska Dept. of Fish and Game	1300 College Road	Fairbanks	AK	99701
Aster	Rick	NM Wilderness Coalition	801 Leroy Place,NMTU	Socorro	NM	
Bailey	Jim	Ret. New Mexico Dept. Game and Fish	30 Altura Road	Santa Fe	NM	87505 -
Ballard	Warren	Texas Tech University	Texas Tech Univ. Box 4125	Lubbock	TX	79409
Bangs	Peter	Univ. of Arizona	325 BSE/SRNR	Tucson	AZ	85721
Barnitz	Jack	Bureau of Land Management	1800 Marquess St.	Las Cruces	NM	
Benzon	Ted	South Dakota Dept. of G, F, and P	3305 W. South Street	Rapid City	SD	57702
Berger	Joel	Wildlife Conservation Society	PO Box 340	Moose	WY	
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Boyce	Walter	Univ. of California, Davis	Dept. VN:PMI, Univ. of CA	Davis	CA	95616
Brown	Ben	Animas Found/Malapais Borderlands	HC 65 Box 179-B	Animas	NM	88020 -
Byers	Onnie	CBSG	12101 Johnny Cake Ridge	Apple Valley	MN	55124
Caccimise	Don	Dept. of Fishery & Wildlife Sciences	PO Box 3003, Dept. 4901	Las Cruces	NM	
Carey	Jean	Government of Yukon	PO Box 2703	Whitehorse	YT	Y1A42
Caudill	Larry	Wildlife Legislative Council	4915 Watercress NE	Albuquerque	NM	
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Cowan	Cordy		HC 65 Box 180	Animas	NM	
Cowan	Mrs.		HC 65 Box 185	Animas	NM	
Cummings	Pat	Nevada Division of Wildlife	4747 W. Vegas Drive	Las Vegas	NV	89108
Darnell	Billy		HC 65 Box 160A	Animas	NM	
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Dragoo	Jerry	University of New Mexico	Museum of Southwestern Bio.	Albuquerque	NM	
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Dunn	Bill	New Mexico Dept. Game and Fish	PO Box 25112	Santa Fe	NM	87504
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Ernes	Holly	Wildlife Health Center	School Vet Med, One Shields Ave	Davis	CA	
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Festa-Bianchet	Marco	Departement de biologie	Universite de Sherbrooke	Sherbrook	QU	
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Gault	Meira		HC 65 Box 181	Animas	NM	
Gilchrist	Duncan	Outdoor Expeditions and Books	405 Dutch Hill Road	Hamilton	MT	
Glaser	Dawn	CBSG	12101 Johnny Cake Ridge	Apple Valley	MN	55124
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Hagen	Ted		PO Box 22	Rodeo	NM	
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Heft	David	Bureau of Land Management	198 Neel Ave	Socorro	NM	87801
Holdermann	Dave	US Army WSMR	STEWS-EL-N	WSMR	NM	
Huddleston-	Rachell	New Mexico State University	PO Box 392	Gila	NM	88038
Humphreys	Doug	Texas Parks and Wildlife	1600 W. Hwy. 90	Alpine	TX	79830
Hunter	Dave	Turner Endangered Species Fund	PO Box 190	Gallatin Gateway	MT	59730
Hurley	Kevin	Wyoming Game and Fish Dept.	356 Nostrum Road	Thermopolis	WY	82443
Jenks	Bob	State Land Office	310 Old Santa Fe Trail	Santa Fe	NM	
Jorgenson	Mark	Anza-Borrego State Park		Borrego Springs	CA	
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Klumps	Levi/Mis		PO Box 111	Animas	NM	
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Lee	Ray	Arizona Game and Fish Dept.	2221 W. Greenway	Phoenix	AZ	85023
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Miller	Phil	CBSG	12101 Johnny Cake Ridge Rd	Apple Valley	MN	55124 -
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Verhelst	Dave	Turner Endangered Species Fund	PO Box 190	Gallatin Gateway	MT	59730
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Winkler	Mary/Ri		PO Box 113	Rodeo	NM	
Woolever	Melanie	USDA Forest Service-Region 2	PO Box 25127	Lakewood	CO	
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Section 3
Life History and Modeling Working Group Report

Life History and Modeling Working Group Report

Introduction

The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in conserving the desert bighorn sheep (*Ovis canadensis mexicana*) in New Mexico. *VORTEX*, a simulation software package written for population viability analysis, was used in this workshop as a tool to study the interaction of a number of desert bighorn life history and population parameters treated stochastically, to explore which demographic parameters may be the most sensitive to alternative management practices, and to test the effects of a suite of possible bighorn management scenarios.

The *VORTEX* package is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. *VORTEX* models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by stepping through the series of events that describe the typical life cycles of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters used as input to the model and because of the random processes involved in nature. Interpretation of the output depends upon our knowledge of the biology of the desert bighorn, the environmental conditions affecting the species, and possible future changes in these conditions. For example, model projections might be different if carrying capacity within habitats were increased by increasing the amount of good bighorn habitat through manipulation (fire and mechanical).

For a more detailed explanation of *VORTEX* and its use in population viability analysis, refer to Appendix I of this working group report as well as Miller and Lacy (1999).

Input Parameters for Simulations

In all of the simulation models that follow, we have focused our attention on four primary metapopulation units and their constituent populations (see Figure 1):

- San Andres, composed of the San Andres – North and San Andres – South populations;
- Bootheel, composed of the Peloncillo, Hatchet, Animas, and Alamo Hueco populations;
- Ladron, composed of the Ladron, Magdalena, San Mateo, and Black Range populations;
- Fra Cristobal, composed of the Fra Cristobal and Caballos populations.

A summary of their demographic characteristics as discussed in this section can be found in Table 1. Furthermore, migration rates for individuals between populations within a given metapopulation are detailed in Table 2. These migration rates describe the probability that a given individual will move from population A to population B from year x to year *x*+1 (in this context, the term "migration" could be viewed as synonymous with "dispersal"). We concern ourselves here with only female migration. Density-dependent movement and additional mortality incurred during movement are not considered.

Inbreeding Depression: While the early work of Sausman (1984) suggested that reduced lamb survival may be a significant consequence of inbreeding in bighorn sheep, recent analyses on much larger datasets spanning more than a decade (Hedrick et al. unpublished) suggest otherwise. Although we included this parameter in our sensitivity analysis, using the default parameters supplied by *VORTEX*, we excluded it from our larger set of risk assessment models with one exception: the metapopulation supplementation models (see below).

Age of first reproduction: *VORTEX* precisely defines breeding as the time at which offspring are born, not simply the age of sexual maturity or breeding. In addition, the program uses the mean (or median) age rather than the earliest recorded age of offspring production.

Data from New Mexico bighorn sheep populations suggest that most females do not produce lambs until 3 years of age (NMDGF Records). However, lamb production by 2-year old ewes has been documented in the Fra Cristobal Mountains (Turner Endangered Species Fund records) as well as in other desert bighorn populations (Bleich 1986; Morgart and Krausman 1983; E. Rubin and W. Boyce unpubl. data; Ostermann et al. in prep.). To investigate the sensitivity of desert bighorn populations to measure uncertainty in this parameter, we developed a set of models in which the age of first reproduction for females was alternatively set at 2 and 3 years.

Although rams may be physiologically able to breed at yearling age, the social structure of bighorn sheep usually prevents this from occurring. No data regarding the age at first reproduction for rams were available for New Mexico populations; therefore, we estimated the age at first reproduction for males (3 years) based on behavioral observations of free-ranging sheep populations.

Age of reproductive senescence: *VORTEX* assumes that animals can breed (at the normal rate) throughout their adult life. Records from the US Fish & Wildlife Service indicate that a 16-year-old ewe produced a lamb in the San Andres Mountains, and data from other desert bighorn populations indicates that ewes 16-years of age can produce lambs (E. Rubin and W. Boyce

Figure 1. Occupied and potential desert bighorn sheep range in New Mexico, showing the population components that comprise the metapopulation units analyzed using population simulation modeling tools.

unpubl. data; Bighorn Institute unpubl. data). We therefore set the age of reproductive senescence for females at 16 years, recognizing that few females would survive to this age.

Male breeding pool: No data were available to provide estimates for this parameter. Although older (larger) rams likely have the highest breeding success, young rams also do breed (Hogg 1984). Based on behavioral observations of free-ranging rams, we estimated that 50% of all rams $\geq$ 3 years of age sired offspring in any given year. Breeding success for a particular ram in one year did not imply breeding success in future years.

Sex ratio at birth: Data from desert bighorn sheep populations indicate no evidence for birth sex ratios other than 50/50 (Turner and Hansen, 1980). We therefore set this parameter at parity in all simulations.

Offspring production: Because desert bighorn ewes typically produce one lamb per year, with twinning being exceedingly rare (Turner and Hansen, 1980; Valdez and Krausman, 1997 – Chapter 1 in new book), we set this parameter at 1 in all models.

Data from desert bighorn sheep in New Mexico (New Mexico Department of Game and Fish, unpubl. data, 1997) suggest that the annual production of lambs is high; therefore, we estimated that 90% of ewes of breeding age produce lambs in a given year. Annual variation in female reproduction is modeled in *VORTEX* by entering a standard deviation (SD) for the proportion of females that reproduce in a give year (SD(Probability of a litter)) = 5%). *VORTEX* then determines the proportion of females breeding each year of the simulation by sampling from a binomial distribution with a specified mean (e.g. 90%) and standard deviation (e.g. 5%).

Density-dependent effects: There is no evidence that reproduction (lamb production) is density dependent. Other parameters – such as emigration rates and rates of additional mortality through predation – may exhibit some form of density dependence. However, difficulty in quantifying these effects and the complexity inherent in simulating them precluded us from tackling these issues at present.

Mortality rates: Age- and sex- specific mortality rates were modified from data on the captive population at Red Rock and free-ranging populations (New Mexico Department of Game and Fish 1997; NMGF files, Turner ESF). When data were not available for a specific population, mortality rates and standard deviations were estimated from data for similar ranges (Table 1). Lamb mortality rates were estimated from fall lamb:ewe ratios (NMGF files), assuming an initial lamb:ewe ratio of 90:100 (see discussion of offspring production above). For example, if a given fall ratio was calculated as 25:100, this would indicate that 65 lambs died before the time of aerial census, giving a mortality rate of 65/90 = 0.72. We estimated mortality rates for all animals 2 years of age and older using data from radio-collared bighorn in the respective area (NMGF files), or a similar area (Table 1). Mortality rates for yearlings were estimated by modifying mortality rates for 2-3 year-old animals. For female yearlings, we doubled the mortality rate for 2-3 year-olds, and for males we increased the 2-3 year-old mortality rate by 40-100%.

Standard deviations for mortality rates were taken from actual data, which were calculated by estimating the expected range observed in a small sample of *n* values taken from an expected normal distribution (Sokal 1981, see Box E in Miller and Lacy 1999).

Impact of additional predation mortality: Desert bighorn in New Mexico appear to be subject to levels of mortality significantly higher than found in other bighorn sheep populations (McCarty and Miller). The proximate cause of most of this mortality in mountain lions. In order to evaluate the quantitative impact of additional lion-caused mortality on the state's desert bighorn populations, we developed a series of models with the following mortality characteristics:

- No additional mortality: This mortality schedule is intended to reflect bighorn sheep populations that are not subjected to known mountain lion predation. Adult mortality estimates were derived primarily from McCarty and Miller (1999), while mortality rates of yearlings and subadults were estimated by desert bighorn sheep biologists in attendance at the workshop. Lamb mortality in this case was considered to be compensatory; in other words, other factors such as coyote predation would act to keep survival of this youngest age class relatively low.

	% Mortality	
Age Class	Female	Male
0 – 1	0.8(current rate)	0.8(current rate)
1 – 2	20.0 (8.0)	25.0 (8.0)
2 - 3	15.0 (8.0)	15.0 (10.0)
Adult	8.0 (5.0)	13.0 (5.0)

- +5% additional mortality: Low levels of additional (mountain lion) predation were included in these models by adding 5% mortality to each of the age classes listed in the above table.
- +10% additional mortality: Moderate levels of additional (mountain lion) predation were included in these models by adding 10% mortality to each of the age classes listed in the above table.
- +20% additional mortality: High levels of additional (mountain lion) predation were included in these models by adding 20% mortality to each of the age classes listed in the above table.

Catastrophes: Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. The primary catastrophe included in these desert bighorn simulations was a severe 2-year drought which occurred, on average, once every 30-50 years. During this type of drought catastrophe, recruitment of lambs does not occur for 2 consecutive years. We were able to use the new functionality in *VORTEX* (see Miller and Lacy 1999 for a complete description of this feature) to simulate this type of event as the elimination of breeding during this 2-year timespan:

```
% adult females breeding = 90.00-(90*(SRAND((Y/2)+(R*100))<0.04))
```

For each year of the simulation, a seeded random number is drawn to determine if a catastrophe occurs in that year. As described in the equation above, the probability of a catastrophe in any one year is 4% so that the probability of such an event occurring two years in a row is 2%. When

it occurs, the percentage of adult females that successfully produce a lamb drops from 90% to zero.
To test the sensitivity of our reference population to uncertainty in both the frequency and severity of this drought catastrophe, a series of models were developed in which the frequency was increased from 2% to 10%. In addition, the severity of the event was reduced from a 100% reduction in the proportion of adult females breeding (see above) to reductions of 80% or 60%. In all of these severity sensitivity models, the annual probability of the event remained constant at 2%.

Initial population size: Initial population sizes used for these simulations were estimated from helicopter surveys (NMGF files 1999), or based on expected future translocation sizes for currently empty habitat. See Table 1 for detailed site-specific information.
(Note that the San Andres population size is taken to be 50 individuals – significantly different from the actual current population size of just one radio-collared ewe. The group was interested in looking at the viability of this metapopulation following successful re-establishment.)

Carrying capacity: The carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed across all age classes in order to return the population size to the value set for K. We estimated K from values reported in *New Mexico's Long-range Plan for Desert Bighorn Sheep Management 1995-2002* (Fisher, 1995).

Supplementation: In order to evaluate the effectiveness of periodic augmentation of desert bighorn metapopulations with animals from external sources (e.g., Red Rock, other U.S. populations, etc.), a series of models was constructed that included one of two alternative seeding and supplementation events:

- Strategy A – Each population is seeded with 48 sheep (24♀♀, 24♂♂) as early as possible in the simulation under constraints of animal availability, with a 2-year interval between seeding events. Using the Bootheel metapopulation as an example, we would seed the Peloncillo population at simulation year 1, the Hatchet at year 3, the Animas at year 5, and the Alamo Hueco at year 7. This was intended to simulate the difficulties of producing the necessary number of animals from a single facility such as Red Rock. Following the initial seedings, each population would then be supplemented with 24 animals each (12 ♀♀, 12 ♂♂) at years x + 5 and x + 10. Because the number of animals added to a population across years must remain constant in *VORTEX*, this schedule equates to adding 32 animals during each specified year.
- Strategy B – Identical to Strategy A, except only 12 animals are added during each specified year.

Modeling the Red Rock captive population: The viability of the Red Rock captive population is a major issue within the larger context of desert bighorn conservation in New Mexico. This stems largely from the recent observations of highly skewed sex ratios at birth among lambs at the facility, with as many as 70-80% of the lambs being male. To evaluate the demographic impact of this skewed ratio, we developed a set of models designed to simulate this population under the following conditions:

- *Sex ratio at birth*

The baseline value was set at 50% males, with subsequent models setting this parameter to 60%, 70%, 80%, 85%, and 90%.

- *Mortality*

	% Mortality	
Age Class	Females	Males
0 – 1	10.0 (3.0)	10.0 (3.0)
1 – 2	5.0 (3.0)	5.0 (3.0)
2 - 3	5.0 (8.0)	5.0 (8.0)
Adult	5.0 (3.0)	5.0 (3.0)

- *Catastrophe*
  A disease event—namely, an outbreak of bluetongue virus—was included in all Red Rock models. The event was estimated to occur about once every 9 years (annual probability of occurrence = 11.1%) with a 20% reduction in survivorship across all age classes. This severity estimate is based on direct observation of recent epidemics within the Red Rock herd (Singer et al. 1998).

- *Initial population size and carrying capacity*
  At this point in time, a new Red Rock breeding population may be founded by about 35 adult females, 20 adult males, and the previous year's lamb crop (taken to be about 20 individuals). For our purposes here, we have defined "adult" as 6 years old in order to make the assignment of initial population structure easier (this will have little impact on the long-term population demographics). Additionally, because of the existing skewed sex ratio among lambs, we have assumed that 20 lambs will be composed of 5 females and 15 males. Consequently, we did not initialize the starting population according to a stable age distribution but specified the age/sex distribution as:
  1 year of age – 5 females, 15 males
  6 years of age (adult) – 35 females, 20 males
  Total population size – 75 animals
  The carrying capacity of the Red Rock facility was set at K = 100 animals.

All other parameters are identical to those baseline values described above.

Iterations and years of projection: All scenarios were simulated 500 times, with the exception of the demographic sensitivity analysis models (see page 33) in which 100 iterations were used, with population projections extending for 100 years. Output results were summarized at 10-year intervals for use in the tables and figures that follow. All simulations were conducted using VORTEX Version 8.21 (Miller and Lacy 1999).

Table 1. Population-specific *VORTEX* baseline input values. See text for sources of information. "*" indicates a value identical to San Andres Mountains.

Parameter	SANA_N	SANA_S	PEL	HAT	ANI	ALA	LAD	MAG	SAN-M	BLA	FRA	CAB
No. of catastrophes	1	*	*	*	*	*	*	*	*	*	*	*
Breeding system	Polygynous	*	*	*	*	*	*	*	*	*	*	*
Age at first breeding, ♀	3	*	*	*	*	*	*	*	*	*	*	*
Age at first breeding, ♂	3	*	*	*	*	*	*	*	*	*	*	*
Maximum breeding age	16	*	*	*	*	*	*	*	*	*	*	*
Sex ratio at birth	1:1	*	*	*	*	*	*	*	*	*	*	*
No. of young per year	1	*	*	*	*	*	*	*	*	*	*	*
Reproduction density dependent?	No	*	*	*	*	*	*	*	*	*	*	*
% ♀♀ breeding per year	90	*	*	*	*	*	*	*	*	*	*	*
SD in % breeding annually	5	*	*	*	*	*	*	*	*	*	*	*
% Mortality (SD)												
♀ year 0-1	45 (17)	*	72 (17)	57 (14)	72 (17)	57 (14)	69 (17)	69 (17)	69 (17)	69 (17)	56 (30)	69 (17)
♀ 1-2	20 (10)	*	26 (20)	26 (20)	26 (20)	26 (20)	50 (20)	50 (20)	50 (20)	50 (20)	15 (15)	50 (20)
♀ 2-3	10 (10)	*	13 (20)	13 (20)	13 (20)	13 (20)	26 (20)	26 (20)	26 (20)	26 (20)	7 (5)	26 (20)
♀ 3+	10 (10)	*	11 (15)	11 (15)	11 (15)	11 (15)	27 (20)	27 (20)	27 (20)	27 (20)	8 (5)	27 (20)
♂ year 0-1	45 (17)	*	72 (17)	57 (14)	72 (17)	57 (14)	69 (17)	69 (17)	69 (17)	69 (17)	56 (30)	69 (17)
♂ 1-2	35 (15)	*	30 (20)	30 (20)	30 (20)	30 (20)	50 (20)	50 (20)	50 (20)	50 (20)	40 (30)	50 (20)
♂ 2-3	25 (15)	*	21 (20)	21 (20)	21 (20)	21 (20)	11 (15)	11 (15)	11 (15)	11 (15)	30 (20)	30 (20)
♂ 3+	25 (15)	*	21 (20)	21 (20)	21 (20)	21 (20)	11 (15)	11 (15)	11 (15)	11 (15)	27 (20)	27 (20)
Freq. of catastrophe (%)	2	*	3.33	3.33	3.33	3.33	*	*	*	*	*	*
Duration of cat. (yrs)	2	*	*	*	*	*	*	*	*	*	*	*
Impact on reproduction	0.0	*	*	*	*	*	*	*	*	*	*	*
Impact on survival	1.0	*	*	*	*	*	*	*	*	*	*	*
% ♂♂ in breeding pool	50	*	*	*	*	*	*	*	*	*	*	*
Initial pop. size	25	25	120	60	10	10	35	0	0	0	46	0
Carrying capacity (K)	150	350	225	125	100	50	50	50	50	50	100	50

SANA_N, San Andres North; SANA_S, San Andreas South; PEL, Peloncillo; HAT, Hatchet; ANI, Animas; ALA, Alamo Hueco; LAD, Ladron; MAG, Magdalena; SAN-M, San Mateo; BLA, Black Range; FRA, Fra Cristobal; CAB, Caballo

Table 2. Probability of migration between pairs of populations within the 4 designated metapopulations comprising this risk analysis (rates are estimates derived from workshop participants). Values indicate the probability that a given female will migrate from population A to population B. Migration is assumed to be equal in both directions.

A. San Andres Metapopulation

	SANA_N	SANA_S
SANA_N	—	0.1
SANA_S	0.1	—

B. Bootheel Metapopulation

	PEL	HAT	ANI	ALA
PEL	—	—	0.01	—
HAT	—	—	0.01	0.01
ANI	0.01	0.01	—	0.01
ALA	—	0.01	0.01	—

C. Ladron Metapopulation

	LAD	MAG	SAN-M	BLA
LAD	—	0.005	—	—
MAG	0.005	—	0.005	—
SAN-M	—	0.005	—	0.005
BLA	—	—	0.005	—

D. Fra Cristobal Metapopulation

	FRA	CAB
FRA	—	0.02
CAB	0.02	—

Results from Simulation Models

Output Table Information

The tables that follow present the numerical results from the nearly 250 different models developed during this workshop. For detailed information on the characteristics of the input data used for each set of models, reference must be made to Tables 1 and 2 as well as the verbal descriptions of the input found in the preceding pages. The results of the models are described in terms of the following:

- r_s(SD) Mean (standard deviation) stochastic growth rate, calculated directly from the observed annual population sizes across the 500 simulations;
- P(E) The probability of population extinction, determined by the proportion of 500 simulated populations within a given model that become extinct during the model's 100-year time frame.
- N_{100} (SD) Mean (standard deviation) population size across those simulated population which are not extinct at 100 years;
- H_{100} Expected heterozygosity (gene diversity) in the simulated populations after 100 years;
- T(E) The median time to extinction for those populations becoming extinct during the simulation. For statistical rigor, the median time is included in only those models for which P(E) exceeded 0.5.

Demographic Sensitivity Analysis

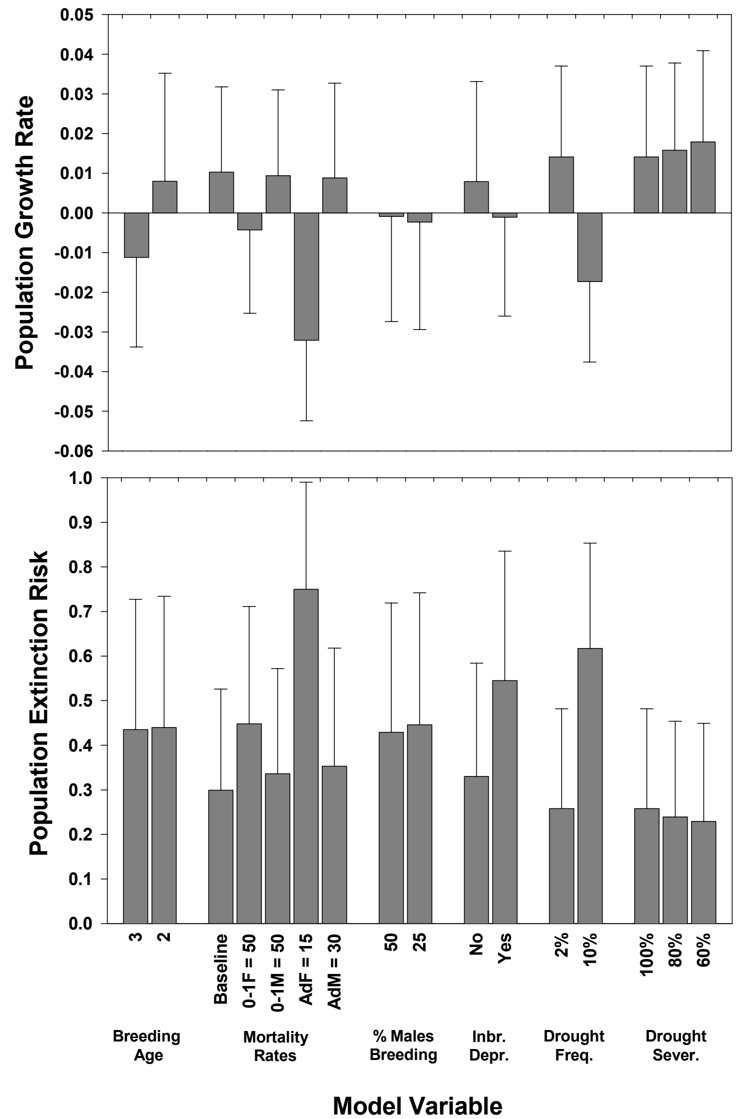
Demographic sensitivity analysis was conducted on a reference population to assess the sensitivity of a New Mexico bighorn sheep population to changes in individual demographic parameters. The baseline model for this analysis includes our best estimate of demographic parameters in the San Andres Mountains population under recent conditions. Eighty models were constructed using various combinations of the parameters discussed below. Refer to Figure 2 for a graphical representation of the results discussed below.

Sensitivity to age of first breeding in females: The age of first breeding in females was changed from 2 to 3 in order to assess the impact of this type of measurement uncertainty on population growth dynamics. Under each of these alternative conditions, other parameters were varied by predetermined increments as described on pages 26-30, resulting in 40 simulations using each of these parameter values. The mean growth and extinction rates were calculated for each set of 40 simulations. When age of first breeding was set at 2 years, the mean stochastic growth rate was 0.008 and the extinction risk over the 100-year timespan of the simulation was 0.44. In contrast, the mean growth rate was -0.011 and the extinction rate was 0.43 when the age of first breeding was set at 3 (note that the reduced extinction risk here is a statistical artifact related to the smaller number of runs used in the sensitivity analysis and is not reflective of biological differences between the simulated populations). This suggests that population growth rate is sensitive to age of first breeding, but that extinction rate is less sensitive to this parameter.

Sensitivity to age-specific mortality rates: In a similar fashion, the effects of changing age-specific mortality rates were assessed. When mortality rates were held at baseline values (see Table 1), the mean growth rate was 0.01 and the risk of extinction was 0.3. Mortality rate in the

0-1 year age class was then increased by 5% (resulting in a mortality of 50%), one sex at a time, so that results could be compared with these baseline results. When this increase was applied to females only, population growth rate declined to -0.004 and extinction risk increased to 0.45. For males, this increased mortality resulted in a growth rate of +0.009 and an extinction risk of 0.33. This revealed that the model is sensitive to mortality rates among female lambs, but that it is relatively insensitive to mortality among male lambs.

Figure 2. Demographic sensitivity analysis summary for a reference desert bighorn sheep population in New Mexico, loosely based on the historic San Andres population (see text for details). Mean population growth rate (top) and 100-year population extinction risk (bottom) under alternative demographic and genetic input variables.



Mortality rates of adults was increased by 5%, resulting in a mortality rate of 15% among females and a mortality rate of 30% among males. When this increase was applied to females, growth rate declined to -0.033 and extinction rate increased to 0.75. When male mortality was increased by 5%, growth rate only declined to 0.008 and extinction risk only increased to 0.34, as compared to 0.01 and 0.3, respectively, in the baseline model.

Both these results suggest that bighorn sheep populations are most sensitive to the mortality rates among females (disregarding age). This finding is expected, given the polygamous breeding system of this species. In addition, the results clearly show that population viability is much more sensitive to survival of adults than survival of lambs.

Sensitivity to degree of polygamy (% males in the breeding pool)
The model was run using two levels of polygamy: one at the expected baseline value of 50% males in the breeding pool, and one using 25% males in the breeding pool. At 50%, the mean growth rate of multiple trials (in which other demographic values were varied) was -0.001 and the risk of extinction was 0.42. At 25%, the mean growth rate was -0.003 and the risk of extinction was 0.45. These results suggest that, demographically, this population doesn't appear to be very sensitive to the % of males in the breeding pool. However, this parameter has more noticeable consequences with regard to genetics (data not presented in this report).

Sensitivity to whether or not inbreeding depression is included in the model
When inbreeding depression was included in the model, the mean growth rate (of multiple trials in which other parameters were varied) was -0.001, while risk of extinction was 0.55. In contrast, mean growth rate was 0.008 and risk of extinction was 0.33 when inbreeding depression was excluded. This suggests that the model is sensitive to inbreeding depression but we have no evidence for inbreeding depression in bighorn sheep populations.

Sensitivity to drought frequency and severity
When the frequency of drought was set at 2% (based on participant's best estimates), the mean growth rate of multiple trials was 0.013 and the risk of extinction was 0.25. When this frequency was increased to 10%, the rate of population growth decreased to -0.017 while the risk of extinction increased to 0.62. This indicates that the population is sensitive to the frequency of catastrophes. In contrast, changes to the severity of the drought lead to comparatively little change in stochastic population growth rate or extinction risk. This preliminary analysis points to the need to more precisely quantify the frequency of this particular type of weather event and its effects on desert bighorn reproductive parameters.

Risk Analysis I: Projections Using Current Conditions

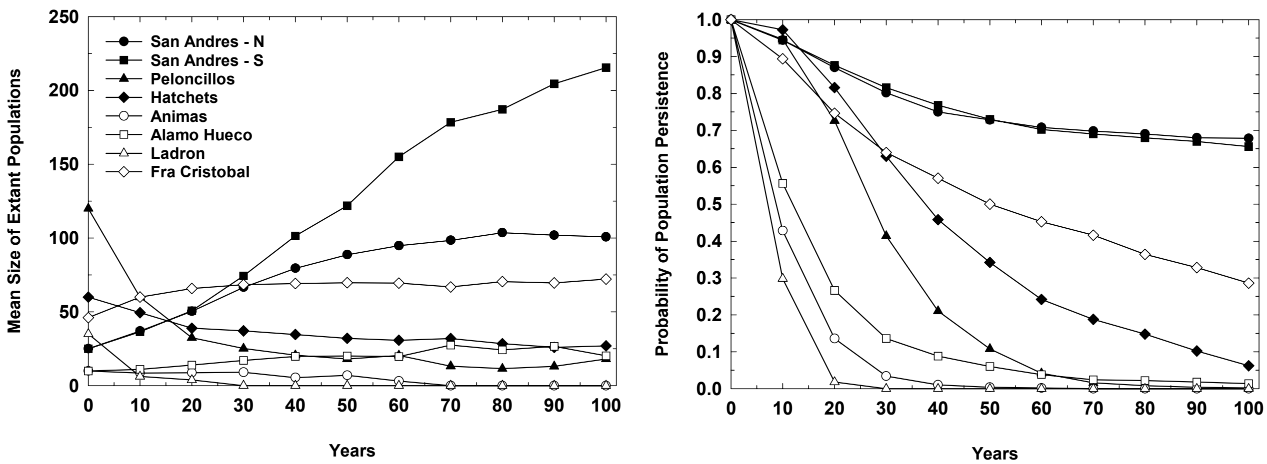
Individual populations
Baseline population models for the 8 individual populations within 4 extant metapopulations were constructed for 100 years using 10-year reporting intervals. Three populations failed to persist for 100 years: the Ladron and Animas populations went extinct on average in about 10 years, and the Peloncillo population became extinct in about 30 years (Table 3, Figure 3). The probability of persistence for the Alamo Hueco population was only 1.5% and the mean population estimate was just 20 animals at 100 years. The probability of persistence for the Fra Cristobal was 29% and the population estimate was 72 at 100 years. The probability of persistence of the Hatchet population was 6% and the mean population estimate at 100 years was 27. The 2 populations with the highest probability of persistence and highest population estimates were the 2 San Andres populations. For the north and south subpopulations the probability of persistence was 68 and 66% respectively and the population estimates were 101 and 215. This initial analysis clearly demonstrates that essentially all of the desert bighorn populations in New Mexico are at a high risk of extinction within the next few decades, with the San Andres region offering the greatest promise for future population stability (assuming the

successful eradication of the scabies problem that played a dominant role in its recent demise; Clark and Jessup 1992).

Table 3. Desert bighorn population risk analysis: individual populations, current conditions. See text for information on input parameters.

Population	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
San Andres – N	0.020 (0.221)	0.322	—	101 (42)	0.681
San Andres – S	0.018 (0.222)	0.344	—	215 (104)	0.700
Peloncillos	-0.101 (0.310)	0.998	28	18 (—)	0.676
Hatchets	-0.049 (0.294)	0.938	38	27 (27)	0.589
Animas	-0.072 (0.309)	1.000	9	—	—
Alamo Hueco	-0.042 (0.299)	0.986	12	20 (18)	0.365
Ladron	-0.222 (0.273)	1.000	8	0 (—)	0.000
Fra Cristobal	0.020 (0.253)	0.714	50	72 (24)	0.629

Figure 3. Mean extant size (left panel) and probability of persistence (right panel) for each of the eight desert bighorn populations currently or recently surviving in New Mexico.



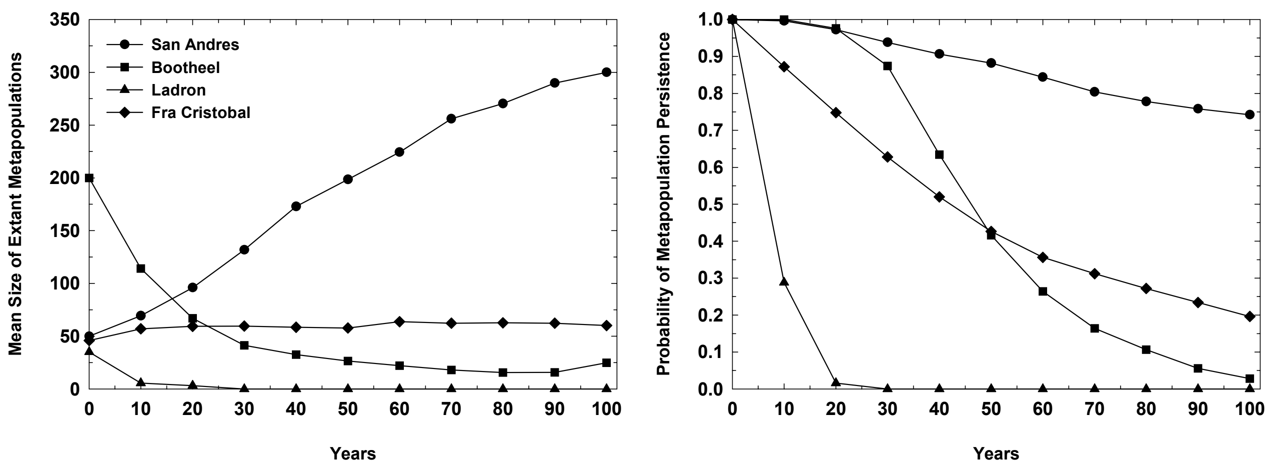
Metapopulations

Treating the 2 San Andres populations as a linked metapopulation did not significantly enhance the overall population estimate, although the probability of persistence increased to 74% (Table 4, Figure 4). Creation of a Bootheel metapopulation did not increase the likelihood of persistence of any of the 4 component populations. Moreover, the Ladron metapopulation did not persist beyond ~10 years because of the absence of demographic support from the now-empty Magdalena, San Mateo and Black Range populations linked to the Ladron population. The Fra Cristobal metapopulation is also plagued with the same problem as the Ladron metapopulation, as the empty Caballo locale cannot become established through natural emigration because of 2 primary factors: the low in- and out-migration (dispersal) rates estimated for this unit, and the potentially high mortality rates resulting from the adjacent community's lack of acceptance for introducing bighorn sheep to the Caballo Mountains. In summary it appears from these analyses that, despite the opportunity for population linkage, metapopulation persistence is projected to be quite low (perhaps with the exception of the San Andres region) as a result of high mortality and low migration rates.

Table 4. Desert bighorn population risk analysis: metapopulations with component populations, current conditions. See text for information on input parameters.

Metapopulation	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
San Andres	0.019 (0.174)	0.258	—	300 (120)	0.841
San Andres – N	0.034 (0.220)	0.274	—	122 (34)	0.838
San Andres – S	0.015 (0.222)	0.276	—	185 (89)	0.842
Bootheel	-0.073 (0.228)	0.972	47	25 (20)	0.611
Peloncillos	-0.101 (0.299)	1.000	30	—	—
Hatchets	-0.056 (0.278)	0.982	37	18 (19)	0.619
Animas	-0.035 (0.307)	1.000	12	—	—
Alamo Hueco	-0.030 (0.294)	0.988	16	28 (21)	0.576
Ladron	-0.226 (0.264)	1.000	8	—	—
Ladron	-0.225 (0.264)	1.000	8	—	—
Magdalena	—	—	—	—	—
San Mateo	—	—	—	—	—
Black Range	—	—	—	—	—
Fra Cristobal	0.003 (0.248)	0.804	42	60 (27)	0.607
Fra Cristobal	0.002 (0.256)	0.804	42	58 (26)	0.606
Caballos	—	—	—	—	—

Figure 4. Mean extant size (left panel) and probability of persistence (right panel) for each of the 4 desert bighorn metapopulations currently or recently surviving in New Mexico.



Influence of emigration rate on metapopulation persistence

Theory and field observatons of metapopulation dynamics (reviewed in Hanski and Gilpin 1997) indicate that the rate of migration of individuals between component populations is a critical factor in determining the persistence of metapopulations. We were interested in evaluating this factor by setting up a series of models for the Bootheel metapopulation with migration rates set at 1%, 2%, 5%, or 10%. The results of this analysis (Table 5, Figure 5) illustrate the complex dynamics inherent in many metapopulations. As migration rates increased throughout the Bootheel metapopulation, the total metapopulation extinction risk actually *increased* (although we recognize that the differences observed are quite small).

Table 5. Bootheel metapopulation, effect of migration rates.

Metapopulation	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
Migration Rate: 1%					
Bootheel	-0.073 (0.228)	0.972	47	25 (20)	0.611
Peloncillos	-0.101 (0.299)	1.000	30	—	—
Hatchets	-0.056 (0.278)	0.982	37	18 (19)	0.619
Animas	-0.035 (0.307)	1.000	12	—	—
Alamo Hueco	-0.030 (0.294)	0.988	16	28 (21)	0.576
Migration Rate: 2%					
Bootheel	-0.078 (0.217)	0.984	46	14 (18)	0.620
Peloncillos	-0.105 (0.300)	1.000	30	—	—
Hatchets	-0.066 (0.287)	0.992	36	8 (6)	0.601
Animas	-0.024 (0.316)	1.000	17	—	—
Alamo Hueco	-0.021 (0.289)	0.990	20	14 (19)	0.603
Migration Rate: 5%					
Bootheel	-0.086 (0.203)	0.994	44	6 (2)	0.320
Peloncillos	-0.109 (0.300)	1.000	28	—	—
Hatchets	-0.073 (0.295)	0.996	33	4 (1)	0.109
Animas	-0.014 (0.309)	1.000	20	—	—
Alamo Hueco	-0.018 (0.299)	0.998	27	7 (—)	0.622
Migration Rate: 10%					
Bootheel	-0.086 (0.192)	0.998	42	14 (—)	0.837
Peloncillos	-0.107 (0.302)	1.000	28	—	—
Hatchets	-0.071 (0.295)	0.998	33	4 (—)	0.813
Animas	-0.012 (0.338)	1.000	24	—	—
Alamo Hueco	-0.014 (0.304)	0.998	30	7 (—)	0.796

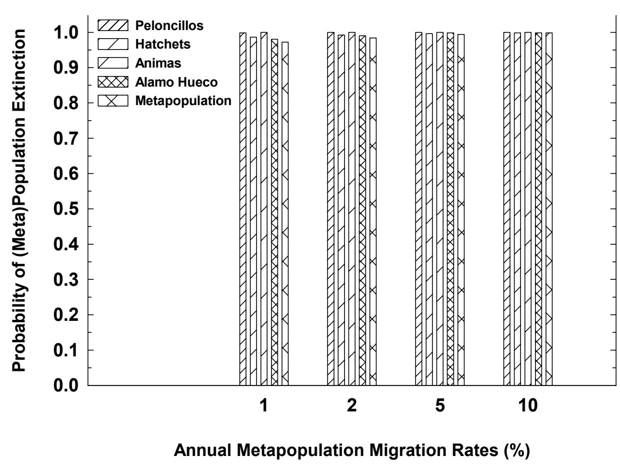


Figure 5. Effect of between-population migration rate on extinction risk for the Bootheel metapopulation and its component populations.

This observation is very similar to that made earlier for each of the current metapopulation risk projections: the unacceptably high mortality, coupled with the small component population sizes, renders any kind of "rescue effect" from the metapopulation structure totally ineffective. In fact, the movement of individuals into particularly unstable populations actually increases the risk of overall metapopulation extinction. This variation of source-sink dynamics can make metapopulation management a more challenging endeavor as the growth dynamics of each component must be carefully studied and monitored. Additional metapopulation modeling efforts could prove extremely valuable in an attempt to understand the influence of spatial structure on population viability.

Risk Analysis II: Impact of Sources of Additional Mortality

Individual Populations and Metapopulations

Because of the uncertainty of our results due to limited sample sizes, and the potential influence of high predation rates on recently released bighorn sheep, a series of baseline models based on long term mortality rates for bighorn sheep not subjected to known lion predation was also run. Adult mortality estimates were primarily derived from McCarty and Miller (1999), and 1-2 and 2-3 year old mortalities were best estimates from desert bighorn sheep biologists in attendance. The reduction in lamb mortality rates to 80% of their current values (see table, page 28) was chosen with less precision because the role of lion predation on desert bighorn sheep lamb mortality rates is not adequately researched.

When no additional mortality sources are included in the models, population growth rates and especially persistence probabilities increase dramatically (Tables 6 and 7, Figure 6). The outstanding exception to this observation is the Animas population where small population size plays a primary role in the risk of extinction over the 100 years of the simulation period. However, despite the relatively low risk of population extinction, the amount of genetic variation (heterozygosity) retained within even the largest population is less than 90% (Table 6). This extent of heterozygosity retention has been used very commonly as a management benchmark for maximizing short-term population viability and longer-term evolutionary (adaptive) potential. The long-term viability of these populations may therefore be questioned from a genetic perspective. A metapopulation structure for the San Andres population, however, does result in the maintenance of at least 90% heterozygosity for 100 years through a reduction in the frequency and severity of inbreeding and genetic drift (Table 7).

As is evident in Table 6 and Figure 6, the addition of just 5% mortality on top of the baseline "None" scenarios results in a dramatic decrease in the rate of population growth and an increase in extinction risk in both individual populations and the larger metapopulations. In the Bootheel, Ladron and Fra Cristobal metapopulations, this additional mortality leads to a major shift in growth rate from positive (or nearly so) to strongly negative. The San Andres metapopulation shows a barely positive growth rate with this additional mortality, although the risk of metapopulation extinction increases sharply. As expected, the inclusion of higher mortality rates equal to 10% and even 20% above the baseline "None" scenarios leads to greatly increased extinction risk and overall population destabilization. Clearly, these high adult mortality rates—when linked to similar increases in mortality across all age/sex classes—are unsustainable in these populations, regardless of the degree of metapopulation migration, initial population sizes, or habitat carrying capacity.

It appears from these analyses that desert bighorn sheep populations in New Mexico are highly vulnerable to an increased risk of extinction in the short term if additional sources of mortality—even as small as 5%—are imposed on populations initially free of these impacts.

Table 6. Impact of additional (lion) mortality on individual population persistence.

Population	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
No Additional Mortality Sources					
San Andres – N	0.055 (0.120)	0.006	—	140 (16)	0.843
San Andres – S	0.057 (0.117)	0.002	—	333 (29)	0.872
Peloncillos	-0.003 (0.127)	0.046	—	100 (63)	0.853
Hatchets	0.029 (0.118)	0.000	—	108 (20)	0.863
Animas	-0.011 (0.186)	0.788	35	39 (29)	0.461
Alamo Hueco	0.024 (0.157)	0.324	—	40 (11)	0.570
Ladron	0.005 (0.147)	0.198	—	32 (14)	0.642
Fra Cristobal	0.033 (0.157)	0.004	—	82 (19)	0.820
5% Additional Mortality Sources					
San Andres – N	-0.012 (0.172)	0.558	82	48 (37)	0.605
San Andres – S	-0.011 (0.172)	0.530	94	59 (63)	0.583
Peloncillos	-0.071 (0.180)	0.994	47	5 (3)	0.515
Hatchets	-0.038 (0.175)	0.822	65	16 (12)	0.581
Animas	-0.072 (0.236)	1.000	13	—	—
Alamo Hueco	-0.041 (0.222)	0.970	19	11 (6)	0.434
Ladron	-0.064 (0.198)	0.992	34	6 (2)	0.224
Fra Cristobal	-0.036 (0.203)	0.816	60	19 (16)	0.574
10% Additional Mortality Sources					
San Andres – N	-0.078 (0.225)	0.998	24	5 (—)	0.560
San Andres – S	-0.079 (0.222)	1.000	23	—	—
Peloncillos	-0.140 (0.204)	1.000	26	—	—
Hatchets	-0.102 (0.206)	1.000	27	—	—
Animas	-0.122 (0.257)	1.000	9	—	—
Alamo Hueco	-0.098 (0.251)	1.000	11	—	—
Ladron	-0.127 (0.224)	1.000	18	—	—
Fra Cristobal	-0.100 (0.234)	1.000	25	—	—
20% Additional Mortality Sources					
San Andres – N	-0.210 (0.269)	1.000	10	—	—
San Andres – S	-0.213 (0.265)	1.000	10	—	—
Peloncillos	-0.284 (0.236)	1.000	13	—	—
Hatchets	-0.250 (0.244)	1.000	12	—	—
Animas	-0.254 (0.295)	1.000	5	—	—
Alamo Hueco	-0.210 (0.294)	1.000	6	—	—
Ladron	-0.270 (0.263)	1.000	9	—	—
Fra Cristobal	-0.234 (0.273)	1.000	11	—	—

Figure 6. Mean extant size (left panel) and probability of persistence (right panel) for each of the four desert bighorn metapopulations currently or recently surviving in New Mexico in the absence of additional mortality ("None") and incremental increases in overall mortality of 5%, 10% and 20% above this baseline level.

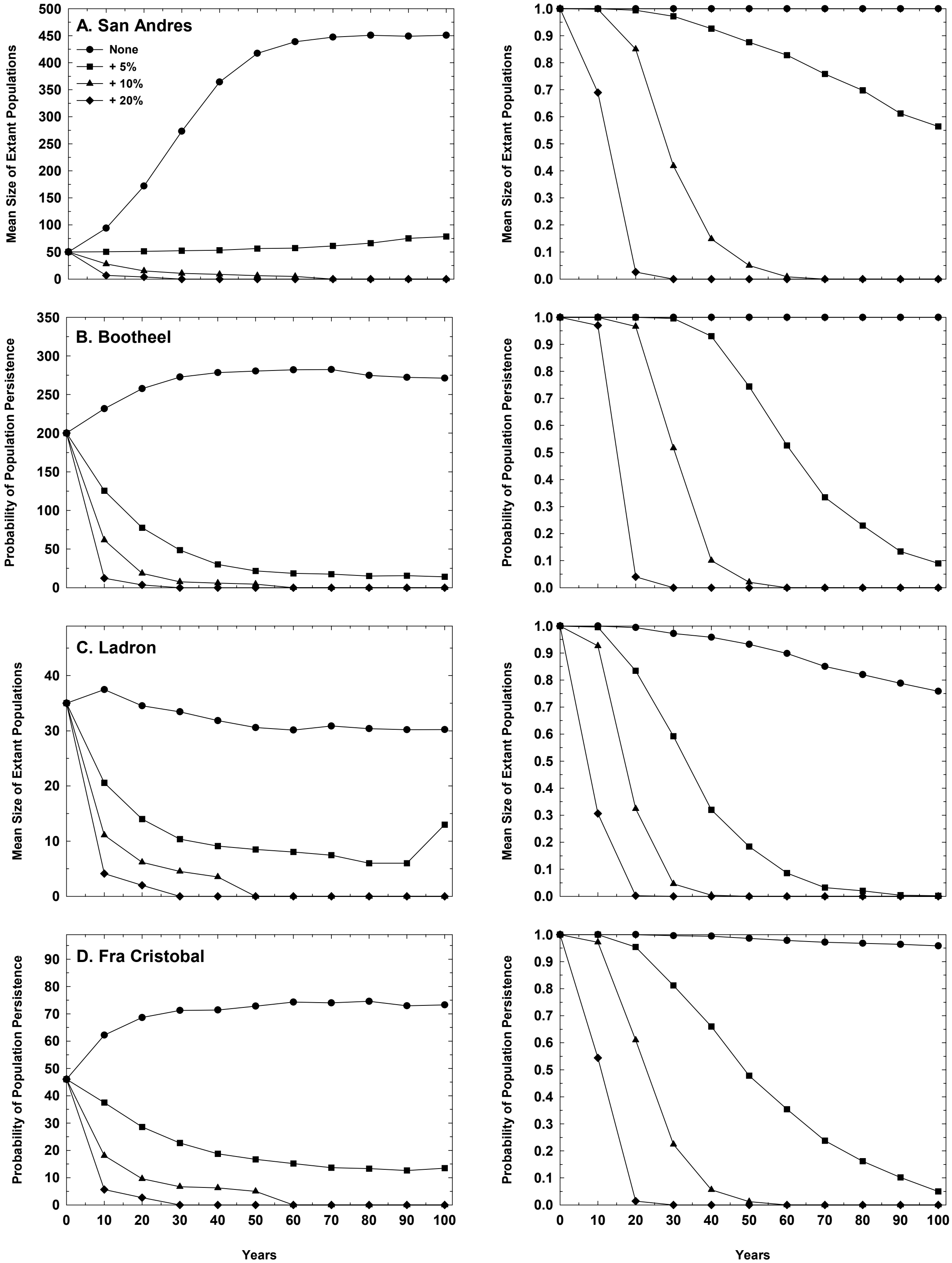


Table 7. Impact of additional (lion) mortality on metapopulation persistence

Metapopulation	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
No Additional Mortality Sources					
San Andres	0.056 (0.099)	0.000	—	451 (51)	0.931
Bootheel	0.015 (0.093)	0.000	—	271 (96)	0.936
Ladron	0.001 (0.152)	0.242	—	30 (15)	0.626
Fra Cristobal	0.016 (0.148)	0.042	—	73 (28)	0.785
5% Additional Mortality Sources					
San Andres	-0.014 (0.140)	0.436	—	79 (72)	0.723
Bootheel	-0.062 (0.156)	0.910	62	14 (11)	0.557
Ladron	-0.065 (0.202)	0.998	34	13 (—)	0.654
Fra Cristobal	-0.048 (0.199)	0.950	49	13 (9)	0.524
10% Additional Mortality Sources					
San Andres	-0.090 (0.192)	1.000	29	—	—
Bootheel	-0.132 (0.174)	1.000	31	—	—
Ladron	-0.129 (0.225)	1.000	17	—	—
Fra Cristobal	-0.109 (0.229)	1.000	23	—	—
20% Additional Mortality Sources					
San Andres	-0.229 (0.231)	1.000	12	—	—
Bootheel	-0.288 (0.203)	1.000	15	—	—
Ladron	-0.270 (0.268)	1.000	9	—	—
Fra Cristobal	-0.247 (0.272)	1.000	11	—	—

Risk Analysis III: Supplementation as a Management Strategy

Given the negative growth rates and the significant risk of extinction observed in these simulations of New Mexico desert bighorn populations, intensive management may become necessary in the near future in order to promote positive population growth. One proposed strategy would involve augmentation (supplementation) of existing populations with bighorn from an external source such as the Red Rock captive facility, or perhaps even from lands outside of New Mexico. We developed a set of models to investigate the expected efficacy of this strategy (see the discussion of input parameters for a detailed description of the characteristics of these strategies).

Individual Populations

Comparison of the results from the supplementation models in Table 8 with the non-supplementation models in Table 3, under current mortality conditions, indicates that short-term supplementation schemes will not significantly increase the probability of population persistence under current mortality pressures. Again, the San Andres populations show an increased growth rate under this supplementation schedule; this has the effect of increasing the rate with which the populations approach carrying capacity. However, for small populations with high current mortality rates, the initial rapid increase in population size following the supplementation events is quickly followed by an equally rapid decline to extinction as the high mortality takes its toll.

Table 8. Impacts of supplementation strategy A under alternative mortality schedules: Populations. See text for more information on the nature of this strategy.

Population	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
Current Mortality Conditions					
San Andres – N	0.037 (0.233)	0.052	—	101 (40)	0.808
San Andres – S	0.037 (0.229)	0.014	—	236 (94)	0.882
Peloncillos	-0.071 (0.320)	0.998	40	4 (—)	0.219
Hatchets	-0.027 (0.303)	0.878	54	27 (24)	0.598
Animas	-0.011 (0.427)	1.000	35	—	—
Alamo Hueco	0.016 (0.388)	0.968	43	17 (15)	0.557
Ladron	-0.050 (0.422)	1.000	23	—	—
Magdalena	-0.062 (0.440)	1.000	20	—	—
San Mateo	-0.061 (0.430)	1.000	20	—	—
Black Range	-0.060 (0.435)	1.000	20	—	—
Fra Cristobal	0.036 (0.264)	0.658	69	70 (24)	0.643
Caballos	-0.103 (0.584)	1.000	19	—	—
No Additional Mortality Sources					
San Andres – N	0.071 (0.144)	0.000	—	142 (13)	0.907
San Andres – S	0.072 (0.150)	0.000	—	331 (30)	0.952
Peloncillos	0.004 (0.139)	0.014	—	109 (61)	0.888
Hatchets	0.040 (0.134)	0.000	—	107 (20)	0.885
Animas	0.021 (0.215)	0.116	—	48 (29)	0.778
Alamo Hueco	0.054 (0.209)	0.022	—	40 (11)	0.725
Ladron	0.026 (0.181)	0.152	—	31 (14)	0.678
Magdalena	0.022 (0.172)	0.128	—	31 (14)	0.679
San Mateo	0.021 (0.174)	0.164	—	33 (14)	0.694
Black Range	0.021 (0.175)	0.144	—	31 (14)	0.677
Fra Cristobal	0.046 (0.179)	0.004	—	79 (21)	0.848
Caballos	0.020 (0.174)	0.148	—	32 (14)	0.679
20% Additional Mortality Sources					
San Andres – N	-0.080 (0.396)	1.000	24	—	—
San Andres – S	-0.082 (0.403)	1.000	24	—	—
Peloncillos	-0.170 (0.375)	1.000	21	—	—
Hatchets	-0.126 (0.361)	1.000	23	—	—
Animas	-0.051 (0.582)	1.000	21	—	—
Alamo Hueco	-0.044 (0.528)	1.000	23	—	—
Ladron	-0.102 (0.478)	1.000	21	—	—
Magdalena	-0.111 (0.515)	1.000	20	—	—
San Mateo	-0.111 (0.504)	1.000	20	—	—
Black Range	-0.112 (0.514)	1.000	20	—	—
Fra Cristobal	-0.113 (0.406)	1.000	23	—	—
Caballos	-0.112 (0.499)	1.000	20	—	—

Metapopulations

The results for the metapopulation supplementation analysis shown in Table 9 and Figure 7 paint a very similar picture to that for the individual populations: with the exception of the San Andres metapopulation, each of the remaining units can not withstand current levels of mortality despite aggressive short-term supplementation from external sources. If external sources of mortality are removed, supplementation can help to retain as much as 85% of the original genetic variation.

Table 9. Impact of supplementation strategy A under alternative mortality schedules: Metapopulations. See text for more information on the nature of this strategy.

Metapopulation	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
Current Mortality Conditions					
San Andres	0.037 (0.173)	0.014	—	283 (108)	0.928
Bootheel	-0.045 (0.204)	0.942	67	22 (20)	0.685
Ladron	-0.028 (0.281)	1.000	32	—	—
Fra Cristobal	0.007 (0.253)	0.840	60	40 (23)	0.658
No Additional Mortality Sources					
San Andres	0.067 (0.113)	0.000	—	444 (53)	0.967
Bootheel	0.023 (0.095)	0.000	—	281 (90)	0.960
Ladron	0.033 (0.143)	0.020	—	63 (36)	0.851
Fra Cristobal	0.039 (0.140)	0.000	—	102 (33)	0.886
20% Additional Mortality Sources					
San Andres	-0.097 (0.282)	1.000	28	—	—
Bootheel	-0.137 (0.222)	1.000	30	—	—
Ladron	-0.074 (0.301)	1.000	29	—	—
Fra Cristobal	-0.101 (0.322)	1.000	26	—	—

Figure 7 shows the immediate impact of the supplementation strategy on metapopulation size and extinction risk through the first 20 years of the simulation. In all cases, metapopulation size increases sharply but, in the case of the Bootheel, Ladron and Fra Cristobal populations, current mortality rates drive the metapopulation sizes down sharply with an accompanying high risk of extinction. Note that the rate of decline in total population size and probability of persistence is actually greater in the supplementation scenarios compared to the models under current conditions. This is explained by the inclusion of inbreeding depression in the metapopulation supplementation models, a feature that was absent from the baseline risk analysis models. The detrimental effects of this genetic process are fully evident here, particularly in those metapopulations with smaller populations. The supplementation strategy can be highly effective at rapidly expanding a stable population towards the habitat carrying capacity, as demonstrated by the San Andres metapopulation under current or relatively more benign mortality conditions.

Clearly, the less aggressive supplementation strategy B will not result in better population performance compared to strategy A under current or high mortality conditions (results not shown). It appears that supplementation with a smaller number of animals can be an effective strategy for rapid expansion of population numbers when sources of mortality are minimized.

In total, one may conclude from these analyses that a supplementation scheme designed to increase (meta)population size can be effective, but only when high levels of mortality are reduced. If this mortality is not controlled, supplementation of desert bighorn into existing metapopulations subjected to current conditions is likely to do nothing more than feed the local predators. This, however, may not be the case if supplementation results in lower predation rates. We could not model reduced mortality rate with higher sheep densities at this workshop.

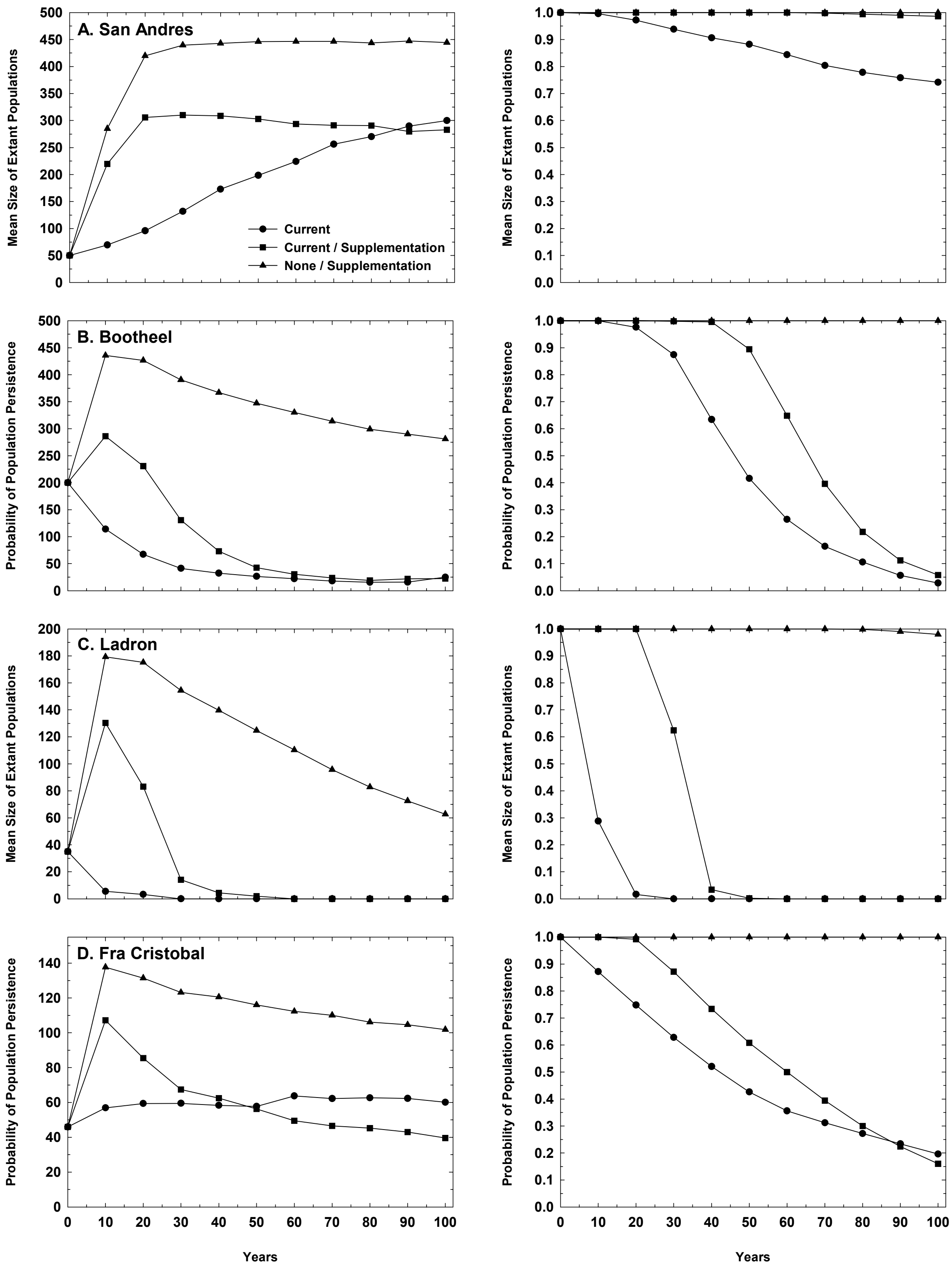


Figure 7. Mean extant size (left panel) and probability of persistence (right panel) for each of the four desert bighorn metapopulations currently or recently surviving in New Mexico under current mortality conditions without supplementation, with supplementation (strategy A, see text for details), and with supplementation and removal of external mortality sources.

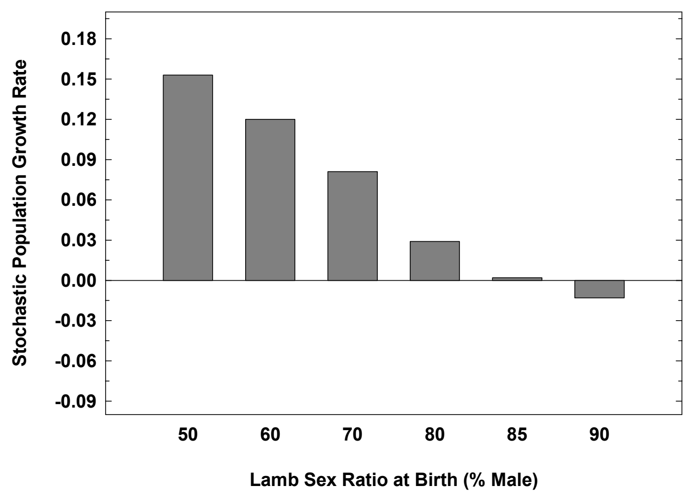
Risk Analysis IV: Viability of the Red Rock Captive Population

The results of the Red Rock captive population models are shown in Table 10 and Figures 8 and 9. Given the extremely low mortality rates that are characteristic of this simulated population, lamb sex ratios as high as 70% male continue to result in strong population growth and reasonable genetic integrity. However, lamb sex ratios approaching 80-85% male result in a dramatic decline in population growth and, at a sex ratio of 85% males, a considerable increase in the risk of overall population extinction. A further increase in this ratio to 90% results in a shift in population growth from positive to negative and a very high risk of population extinction.

Table 10. Impact of variable skewed male-biased lamb sex ratio on viability of a simulated Red Rock captive population. See text for more information on the details of these models.

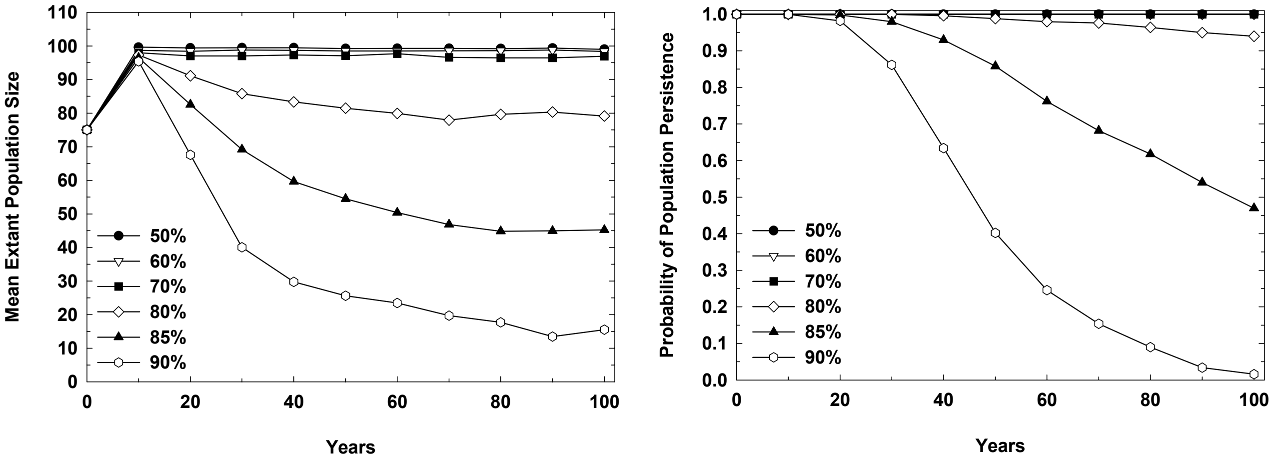
Lamb Sex Ratio	r_s (SD)	P(E)	T(E)	N_{100}–Ext. (SD)	H_{100}
50% Male	0.153 (0.191)	0.000	—	99 (5)	0.853
60%	0.120 (0.092)	0.000	—	98 (5)	0.862
70%	0.081 (0.094)	0.000	—	97 (8)	0.861
80%	0.029 (0.101)	0.060	—	79 (23)	0.806
85%	0.002 (0.112)	0.530	97	45 (28)	0.695
90%	-0.013 (0.127)	0.984	47	16 (8)	0.397

Figure 8. Mean stochastic growth rate of a simulated Red Rock captive population under alternative sex ratios of lambs at birth, starting from a baseline value of parity (50% males). See text for additional description of these models.



It appears from this set of simulations that a captive population similar to that at Red Rock may not be viable in the long-term if the highly male-biased sex ratio among lambs persists. While some level of male bias among lambs appears to be tolerable demographically, ratios approaching 80-85% results in populations that are highly unstable demographically and are at a significant risk of extinction unless the cause of this bias is identified and remedied.

Figure 9. Mean extant size (left panel) and probability of persistence (right panel) for simulated Red Rock captive populations under alternative male-biased lamb sex ratios.



Conclusions

- Using the best available estimates of population demographic parameters for the desert bighorn sheep of New Mexico, a group of workshop participants constructed a set of stochastic population simulation models to assess desert bighorn population viability under current and projected environmental conditions. Under current conditions, both the component populations and the aggregate metapopulations, with the exception of a proposed reintroduction into the San Andres mountains, show significant risks of extinction over a 100-year timeframe. This is most likely due to significant levels of lion-caused mortality.

- Because of the relatively low growth potential inherent to desert bighorn sheep populations, the addition of as little as 5% mortality among all age/sex classes to the "baseline" levels drives most populations towards relatively rapid extinction. This demonstrates the considerable sensitivity these populations express to increases in mortality—especially among adult females.

- If supplementation of existing (or proposed) populations is to be effective at expanding the total numbers of individuals in each metapopulation unit, mortality must be reduced. If this cannot occur, supplementation must be essentially continuous and substantial if long-term persistence is to be realized.

- It appears from this set of simulations that a captive population similar to that at Red Rock may not be viable in the long-term if the highly male-biased sex ratio among lambs persists. While some level of male bias among lambs appears to be tolerable demographically, ratios approaching 80-85% results in populations that are highly unstable demographically and are at a significant risk of extinction unless the cause of this bias is identified and remedied.

*Working group members:*Bill Dunn, Amy Fisher, Phil Hedrick, Kyran Kunkel, Stacey Ostermann, Eric Rominger, Esther Rubin and Phil Miller, facilitator.

Appendix I:
An Introduction to Simulation Modeling and Population Viability Analysis

A model is any simplified representation of a real system. We use models in all aspects of our lives, in order to: (1) extract the important trends from complex processes, (2) permit comparison among systems, (3) facilitate analysis of causes of processes acting on the system, and (4) make predictions about the future. A complete description of a natural system, if it were possible, would often decrease our understanding relative to that provided by a good model, because there is "noise" in the system that is extraneous to the processes we wish to understand. For example, the typical representation of the growth of a wildlife population by an annual percent growth rate is a simplified mathematical model of the much more complex changes in population size. Representing population growth as an annual percent change assumes constant exponential growth, ignoring the irregular fluctuations as individuals are born or immigrate, and die or emigrate. For many purposes, such a simplified model of population growth is very useful, because it captures the essential information we might need regarding the average change in population size, and it allows us to make predictions about the future size of the population. A detailed description of the exact changes in numbers of individuals, while a true description of the population, would often be of much less value because the essential pattern would be obscured, and it would be difficult or impossible to make predictions about the future population size.

In considerations of the vulnerability of a population to extinction, as is so often required for conservation planning and management, the simple model of population growth as a constant annual rate of change is inadequate for our needs. The fluctuations in population size that are omitted from the standard ecological models of population change can cause population extinction, and therefore are often the primary focus of concern. In order to understand and predict the vulnerability of a wildlife population to extinction, we need to use a model which incorporates the processes which cause fluctuations in the population, as well as those which control the long-term trends in population size (Shaffer 1981). Many processes can cause fluctuations in population size: variation in the environment (such as weather, food supplies, and predation), genetic changes in the population (such as genetic drift, inbreeding, and response to natural selection), catastrophic effects (such as disease epidemics, floods, and droughts), decimation of the population or its habitats by humans, the chance results of the probabilistic events in the lives of individuals (sex determination, location of mates, breeding success, survival), and interactions among these factors (Gilpin and Soulé 1986).

Models of population dynamics which incorporate causes of fluctuations in population size in order to predict probabilities of extinction, and to help identify the processes which contribute to a population's vulnerability, are used in "Population Viability Analysis" (PVA) (Lacy 1993/4). For the purpose of predicting vulnerability to extinction, any and all population processes that impact population dynamics can be important. Much analysis of conservation issues is conducted by largely intuitive assessments by biologists with experience with the system. Assessments by experts can be quite valuable, and are often contrasted with "models" used to evaluate population vulnerability to extinction. Such a contrast is not valid, however, as *any* synthesis of facts and understanding of processes constitutes a model, even if it is a mental model within the mind of the expert and perhaps only vaguely specified to others (or even to the expert himself or herself).

A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and many of the factors interact in complex ways. For example, increased fragmentation of habitat can make it more difficult to locate mates, can lead to greater mortality as individuals disperse greater distances across unsuitable habitat, and can lead to increased inbreeding which in turn can further reduce ability to attract mates and to survive. In addition, many of the processes impacting population dynamics are intrinsically probabilistic, with a random component. Sex determination, disease, predation, mate acquisition -- indeed, almost all events in the life of an individual -- are stochastic events, occurring with certain probabilities rather than with absolute certainty at any given time. The consequences of factors influencing population dynamics are often delayed for years or even generations. With a long-lived species, a population might persist for 20 to 40 years beyond the emergence of factors that ultimately cause extinction. Humans can synthesize mentally only a few factors at a time, most people have difficulty assessing probabilities intuitively, and it is difficult to consider delayed effects. Moreover, the data needed for models of population dynamics are often very uncertain. Optimal decision-making when data are uncertain is difficult, as it involves correct assessment of probabilities that the true values fall within certain ranges, adding yet another probabilistic or chance component to the evaluation of the situation.

The difficulty of incorporating multiple, interacting, probabilistic processes into a model that can utilize uncertain data has prevented (to date) development of analytical models (mathematical equations developed from theory) which encompass more than a small subset of the processes known to affect wildlife population dynamics. It is possible that the mental models of some biologists are sufficiently complex to predict accurately population vulnerabilities to extinction under a range of conditions, but it is not possible to assess objectively the precision of such intuitive assessments, and it is difficult to transfer that knowledge to others who need also to evaluate the situation. Computer simulation models have increasingly been used to assist in PVA. Although rarely as elegant as models framed in analytical equations, computer simulation models can be well suited for the complex task of evaluating risks of extinction. Simulation models can include as many factors that influence population dynamics as the modeler and the user of the model want to assess. Interactions between processes can be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes. In theory, simulation programs can be used to build models of population dynamics that include all the knowledge of the system which is available to experts. In practice, the models will be simpler, because some factors are judged unlikely to be important, and because the persons who developed the model did not have access to the full array of expert knowledge.

Although computer simulation models can be complex and confusing, they are precisely defined and all the assumptions and algorithms can be examined. Therefore, the models are objective, testable, and open to challenge and improvement. PVA models allow use of all available data on the biology of the taxon, facilitate testing of the effects of unknown or uncertain data, and expedite the comparison of the likely results of various possible management options.

PVA models also have weaknesses and limitations. A model of the population dynamics does not define the goals for conservation planning. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used. Because the models incorporate many factors, the number of possibilities to test can seem endless, and it can be difficult to determine which of the factors that were analyzed are most important to the population dynamics. PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models probably underestimate the threats facing the population. Finally, the models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed.

The *VORTEX* Population Viability Analysis Model

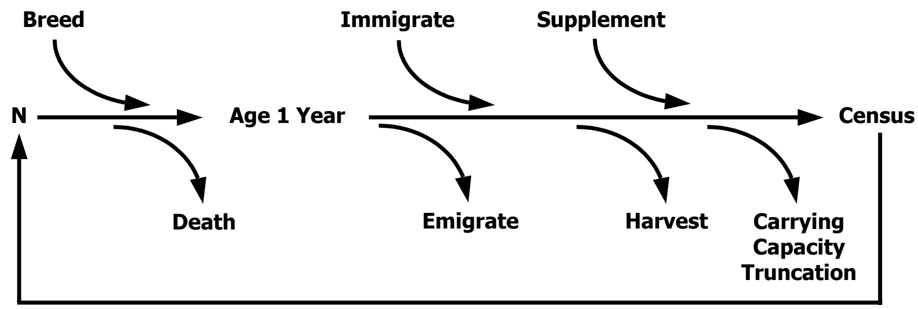
For the analyses presented here, the *VORTEX* computer software package (Lacy 1993a, Miller and Lacy 1999) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. (See figure below.) Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX Simulation Model Timeline



Events listed above the timeline increase N, while events listed below the timeline decrease N.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on *VORTEX* is available in Lacy (1993a) and Miller and Lacy (1999).

Dealing with Uncertainty

It is important to recognize that uncertainty regarding the biological parameters of a population and its consequent fate occurs at several levels and for independent reasons. Uncertainty can occur because the parameters have never been measured on the population; limited field data have yielded estimates with potentially large sampling error; independent studies have generated discordant estimates; environmental conditions or population status have been changing over time, and field surveys were conducted during periods which may not be representative of long-term averages; and the environment will change in the future, so that measurements made in the past may not accurately predict future conditions.

Sensitivity testing is necessary to determine the extent to which uncertainty in input parameters results in uncertainty regarding the future fate of the desert bighorn sheep population in New Mexico. If alternative plausible parameter values result in divergent predictions for the population, then it is important to try to resolve the uncertainty with better data. Sensitivity of population dynamics to certain parameters also indicates that those parameters describe factors that could be critical determinants of population viability. Such factors are therefore good candidates for efficient management actions designed to ensure the persistence of the population. The above kinds of uncertainty should be distinguished from several more sources of uncertainty about the future of the population. Even if long-term average demographic rates are known with precision, variation over time caused by fluctuating environmental conditions will cause uncertainty in the fate of the population at any given time in the future. Such environmental variation should be incorporated into the model used to assess population dynamics, and will generate a range of possible outcomes (perhaps represented as a mean and standard deviation) from the model. In addition, most biological processes are inherently stochastic, having a random component. The stochastic or probabilistic nature of survival, sex determination, transmission of genes, acquisition of mates, reproduction, and other processes preclude exact determination of the future state of a population. Such demographic stochasticity should also be incorporated into a population model, because such variability both increases our uncertainty about the future and can also change the expected or mean outcome relative to that which would result if there were no such variation. Finally, there is "uncertainty" which represents the alternative actions or interventions which might be pursued as a management strategy. The likely effectiveness of such management options can be explored by testing alternative scenarios in the model of population dynamics, in much the same way that sensitivity testing is used to explore the effects of uncertain biological parameters.

Results

Results reported for each scenario include:

<u>Deterministic r</u> -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When $r = 0$, a population with no growth is expected; $r < 0$ indicates population decline; $r > 0$ indicates long-term population growth. The value of r is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat "carrying capacity" limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

<u>Stochastic r</u> -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic r will be less than the deterministic r predicted from birth and death rates. The stochastic r from the simulations will be close to the deterministic r if the population growth is steady and robust. The stochastic r will be notably less than the deterministic r if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the

genetic and demographic instabilities inherent in small populations.

P(E) -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the VORTEX model as the lack of either sex.

N -- mean population size, averaged across those simulated populations which are not extinct.

SD(N) -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.

H -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993b), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls et al. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez et al. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé et al. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

Appendix II:
Genetic Considerations

Genetic considerations can make a substantial difference in a number of factors that may influence the successful recovery and management of an endangered species. In New Mexico desert bighorn sheep, the potentially important genetic considerations are the original ancestry (source) of the different populations, the amount of genetic variation within and between populations, the relative fitness of different populations, and the long-term maintenance of genetic variation.

Ancestry of the Populations

Red Rock Population. Red Rock is a captive population started in 1972 with five ewes from Pico Johnson (Loma Prieta), Mexico impregnated by Mexican rams. *Calculate potential ancestry from records*. As a result, it appears that the Red Rock population has a substantial ancestry from Mexican as well as San Andres sheep.

Wild Populations. Two of the wild populations, Fra Cristobal and Ladron, descend only from Red Rock animals. The remaining San Andres ewe is only of San Andres ancestry. In addition to ancestry from the captive Red Rock populations through transplants, there appears to be some ancestry in the wild populations from transplants in 1980 from Kofa, Arizona and from a relict population in the Hatchets. The Peloncillos population has ancestry from Red Rock, Arizona, and possibly from the Hatchets. Similarly, the other Bootheel populations – Hatchets, Animas, and Alamo Hueco – have ancestry from Red Rock, Hatchets, and Arizona (Arizona ancestry originated from bighorn transplanted to the Peloncillos which subsequently traveled to the other Bootheel populations).

Genetic Variation Within and Between Populations

Molecular genetic markers can give an estimate of the amount of genetic variation within populations and the amount of genetic difference between populations. The most reliable estimates in *O. c. mexicana* are from the survey of ten microsatellite loci from Gutierrez et al. (1998) and Gutierrez et al. (manuscript).

Within populations. The major findings relevant here are that the amount of heterozygosity is equal to 0.36 for the Red Rock population and 0.57 for the population from Arizona. In other words, the extent of genetic variation in Red Rock is only 63% of that found in the most closely related populations of the same subspecies. At this point, there are no estimates of genetic variation using comparable markers in Mexico, San Andres, Hatchets, and Peloncillos samples.

Between populations. For these markers, the genetic distance between *mexicana* in Arizona and Red Rock, D(AZ-RR)=0.271; within *mexicana* in AZ, D(Kofa-Stewart)=0.154; between *mexicana* and *nelsoni* in AZ, D(mex-nel)=0.644. AZ *mexicana* and Red Rock are much closer than *mexicana* and *nelsoni* in AZ and really don't have a much greater distance than the two *mexicana* populations in AZ (Hedrick, pers. comm.).

Genetically Based Fitness Differences

Molecular markers may, by statistical association, reflect differences in fitness. In addition, there may be other genes that have important effects on fitness that are not correlated or detected by these markers.

Resistance to Scabies and other Diseases. The San Andres population has gone extinct with direct and indirect mortality from scabies one of the primary causes. Other populations in New Mexico are not infected with scabies. Arizona populations are infected with scabies but it does not cause mortality. The different mortality effects between Arizona and San Andres sheep may be the result of either differential resistance in the sheep from the two sources or different levels of virulence in the mites from Arizona and New Mexico. Experiment have not been conducted to determine if Arizona sheep are resistant to mites from San Andres. Experiments have shown that Red Rock sheep are highly susceptible to San Andres mites (Kinzer et al.1983).

Inbreeding Effects on Fitness. Inbreeding often reduces or changes traits related to fitness, such as viability, mating, reproduction, and primary sex ratio. The Red Rock population is descended from a small number of individuals and the estimated inbreeding coefficient is *to be estimated.* This may partly explain the reduced heterozygosity observed for microsatellite loci in the Red Rock sample and influence recruitment and sex ratio in the Red Rock population.

Genetic Effects on Transplant Success. Transplants may have lower or higher success because of genetic differences between populations. For example, differential resistance to scabies or different fitness from past inbreeding may influence transplant success. In addition other genetic differences if present, such as local adaptation, may differ between populations.

Source of Animals for Transplants and/or Supplementation

Red Rock animals are the only source for transplants used to date except for the Arizona sheep introduced to the Peloncillos in 1980. Because Red Rock sheep have lower genetic variation than Arizona populations and also are susceptible to scabies, other sources of animals may be advisable. If there are excess animals from the Bootheel populations, they may be useful for transplantation or supplementation because they have ancestry from the Hatchets and/or Arizona. In addition, animals from Arizona that appear to have resistance to scabies and higher genetic variation may be important. Animals from Mexico may have other genetic variation but their resistance to scabies is unknown (however, the Red Rock population with high Mexican ancestry has high susceptibility). In addition, the Tiburon Island population, one source of Mexican animals, descends from only a few animals from the Mexican mainland and therefore should have limited genetic diversity.

Augmentation or Replacement of Red Rock

The Red Rock population has lower genetic variation than Arizona sheep and is susceptible to scabies. As a result, it may be advisable to add sheep from Arizona, from other New Mexico populations, or Mexico to the Red Rock population. Or, it may be advisable to replace the Red Rock stock entirely with sheep from another source, perhaps Arizona.

Management of Red Rock

The Red Rock population for most of its history has been maintained as a free ranging, confined population. As a result, there is some early information about parentage in the early generations but in recent years, there is no information about the paternity or maternity of specific animals and only a few animals are individually recognized. To keep the Red Rock effective population size as large as possible, it would be useful to equalize the contribution of individual males and females. In particular, the contribution of dominant males may be limited by removal or separation from the ewes during breeding.

Long-term Maintenance of Genetic Variation in New Mexico Populations

For the long-term maintenance of genetic variation, an effective population size of 500 or higher has been recommended. Generally the ratio of effective population size to adult breeding size within a generation is approximately 0.5 but may be lower in bighorn sheep because dominant males may do much of the mating for a number of years. In other words, the goal of the number of breeding adults may be nearly 1000 animals if the all the New Mexico populations are connected by either natural or artificial gene flow. The potential carrying capacity is 1250. However, this number includes both lambs and one-year-olds that are non-reproductive. Therefore, the total population is approximately the number thought necessary to maintain genetic variation for future adaptation.

The San Andres, Bootheel, Fra Cristobal, and Ladron metapopulations have carrying capacities of 650, 500, 150, and 200, respectively (Fisher, 1995). Assuming little or no exchange between them, the San Andres and Bootheel metapopulations would therefore retain much more genetic variation than would the Fra Cristobal and Ladron metapopulations. Within metapopulations, the individual populations are generally small except for the estimated 350 animals in the southern San Andres. Therefore, these individual populations probably would not maintain adequate long-term genetic variation without supplementation from other populations. One approach to overcome these low numbers is to supplement the population with sheep from other populations or metapopulations, such as Arizona or Mexico.

Literature Cited

Bleich, V. C. 1986. Early breeding in free-ranging mountain sheep. *The Southwestern Naturalist* 31(4):530-531.

Clark, R.K., and D.A. Jessup. 1992. The health of mountain sheep in the San Andres Mountains, New Mexico. *Desert Bighorn Council Trans*. 36:30-35.

Evans, W. 1986. Desert bighorn survival and mortality parameters in the San Andres Mountains, New Mexico, 1980-85. New Mexico Dep. of Game and Fish, Santa Fe. 34pp.

Fisher, A.S. 1995. *New Mexico's Long-Range Plan for Desert Bighorn Sheep Management, 1995-2002*. Final Rep. Fed. Aid in Wildlife Restor. Proj. W-127-R10, Job 1. New Mexico Dept. Game and Fish, Santa Fe.

Gilpin, M.E., and M.E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19 – 34 in: Soulé, M.E. (ed.). *Conservation Biology: The Science of Scarcity and Diversity*. Sunderland, MA: Sinauer Associates.

Gutiérrez-Espeleta, G.A., S.T. Kalinowski, W.M. Boyce, and P.W. Hedrick. 1998. Genetic variation in desert bighorn sheep. Pages 1-10 in: Lee, R.M. (ed.). *Desert Bighorn Council 1998 Transactions: A Compilation of Papers Presented at the 42nd Annual Meeting*.

Hogg, J.T. 1984. Mating in bighorn sheep: Multiple creative male strategies. *Science* 225:526-528.

Jiménez, J.A., K.A. Hughes, G. Alaks, L. Graham, and R.C. Lacy. 1994. An experimental study of Iinbreeding depression in a natural habitat. *Science* 266:271-273.

Kinzer, H.G., W.P. Meleney, R.E. Lange, and W.I. Houghton. 1983. *Psoroptes ovis* research with bighorn sheep in New Mexico. Desert Bighorn Council Transactions 27:6-8.

Lacy, R.C. 1993a. *VORTEX*: A computer simulation model for Population Viability Analysis. *Wildlife Research* 20:45-65.

Lacy, R.C. 1993b. Impacts of inbreeding in natural and captive populations of vertebrates: implications for conservation. *Perspectives in Biology and Medicine* 36:480-496.

Lacy, R.C. 1993/1994. What is Population (and Habitat) Viability Analysis? *Primate Conservation* 14/15:27-33.

Logan, K. A., L. L. Sweanor, T. K. Ruth and M. G. Hornocker. 1996. Cougars of the San Andres Mountains, New Mexico. Fed. Aid in Wildl. Restor. Proj. W-128-R. Final Report submitted to New Mexico Dep. Of Game and Fish, Santa Fe. 280pp.

McCarty and Miller. 1982.

McCarty and Miller. 1999.

Miller, P.S., and R.C. Lacy. 1999. *VORTEX: A Stochastic Simulation of the Extinction Process. Version 8 User's Manual*. Apple Valley, MN: Conservation Breeding Specialist Group (SSC/IUCN).

Morgart, J. R. and P. R. Krausman. 1983. Early breeding in bighorn sheep. *The Southwestern Naturalist* 28:460-461.

Ralls, K., J.D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* 2:185-193.

Sausman, K. A. 1984. Survival of captive-born *Ovis canadensis* in North American zoos. *Zoo Biology* 3:111-121.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. *BioScience* 1:131-134.

Singer, R.S., W.M. Boyce, I.A. Gardner, W.O. Johnson, and A.S. Fisher. 1998. Evaluation of bluetongue virus diagnostic tests in free-ranging bighorn sheep. *Preventative Veterinary Medicine* 35:265-282.

Sokal. 1981.

Soulé, M., M. Gilpin, W. Conway, and T. Foose. 1986. The millennium ark: How long a voyage, how many staterooms, how many passengers? *Zoo Biology* 5:101-113.

Turner, J.C., and C.G. Hansen. 1980. Reproduction. Pages 145-151 in G. Monson and L. Sumner, editors. *The desert bighorn: its life history, ecology, and management*. University of Arizona Press. Tucson.

Valdez and Krausman 1997 – Chapter 1 in new book

Appendix III: Sample *VORTEX* Input File

```
ANDMS.OUT     ***Output Filename***
Y     ***Graphing Files?***
N     ***Details each Iteration?***
500     ***Simulations***
100     ***Years***
10     ***Reporting Interval***
0     ***Definition of Extinction***
2     ***Populations***
Y     ***Inbreeding Depression?***
3.140000     ***Lethal equivalents***
50.000000     ***Percent of genetic load as lethals***
Y     ***EV concordance between repro and surv?***
0.500000     ***Correlation of EV among populations***
0     ***Types Of Catastrophes***
P     ***Monogamous, Polygynous, or Hermaphroditic***
3     ***Female Breeding Age***
3     ***Male Breeding Age***
16     ***Maximum Breeding Age***
50.000000     ***Sex Ratio (percent males)***
1     ***Maximum Litter Size (0 = normal distribution) *****
N     ***Density Dependent Breeding?***
SanAndres_N
SanAndres_S
2     ***Lower Age For Migration***
16     ***Upper Age For Migration***
F     ***MigratingSex: F, M, or Both***
100.000000 **Migration Survival (percent)**
0.000000 **Density for Emigration**
         10.000000    ***Percent migration from SanAndres_N***
10.000000             ***Percent migration from SanAndres_S***
90.00-(90*(SRAND((Y/2)+(R*100))<0.04))  **breeding
5.00  **EV-breeding
45.000000  *FMort age 0
17.000000  ***EV
20.000000  *FMort age 1
10.000000  ***EV
10.000000  *FMort age 2
10.000000  ***EV
10.000000  *Adult FMort
10.000000  ***EV
45.000000  *MMort age 0
17.000000  ***EV
35.000000  *MMort age 1
15.000000  ***EV
25.000000  *MMort age 2
15.000000  ***EV
25.000000  *Adult MMort
15.000000  ***EV
N     ***All Males Breeders?***
N     ***Answer--A--Known?***
Y     ***Answer--B--Known?***
50.000000     ***Percent Males Successful***
N     ***Answer--C--Known?***
Y     ***Start At Stable Age Distribution?***
25     ***Initial Population Size***
150     ***K***
0.000000     ***EV--K***
N     ***Trend In K?***
N      ***Harvest?***
```

Sample Vortex Input File (Contd.)

```
Y     ***Supplement?***
1     ***First Year Supplementation***
11     ***Last Year Supplementation***
5     ***Supplementation Interval***
0     ***Females Age 1 Supplemented***
0     ***Females Age 2 Supplemented***
16     ***Females Age 3 Supplemented***
0     ***Males Age 1 Supplemented***
0     ***Males Age 2 Supplemented***
16     ***Males Age 3 Supplemented***
90.00-(90*(SRAND((Y/2)+(R*100))<0.04))  **breeding
5.00  **EV-breeding
45.000000  *FMort age 0
17.000000  ***EV
20.000000  *FMort age 1
10.000000  ***EV
10.000000  *FMort age 2
10.000000  ***EV
10.000000  *Adult FMort
10.000000  ***EV
45.000000  *MMort age 0
17.000000  ***EV
35.000000  *MMort age 1
15.000000  ***EV
25.000000  *MMort age 2
15.000000  ***EV
25.000000  *Adult MMort
15.000000  ***EV
N     ***All Males Breeders?***
N     ***Answer--A--Known?***
Y     ***Answer--B--Known?***
50.000000     ***Percent Males Successful***
N     ***Answer--C--Known?***
Y     ***Start At Stable Age Distribution?***
25     ***Initial Population Size***
350     ***K***
0.000000     ***EV--K***
N     ***Trend In K?***
N      ***Harvest?***
Y     ***Supplement?***
3     ***First Year Supplementation***
13     ***Last Year Supplementation***
5     ***Supplementation Interval***
0     ***Females Age 1 Supplemented***
0     ***Females Age 2 Supplemented***
16     ***Females Age 3 Supplemented***
0     ***Males Age 1 Supplemented***
0     ***Males Age 2 Supplemented***
16     ***Males Age 3 Supplemented***
Y     ***AnotherSimulation?***
```

Appendix IV: Sample *VORTEX* Output File

```
VORTEX 8.21 -- simulation of genetic and demographic stochasticity

ANDMS.OUT
Mon Aug  9 21:32:46 1999


  2 population(s) simulated for 100 years, 500 iterations

  Extinction is defined as no animals of one or both sexes.

  Inbreeding depression modeled with 3.14000 lethal equivalents per individual,
    comprised of 1.57000 recessive lethal alleles,
    and 1.57000 lethal equivalents not subject to removal by selection.

  Minimum age at migration is 2.
  Maximum age at migration is 16.
  Females migrate.
  Percent survival during migration = 100.000000
  Threshold density (N/K) for emigration = 0.000000

  Migration matrix:
         SanAndres_NSanAndres_S
SanAndres_N   90.000  10.000
SanAndres_S   10.000  90.000

  First age of reproduction for females: 3   for males: 3
  Maximum breeding age (senescence): 16
  Sex ratio at birth (percent males): 50.000000

Population: SanAndres_N

  Polygynous mating;
    50.00 percent of adult males are successful breeders
   Therefore, 50.43 percent of adult males are in the breeding pool.
     (Male mating success is assumed to follow a Poisson distribution.)

  % adult females breeding = 90.00-(90*(SRAND((Y/2)+(R*100))<0.04))
   EV in % adult females breeding = 5.00 SD

   Of those females producing litters, ...
   100.00 percent of females produce litters of size 1

   45.00 percent mortality of females between ages 0 and 1
    EV in % mortality = 17.000000 SD
   20.00 percent mortality of females between ages 1 and 2
    EV in % mortality = 10.000000 SD
   10.00 percent mortality of females between ages 2 and 3
    EV in % mortality = 10.000000 SD
   10.00 percent mortality of adult females (3<=age<=16)
    EV in % mortality = 10.000000 SD
   45.00 percent mortality of males between ages 0 and 1
    EV in % mortality = 17.000000 SD
   35.00 percent mortality of males between ages 1 and 2
    EV in % mortality = 15.000000 SD
   25.00 percent mortality of males between ages 2 and 3
    EV in % mortality = 15.000000 SD
   25.00 percent mortality of adult males (3<=age<=16)
    EV in % mortality = 15.000000 SD
```

Sample *VORTEX* Output File (Contd.)

```
 EVs may be adjusted to closest values possible for binomial distribution.
    EV in reproduction and mortality will be concordant.
    Correlation of EV among populations = 0.500000

  Initial size of SanAndres_N:       25
    (set to reflect stable age distribution)
 Age 1     2     3     4     5     6     7     8     9    10    11    12    13    14
15    16    Total
     3     1     2     1     0     1     0     0     0     0     1     0     0     0
0     0       9  Males
     3     2     2     1     2     1     1     1     0     1     0     1     0     1
0     0      16  Females

  Carrying capacity = 150
    EV in Carrying capacity = 0.00 SD

  Animals added to SanAndres_N, year 1 through year 11 at 5 year intervals:
    16 females 3 years old
    16 males 3 years old

Deterministic population growth rate (based on females, with assumptions of
  no limitation of mates, no density dependence, and no inbreeding depression):

     r =  0.042     lambda = 1.043     R0 =     1.374
   Generation time for:  females = 7.55    males = 5.58

Stable age distribution:  Age class    females    males
                                0        0.146      0.146
                                1        0.077      0.077
                                2        0.059      0.048
                                3        0.051      0.035
                                4        0.044      0.025
                                5        0.038      0.018
                                6        0.033      0.013
                                7        0.028      0.009
                                8        0.024      0.007
                                9        0.021      0.005
                               10        0.018      0.003
                               11        0.016      0.002
                               12        0.014      0.002
                               13        0.012      0.001
                               14        0.010      0.001
                               15        0.009      0.001
                               16        0.007      0.000

Ratio of adult (>= 3) males to adult (>= 3) females: 0.375

Population: SanAndres_S

  Polygynous mating;
    50.00 percent of adult males are successful breeders
   Therefore, 50.43 percent of adult males are in the breeding pool.
     (Male mating success is assumed to follow a Poisson distribution.)

  % adult females breeding = 90.00-(90*(SRAND((Y/2)+(R*100))<0.04))
   EV in % adult females breeding = 5.00 SD

   Of those females producing litters, ...
   100.00 percent of females produce litters of size 1
```

Sample *VORTEX* Output File (Contd.)

```
   45.00 percent mortality of females between ages 0 and 1
    EV in % mortality = 17.000000 SD
   20.00 percent mortality of females between ages 1 and 2
    EV in % mortality = 10.000000 SD
   10.00 percent mortality of females between ages 2 and 3
    EV in % mortality = 10.000000 SD
   10.00 percent mortality of adult females (3<=age<=16)
    EV in % mortality = 10.000000 SD
   45.00 percent mortality of males between ages 0 and 1
    EV in % mortality = 17.000000 SD
   35.00 percent mortality of males between ages 1 and 2
    EV in % mortality = 15.000000 SD
   25.00 percent mortality of males between ages 2 and 3
    EV in % mortality = 15.000000 SD
   25.00 percent mortality of adult males (3<=age<=16)
    EV in % mortality = 15.000000 SD

    EVs may be adjusted to closest values possible for binomial distribution.
    EV in reproduction and mortality will be concordant.
    Correlation of EV among populations = 0.500000

  Initial size of SanAndres_S:       25
    (set to reflect stable age distribution)
 Age 1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16    Total
     3  1  2  1  0  1  0  0  0   0   1   0   0   0   0   0       9  Males
     3  2  2  1  2  1  1  1  0   1   0   1   0   1   0   0      16  Females

  Carrying capacity = 350
    EV in Carrying capacity = 0.00 SD

  Animals added to SanAndres_S, year 3 through year 13 at 5 year intervals:
    16 females 3 years old
    16 males 3 years old

Deterministic population growth rate (based on females, with assumptions of
  no limitation of mates, no density dependence, and no inbreeding depression):

     r =  0.042     lambda = 1.043     R0 =     1.374
   Generation time for:  females = 7.55    males = 5.58

Stable age distribution:  Age class    females    males
                              0        0.146      0.146
                              1        0.077      0.077
                              2        0.059      0.048
                              3        0.051      0.035
                              4        0.044      0.025
                              5        0.038      0.018
                              6        0.033      0.013
                              7        0.028      0.009
                              8        0.024      0.007
                              9        0.021      0.005
                             10        0.018      0.003
                             11        0.016      0.002
                             12        0.014      0.002
                             13        0.012      0.001
                             14        0.010      0.001
                             15        0.009      0.001
                             16        0.007      0.000
```

```
Ratio of adult (>= 3) males to adult (>= 3) females: 0.375
```

Sample *VORTEX* Output File (Contd.)

```
Population 1: SanAndres_N

Year 10
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  102.30 (   1.36 SE,   30.37 SD)
  Means across extant populations only:
     Population size =          102.30 (   1.36 SE,   30.37 SD)
     Expected heterozygosity =    0.985 (  0.000 SE,   0.004 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,   0.004 SD)
     Number of extant alleles =  104.27 (   0.94 SE,   21.07 SD)
     Lethal alleles / diploid =    1.55 (   0.01 SE,    0.20 SD)

Year 20
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  126.21 (   1.24 SE,   27.65 SD)
  Means across extant populations only:
     Population size =          126.21 (   1.24 SE,   27.65 SD)
     Expected heterozygosity =    0.983 (  0.000 SE,   0.005 SD)
     Observed heterozygosity =    0.995 (  0.000 SE,   0.007 SD)
     Number of extant alleles =  104.26 (   0.75 SE,   16.70 SD)
     Lethal alleles / diploid =    1.55 (   0.01 SE,    0.21 SD)

Year 30
     N[Extinct] =       3, P[E] =  0.006
     N[Surviving] =   497, P[S] =  0.994
     Mean size (all populations) =  124.51 (   1.33 SE,   29.82 SD)
  Means across extant populations only:
     Population size =          125.16 (   1.29 SE,   28.72 SD)
     Expected heterozygosity =    0.975 (  0.000 SE,   0.009 SD)
     Observed heterozygosity =    0.987 (  0.000 SE,   0.011 SD)
     Number of extant alleles =   78.50 (   0.65 SE,   14.43 SD)
     Lethal alleles / diploid =    1.53 (   0.01 SE,    0.25 SD)

Year 40
     N[Extinct] =       4, P[E] =  0.008
     N[Surviving] =   496, P[S] =  0.992
     Mean size (all populations) =  123.53 (   1.41 SE,   31.53 SD)
  Means across extant populations only:
     Population size =          124.34 (   1.36 SE,   30.31 SD)
     Expected heterozygosity =    0.967 (  0.001 SE,   0.012 SD)
     Observed heterozygosity =    0.980 (  0.001 SE,   0.016 SD)
     Number of extant alleles =   62.14 (   0.57 SE,   12.61 SD)
     Lethal alleles / diploid =    1.49 (   0.01 SE,    0.28 SD)

Year 50
     N[Extinct] =       4, P[E] =  0.008
     N[Surviving] =   496, P[S] =  0.992
     Mean size (all populations) =  120.88 (   1.52 SE,   34.04 SD)
  Means across extant populations only:
     Population size =          121.77 (   1.47 SE,   32.71 SD)
     Expected heterozygosity =    0.960 (  0.001 SE,   0.015 SD)
     Observed heterozygosity =    0.973 (  0.001 SE,   0.019 SD)
     Number of extant alleles =   51.25 (   0.53 SE,   11.72 SD)
     Lethal alleles / diploid =    1.46 (   0.01 SE,    0.31 SD)
```

Sample *VORTEX* Output File (Contd.)

```
Year 60
     N[Extinct] =       4, P[E] =  0.008
     N[Surviving] =   496, P[S] =  0.992
  Mean size (all populations) =  119.99 (   1.55 SE,   34.67 SD)
  Means across extant populations only:
     Population size =          120.88 (   1.50 SE,   33.33 SD)
     Expected heterozygosity =    0.952 (  0.001 SE,   0.020 SD)
     Observed heterozygosity =    0.965 (  0.001 SE,   0.023 SD)
     Number of extant alleles =   43.42 (   0.47 SE,   10.47 SD)
     Lethal alleles / diploid =    1.41 (   0.01 SE,    0.32 SD)

Year 70
     N[Extinct] =       6, P[E] =  0.012
     N[Surviving] =   494, P[S] =  0.988
     Mean size (all populations) =  119.38 (   1.58 SE,   35.30 SD)
  Means across extant populations only:
     Population size =          120.76 (   1.49 SE,   33.22 SD)
     Expected heterozygosity =    0.943 (  0.001 SE,   0.024 SD)
     Observed heterozygosity =    0.956 (  0.001 SE,   0.028 SD)
     Number of extant alleles =   37.75 (   0.41 SE,    9.10 SD)
     Lethal alleles / diploid =    1.34 (   0.02 SE,    0.34 SD)

Year 80
     N[Extinct] =       6, P[E] =  0.012
     N[Surviving] =   494, P[S] =  0.988
     Mean size (all populations) =  118.15 (   1.59 SE,   35.60 SD)
  Means across extant populations only:
     Population size =          119.54 (   1.51 SE,   33.48 SD)
     Expected heterozygosity =    0.935 (  0.001 SE,   0.027 SD)
     Observed heterozygosity =    0.948 (  0.001 SE,   0.033 SD)
     Number of extant alleles =   32.94 (   0.38 SE,    8.35 SD)
     Lethal alleles / diploid =    1.27 (   0.02 SE,    0.34 SD)

Year 90
     N[Extinct] =       7, P[E] =  0.014
     N[Surviving] =   493, P[S] =  0.986
     Mean size (all populations) =  116.43 (   1.62 SE,   36.33 SD)
  Means across extant populations only:
     Population size =          118.04 (   1.53 SE,   33.94 SD)
     Expected heterozygosity =    0.928 (  0.002 SE,   0.034 SD)
     Observed heterozygosity =    0.941 (  0.002 SE,   0.040 SD)
     Number of extant alleles =   29.33 (   0.33 SE,    7.31 SD)
     Lethal alleles / diploid =    1.20 (   0.02 SE,    0.35 SD)

Year 100
     N[Extinct] =       8, P[E] =  0.016
     N[Surviving] =   492, P[S] =  0.984
     Mean size (all populations) =  115.88 (   1.70 SE,   38.05 SD)
  Means across extant populations only:
     Population size =          117.73 (   1.60 SE,   35.46 SD)
     Expected heterozygosity =    0.920 (  0.001 SE,   0.033 SD)
     Observed heterozygosity =    0.933 (  0.002 SE,   0.039 SD)
     Number of extant alleles =   26.26 (   0.30 SE,    6.61 SD)
     Lethal alleles / diploid =    1.14 (   0.02 SE,    0.36 SD)

In 500 simulations of SanAndres_N for 100 years:
  8 went extinct and 492 survived.
```

```
This gives a probability of extinction of 0.0160 (0.0056 SE),
  or a probability of success of         0.9840 (0.0056 SE).
```

Sample *VORTEX* Output File (Contd.)

```
8 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 55.00 years (9.61 SE, 27.18 SD).

Means across all populations (extant and extinct) ...
Mean final population was 115.88 (1.70 SE, 38.05 SD)

   Age 1       2   Adults    Total
   11.92    7.55   17.57     37.04  Males
   11.88    9.60   57.35     78.84  Females

Means across extant populations only ...
Mean final population for successful cases was 117.73 (1.60 SE, 35.46 SD)

   Age 1       2   Adults    Total
   12.00    7.00   17.85     37.64  Males
   12.00    9.00   58.28     80.12  Females

During years of harvest and/or supplementation
  mean growth rate (r) was 0.5425 (0.0072 SE, 0.2783 SD)

During years without harvest or supplementation,
  mean growth rate (r) was 0.0439 (0.0009 SE, 0.2040 SD)

Across all years, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0589 (0.0010 SE, 0.2235 SD)

Final expected heterozygosity was      0.9204 ( 0.0015 SE,  0.0328 SD)
Final observed heterozygosity was      0.9332 ( 0.0018 SE,  0.0391 SD)
Final number of alleles was             26.26 (   0.30 SE,    6.61 SD)
Number of lethal alleles per diploid     1.14 (   0.02 SE,    0.36 SD)
*************************************************************************


Population 2: SanAndres_S

Year 10
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  117.33 (   1.85 SE,   41.41 SD)
  Means across extant populations only:
     Population size =           117.33 (   1.85 SE,   41.41 SD)
     Expected heterozygosity =    0.988 (  0.000 SE,   0.002 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,   0.004 SD)
     Number of extant alleles =  124.19 (   1.11 SE,   24.81 SD)
     Lethal alleles / diploid =    1.58 (   0.01 SE,    0.18 SD)

Year 20
     N[Extinct] =       1, P[E] =  0.002
     N[Surviving] =   499, P[S] =  0.998
     Mean size (all populations) =  179.61 (   3.28 SE,   73.34 SD)
  Means across extant populations only:
     Population size =           179.86 (   3.28 SE,   73.20 SD)
     Expected heterozygosity =    0.985 (  0.000 SE,   0.004 SD)
     Observed heterozygosity =    0.995 (  0.000 SE,   0.005 SD)
     Number of extant alleles =  124.18 (   1.25 SE,   27.91 SD)
     Lethal alleles / diploid =    1.55 (   0.01 SE,    0.21 SD)
```

Sample *VORTEX* Output File (Contd.)

```
Year 30
     N[Extinct] =       1, P[E] =  0.002
     N[Surviving] =   499, P[S] =  0.998
  Mean size (all populations) =  185.47 (   3.56 SE,   79.65 SD)
  Means across extant populations only:
     Population size =          185.76 (   3.56 SE,   79.46 SD)
     Expected heterozygosity =    0.978 (  0.000 SE,   0.008 SD)
     Observed heterozygosity =    0.988 (  0.000 SE,   0.010 SD)
     Number of extant alleles =   89.52 (   1.00 SE,   22.29 SD)
     Lethal alleles / diploid =    1.53 (   0.01 SE,    0.25 SD)

Year 40
     N[Extinct] =       1, P[E] =  0.002
     N[Surviving] =   499, P[S] =  0.998
     Mean size (all populations) =  185.07 (   3.72 SE,   83.19 SD)
  Means across extant populations only:
     Population size =          185.38 (   3.72 SE,   82.99 SD)
     Expected heterozygosity =    0.970 (  0.001 SE,   0.013 SD)
     Observed heterozygosity =    0.981 (  0.001 SE,   0.015 SD)
     Number of extant alleles =   68.99 (   0.80 SE,   17.87 SD)
     Lethal alleles / diploid =    1.50 (   0.01 SE,    0.27 SD)

Year 50
     N[Extinct] =       1, P[E] =  0.002
     N[Surviving] =   499, P[S] =  0.998
     Mean size (all populations) =  182.10 (   3.77 SE,   84.23 SD)
  Means across extant populations only:
     Population size =          182.39 (   3.76 SE,   84.07 SD)
     Expected heterozygosity =    0.962 (  0.001 SE,   0.017 SD)
     Observed heterozygosity =    0.972 (  0.001 SE,   0.019 SD)
     Number of extant alleles =   56.02 (   0.68 SE,   15.20 SD)
     Lethal alleles / diploid =    1.46 (   0.01 SE,    0.30 SD)

Year 60
     N[Extinct] =       1, P[E] =  0.002
     N[Surviving] =   499, P[S] =  0.998
     Mean size (all populations) =  173.56 (   3.69 SE,   82.56 SD)
  Means across extant populations only:
     Population size =          173.89 (   3.68 SE,   82.30 SD)
     Expected heterozygosity =    0.954 (  0.001 SE,   0.021 SD)
     Observed heterozygosity =    0.965 (  0.001 SE,   0.023 SD)
     Number of extant alleles =   46.49 (   0.57 SE,   12.73 SD)
     Lethal alleles / diploid =    1.40 (   0.01 SE,    0.32 SD)

Year 70
     N[Extinct] =       3, P[E] =  0.006
     N[Surviving] =   497, P[S] =  0.994
     Mean size (all populations) =  171.28 (   3.83 SE,   85.61 SD)
  Means across extant populations only:
     Population size =          172.27 (   3.81 SE,   84.90 SD)
     Expected heterozygosity =    0.947 (  0.001 SE,   0.022 SD)
     Observed heterozygosity =    0.959 (  0.001 SE,   0.024 SD)
     Number of extant alleles =   39.84 (   0.48 SE,   10.81 SD)
     Lethal alleles / diploid =    1.35 (   0.02 SE,    0.34 SD)
```

Sample *VORTEX* Output File (Contd.)

```
Year 80
     N[Extinct] =       6, P[E] =  0.012
     N[Surviving] =   494, P[S] =  0.988
     Mean size (all populations) =  170.73 (   3.84 SE,   85.78 SD)
  Means across extant populations only:
     Population size =           172.69 (   3.80 SE,   84.41 SD)
     Expected heterozygosity =    0.939 (  0.001 SE,   0.027 SD)
     Observed heterozygosity =    0.950 (  0.001 SE,   0.029 SD)
     Number of extant alleles =   34.75 (   0.42 SE,    9.35 SD)
     Lethal alleles / diploid =    1.28 (   0.02 SE,    0.34 SD)

Year 90
     N[Extinct] =       8, P[E] =  0.016
     N[Surviving] =   492, P[S] =  0.984
     Mean size (all populations) =  160.69 (   3.66 SE,   81.85 SD)
  Means across extant populations only:
     Population size =           163.24 (   3.61 SE,   80.01 SD)
     Expected heterozygosity =    0.931 (  0.001 SE,   0.028 SD)
     Observed heterozygosity =    0.942 (  0.002 SE,   0.033 SD)
     Number of extant alleles =   30.48 (   0.37 SE,    8.29 SD)
     Lethal alleles / diploid =    1.21 (   0.02 SE,    0.35 SD)

Year 100
     N[Extinct] =      10, P[E] =  0.020
     N[Surviving] =   490, P[S] =  0.980
     Mean size (all populations) =  163.09 (   3.77 SE,   84.34 SD)
  Means across extant populations only:
     Population size =           166.34 (   3.71 SE,   82.02 SD)
     Expected heterozygosity =    0.924 (  0.001 SE,   0.029 SD)
     Observed heterozygosity =    0.936 (  0.002 SE,   0.034 SD)
     Number of extant alleles =   27.40 (   0.33 SE,    7.34 SD)
     Lethal alleles / diploid =    1.15 (   0.02 SE,    0.35 SD)


In 500 simulations of SanAndres_S for 100 years:
  10 went extinct and 490 survived.

This gives a probability of extinction of 0.0200 (0.0063 SE),
  or a probability of success of          0.9800 (0.0063 SE).

10 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 72.00 years (6.92 SE, 21.88 SD).

Means across all populations (extant and extinct) ...
Mean final population was 163.09 (3.77 SE, 84.34 SD)

   Age 1       2   Adults    Total
   16.91   11.10   31.41     59.41  Males
   16.24   12.89   74.54    103.67  Females

Means across extant populations only ...
Mean final population for successful cases was 166.34 (3.71 SE, 82.02 SD)

   Age 1       2   Adults    Total
   17.00   11.00   32.05     60.63  Males
```

```
   16.00   13.00   76.06    105.79  Females

During years of harvest and/or supplementation
  mean growth rate (r) was 0.5130 (0.0078 SE, 0.3031 SD)
```

Sample *VORTEX* Output File (Contd.)

```
During years without harvest or supplementation,
  mean growth rate (r) was 0.0050 (0.0009 SE, 0.2063 SD)

Across all years, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0204 (0.0010 SE, 0.2272 SD)

Final expected heterozygosity was      0.9236 ( 0.0013 SE,  0.0294 SD)
Final observed heterozygosity was      0.9363 ( 0.0015 SE,  0.0338 SD)
Final number of alleles was             27.40 (   0.33 SE,    7.34 SD)
Number of lethal alleles per diploid     1.15 (   0.02 SE,    0.35 SD)
*************************************************************************

 ********  Meta-population Summary  ********

Year 10
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  219.63 (   2.73 SE,   60.96 SD)
  Means across extant populations only:
     Population size =           219.63 (   2.73 SE,   60.96 SD)
     Expected heterozygosity =    0.992 (  0.000 SE,   0.001 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,   0.003 SD)
     Number of extant alleles =  194.01 (   1.29 SE,   28.96 SD)
     Lethal alleles / diploid =    1.57 (   0.01 SE,    0.15 SD)

Year 20
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  305.83 (   3.99 SE,   89.11 SD)
  Means across extant populations only:
     Population size =           305.83 (   3.99 SE,   89.11 SD)
     Expected heterozygosity =    0.989 (  0.000 SE,   0.002 SD)
     Observed heterozygosity =    0.995 (  0.000 SE,   0.004 SD)
     Number of extant alleles =  169.03 (   1.20 SE,   26.85 SD)
     Lethal alleles / diploid =    1.55 (   0.01 SE,    0.17 SD)

Year 30
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  309.98 (   4.37 SE,   97.82 SD)
  Means across extant populations only:
     Population size =           309.98 (   4.37 SE,   97.82 SD)
     Expected heterozygosity =    0.982 (  0.000 SE,   0.006 SD)
     Observed heterozygosity =    0.987 (  0.000 SE,   0.007 SD)
     Number of extant alleles =  110.71 (   0.98 SE,   21.87 SD)
     Lethal alleles / diploid =    1.53 (   0.01 SE,    0.22 SD)

Year 40
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  308.60 (   4.62 SE,  103.35 SD)
  Means across extant populations only:
     Population size =           308.60 (   4.62 SE,  103.35 SD)
     Expected heterozygosity =    0.974 (  0.000 SE,   0.009 SD)
     Observed heterozygosity =    0.980 (  0.001 SE,   0.012 SD)
     Number of extant alleles =   81.26 (   0.80 SE,   17.97 SD)
```

```
     Lethal alleles / diploid =    1.49 (   0.01 SE,    0.25 SD)
```

Sample *VORTEX* Output File (Contd.)

```
Year 50
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  302.98 (   4.81 SE,  107.57 SD)
  Means across extant populations only:
     Population size =          302.98 (   4.81 SE,  107.57 SD)
     Expected heterozygosity =    0.967 (  0.001 SE,   0.013 SD)
     Observed heterozygosity =    0.973 (  0.001 SE,   0.016 SD)
     Number of extant alleles =   63.90 (   0.69 SE,   15.38 SD)
     Lethal alleles / diploid =    1.46 (   0.01 SE,    0.28 SD)

Year 60
     N[Extinct] =       0, P[E] =  0.000
     N[Surviving] =   500, P[S] =  1.000
     Mean size (all populations) =  293.55 (   4.74 SE,  106.06 SD)
  Means across extant populations only:
     Population size =          293.55 (   4.74 SE,  106.06 SD)
     Expected heterozygosity =    0.959 (  0.001 SE,   0.018 SD)
     Observed heterozygosity =    0.965 (  0.001 SE,   0.019 SD)
     Number of extant alleles =   52.35 (   0.59 SE,   13.14 SD)
     Lethal alleles / diploid =    1.41 (   0.01 SE,    0.30 SD)

Year 70
     N[Extinct] =       1, P[E] =  0.002
     N[Surviving] =   499, P[S] =  0.998
     Mean size (all populations) =  290.66 (   4.96 SE,  110.89 SD)
  Means across extant populations only:
     Population size =          291.24 (   4.93 SE,  110.24 SD)
     Expected heterozygosity =    0.951 (  0.001 SE,   0.021 SD)
     Observed heterozygosity =    0.958 (  0.001 SE,   0.021 SD)
     Number of extant alleles =   44.19 (   0.50 SE,   11.20 SD)
     Lethal alleles / diploid =    1.35 (   0.01 SE,    0.32 SD)

Year 80
     N[Extinct] =       3, P[E] =  0.006
     N[Surviving] =   497, P[S] =  0.994
     Mean size (all populations) =  288.88 (   4.96 SE,  110.94 SD)
  Means across extant populations only:
     Population size =          290.60 (   4.89 SE,  109.03 SD)
     Expected heterozygosity =    0.943 (  0.001 SE,   0.027 SD)
     Observed heterozygosity =    0.949 (  0.001 SE,   0.027 SD)
     Number of extant alleles =   38.01 (   0.44 SE,    9.76 SD)
     Lethal alleles / diploid =    1.28 (   0.01 SE,    0.32 SD)

Year 90
     N[Extinct] =       5, P[E] =  0.010
     N[Surviving] =   495, P[S] =  0.990
     Mean size (all populations) =  277.12 (   4.83 SE,  108.11 SD)
  Means across extant populations only:
     Population size =          279.91 (   4.72 SE,  105.01 SD)
     Expected heterozygosity =    0.935 (  0.001 SE,   0.031 SD)
     Observed heterozygosity =    0.941 (  0.002 SE,   0.036 SD)
     Number of extant alleles =   33.14 (   0.38 SE,    8.55 SD)
     Lethal alleles / diploid =    1.20 (   0.01 SE,    0.33 SD)
```

Sample *VORTEX* Output File (Contd.)

```
Year 100
     N[Extinct] =       7, P[E] =  0.014
     N[Surviving] =   493, P[S] =  0.986
     Mean size (all populations) =  278.97 (   5.03 SE,  112.44 SD)
  Means across extant populations only:
     Population size =           282.92 (   4.87 SE,  108.19 SD)
     Expected heterozygosity =    0.928 (  0.001 SE,   0.030 SD)
     Observed heterozygosity =    0.934 (  0.001 SE,   0.033 SD)
     Number of extant alleles =   29.49 (   0.35 SE,    7.67 SD)
     Lethal alleles / diploid =    1.14 (   0.02 SE,    0.34 SD)


In 500 simulations of Meta-population for 100 years:
  7 went extinct and 493 survived.
This gives a probability of extinction of 0.0140 (0.0053 SE),
  or a probability of success of          0.9860 (0.0053 SE).

7 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 81.14 years (4.14 SE, 10.95 SD).

Means across all populations (extant and extinct) ...
Mean final population was 278.97 (5.03 SE, 112.44 SD)

   Age 1       2   Adults    Total
   28.83   18.65   48.98     96.46  Males
   28.12   22.50  131.89    182.51  Females

Means across extant populations only ...
Mean final population for successful cases was 282.92 (4.87 SE, 108.19 SD)

   Age 1       2   Adults    Total
   29.00   18.00   49.68     97.83  Males
   28.00   22.00  133.77    185.10  Females

During years of harvest and/or supplementation
  mean growth rate (r) was 0.2700 (0.0034 SE, 0.1860 SD)

During years without harvest or supplementation,
  mean growth rate (r) was 0.0222 (0.0007 SE, 0.1612 SD)

Across all years, prior to carrying capacity truncation,
  mean growth rate (r) was 0.0371 (0.0008 SE, 0.1731 SD)

Final expected heterozygosity was      0.9279 ( 0.0014 SE,  0.0304 SD)
Final observed heterozygosity was      0.9343 ( 0.0015 SE,  0.0325 SD)
Final number of alleles was             29.49 (   0.35 SE,    7.67 SD)
Number of lethal alleles per diploid     1.14 (   0.02 SE,    0.34 SD)
*************************************************************************
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POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE DESERT BIGHORN SHEEP OF NEW MEXICO
(*Ovis canadensis*)

Sunrise Springs
Santa Fe, New Mexico
27-30 July 1999

Final Report
November 1999

Section 4
Threats Working Group Report

Threats Working Group Report

After brainstorming issues and problems that threaten the short-term survival of Bighorn Sheep in New Mexico, the group defined the issues of concern and developed goals and actions designed to address the problems. Because of the overlap of issues between the threats group and the management group, several of the issues the threats group initially identified, such as habitat, management and public issues, were covered by the management group. The issues and goals below are listed in order of priority as determined by paired ranking.

1. Predation

There are 3 principle approaches to managing the effects of predation on bighorn populations: reduce the number of predators, manipulate bighorn habitat to enhance visibility and reduce cover for predators, and/or increase the prey:predator ratio which may reduce predation on bighorn. The Management Working Group (MWG) addressed the relationship between habitat and predation. The discussion below briefly illuminates this issue but the details are covered by the MWG. The following goals address predator management and predator/prey dynamics.

<u>Goal 1. Manage predators /prey based on science by obtaining reliable knowledge of the effectiveness of predator control methods to enhance bighorn sheep populations.</u>

Action 1:	Review other states' procedures.
Responsible party:	NMDGF
Timeline:	Before 1 October 1999
Action 2:	Design predator control experiments using controls (e.g., San Andres metapopulation), randomization, and replication
Responsible party:	NMDGF and other pertinent cooperators
Timeline:	Prior to implementation of predator control measures.
Action 3:	The trigger for implementing predator control procedures is site and situation specific. However, when populations fall below an identified size for population viabilty (e.g., >25 ewes) and predation has been demonstrated to be the primary proximate cause of mortality, predator control measures should be implemented.
Responsible party:	NMDGF
Timeline:	Prior to implementing predator control procedures.
Action 4:	Experimental design should be peer reviewed.
Responsible party:	NMDGF to establish peer review protocol
Timeline:	When significant management actions are considered or significant resources are committed by NMDGF.

Goal 2. Determine predator/prey dynamics in multiple prey systems.

Action 1:	Engage in collaborative efforts to develop and implement research strategies that address the effects of alternate prey populations (i.e., the role of buffer species such as deer).
Responsible party:	Interagency and research communities
Timeline:	As soon as possible.
Action 2:	Monitor population status of cougars, bighorn, and alternate ungulates using the best available scientific knowledge.
Responsible party:	Site specific appropriate agencies (i.e., NMDGF, USFWS, BLM, interested landowners)
Action 3:	Assess the effect of increasing the prey:predator ratio on bighorn predation rates.
Responsible party:	Site specific appropriate agencies (i.e., NMDGF, USFWS, BLM, other landowners)
Action 4:	Evaluate characteristics of bighorn habitat with regard to predation vulnerability.
Responsible party:	NMDGF, USFWS, BLM, interested landowners

Goal 3. Develop public understanding and support for NMDGF management of bighorn and predators on bighorn ranges.

Action 1:	Make available to the public all plans and reports for review and comment
Responsible party:	NMDGF and other relevant agencies
Timeline:	At the onset of any predator management plan and continued as needed throughout the life of the plan.
Action 2:	Identify and involve stakeholders in the initial planning and implementation phases and throughout the course of the program.
Responsible party:	NMDGF and other relevant agencies
Timeline:	At the onset of any predator management plan and continued as needed throughout the life of the plan.
Action 3:	Conduct more active public education outreach on predator /prey issues.
Responsible party:	NMDGF and other relevant agencies
Timeline:	At the onset of any predator management plan and continued as needed throughout the life of the plan.

2. Disease

Scabies is a significant problem in the San Andres population and is a potential problem for all other populations in New Mexico because of potential genetic predisposition of host/mite, lack of reliable biological knowledge about alternate host transmission of mites, and demographic effects on small populations. Scabies appears impractical to control in New Mexico and eradication may be more reasonable than control. Scabies can predispose bighorn to predation.

<u>Goal 1: Evaluate options that minimize scabies as a management issue in the San Andres Mountains.</u>

Action 1:	A panel of experts should convene to present current scientific information regarding disease and genetics to the USFWS, NMDGF and White Sands Missile Range (US Army) for inclusion in the Draft Document for the Recovery of Desert Bighorn Sheep in the San Andres Mountains, New Mexico. This document is in the final stage and input must be received immediately.
Responsible party:	NMDGF to coordinate
Timeline:	Immediately

Action 2:	Incorporate the most current scientific knowledge into the final San Andres Mountain Desert Bighorn Recovery Plan.
Responsible party:	USFWS

Action 3:	Reevaluate the design of the sentinel ram study and translocation of bighorn into the San Andres Mountains proposed in the Draft Document for the Recovery of Desert Bighorn Sheep in the San Andres Mountains, New Mexico, to provide alternative adaptive management strategies. This document is in the final stage and input must be received immediately.
Responsible party:	USFWS and NMDGF
Timeline:	Immediately
	Option 1: Restock the San Andres Mountains (SAM) with desert bighorn from Arizona into vacant SAM range (i.e., scabies infected animals will be removed prior to restocking effort).

Comment: There was substantial group discussion regarding the proposed sentinel ram study and restocking of the SAM. Concerns were voiced that there might be different scabies mites on AZ vs. NM bighorn. Additionally, the issue of diluting genetic resistant bighorn stock out of AZ when bred with Red Rock sheep raised concern.

Option 2:	Restock the SAM with Red Rock bighorn.

Action 4:	Evaluate Turner Enterprises' offer to construct a boundary fence completely around the Fra Cristobal (FC) range which may

	minimize bighorn emigration and potential disease transmission from the SAM to FC.
Responsible party:	NMDGF
Timeline:	As soon as possible

Comment: Members of the group expressed concern regarding the ecological implications (i.e., corridor impediment) of a fenced bighorn enclosure/predator exclosure of the FC.

Bluetongue: All bighorn populations in New Mexico are potentially threatened. There are more documented cases of bluetongue virus than of pasteurella pnuemonia. Bighorn that had no titer for bluetongue while at Red Rock did have positive titers after transplantation. Direct mortality puts other populations at risk. There are separate patterns of infection between bighorn and cattle at Red Rock but domestic livestock and other native and nonnative ungulates serve as a source to bighorn. Therefore, livestock:bighorn interaction is very important in all bighorn populations in New Mexico.

<u>Goal 2: Minimize fitness implications of presence of bluetongue.</u>

Elaeophora is a problem in the Fra Cristobal population and a potential problem in all populations causing severe debilitation of bighorn. The obligate requirements are an infected mule deer population and an appropriate vector (horseflies).

<u>Goal 3: Gather additional scientific information to determine whether Elaeophora is an important pathogen.</u>

Viruses and bacteria are potentially a threat in all populations in New Mexico resulting in severe debilitation to bighorn.

<u>Goal 4: Minimize potential interaction between domestic sheep and cattle and bighorn sheep.</u>

Action 1:	Acquire or convert (to cattle) existing domestic sheep grazing allotments in occupied or potential bighorn habitat.
Responsible party:	Responsible land management agencies
Timeline:	When possible
Action 2:	Avoid translocating bighorn into habitat adjacent to domestic sheep.
Responsible party:	NMDGF
Timeline:	Always
Action 3:	Determine research needs regarding disease transmission between bighorn and other livestock.
Responsible party:	Relevant land management agencies
Timeline:	As soon as possible

Comment: Although scientific evidence demonstrating transmission of diseases from cattle to bighorn are lacking, cattle harbor many of the same diseases (e.g. blue tongue, *Pasteurella* spp.) that are devastating to bighorn populations. Therefore, we recommend that managers minimize contact between bighorn and cattle, when possible. Acquisition of grazing allotments is an agency specific process. The BLM requires that allotments either be actively grazed or be retired by modification of land use plans. The US Forest Service (USFS) does not require that allotments be actively grazed. Consult other states and land management agencies regarding acquisition procedure and success.

Action 4:	Educate agricultural public about harmful implications of interactions between livestock and bighorn.
Responsible party:	Agencies
Timeline:	On-going

Action 5:	Evaluate the benefits of removing exotic game species (oryx, ibex, Barbary sheep) from bighorn habitat, because they are potential disease reservoirs, and implement Problem 6, Strategy 12 of the New Mexico Long-range Plan for Desert Bighorn Sheep Management, 1995-2002.
Responsible party:	NMDGF
Timeline:	On-going

Action 6:	Develop policy to exclude use of exotic or domestic pack ungulates in bighorn habitat through legislation and planning process.
Responsible party:	Appropriate agencies
Timeline:	When plans come up for review or as identified as a problem area.

<u>Goal 5: Identify and focus research efforts on diseases that have negative population impacts.</u>

Action 1:	Review available scientific information
Responsible party:	Bighorn managers in coordination with disease experts
Timeline:	Immediately

Action 2:	Collaboratively develop experimental studies
Responsible party:	Bighorn managers
Timeline:	Immediately (and on-going)

Action 3:	Work with research scientists to find funding
Responsible party:	Agencies
Timeline:	Immediately (and on-going)

Goal 6: Manage translocations, supplementations, and movement corridors to minimize disease impacts.

Action 1:	When translocating bighorn, evaluate source and recipient populations for compatible health and disease profiles.
Responsible party:	NMDGF
Timeline:	Always
Action 2:	Monitor bighorn populations (both wild and captive) for density dependent disease implications
Responsible party:	NMDGF
Timeline:	At least every other year

Goal 7: Ensure availability of source stock by minimizing consequences of disease in captive and free-ranging populations.

Action 1:	Develop multiple sources of translocation stock.
Responsible party:	NMDGF
Timeline:	As soon as possible
Option 1:	Red Rock (Note: RR is the current source population but may be more vulnerable to scabies)
Option 2:	Free-ranging populations in NM (e.g. FC but note implications of *Elaeophora*)
Option 3:	Out of state (e.g. AZ, Mexico but note unknown disease implications).
Action 2:	Include disease detection in Red Rock Management Plan. (See Problem 6 of Red Rock Plan).
Responsible party:	NMDGF
Timeline:	As soon as possible

3. Genetics and Demographics

Persistence of small populations is an inherent problem for bighorn in New Mexico. Populations are at higher risk of extinction due to small size. Because of small population sizes and small habitat patches available there is a need to continue metapopulation management and to collect genetic samples whenever possible. Active management may be needed (i.e., move animals within a metapopulation). It is also necessary to determine how tightly to adhere to a metapopulation definition.

Goal 1: Conserve and enhance genetic variation in desert bighorn.

Action 1:	Manage metapopulations through artificial or natural exchange, with preference on natural exchange.
Responsible party:	NMDGF
Timeline:	As soon as possible

Option 1:	NMDGF should move sheep if necessary. (e.g. consider barriers, genetic issues).
Option 2:	Agencies should conserve and restore movement corridors.
Option 3:	NMDGF should allow extinction of a local population having no unique genetic characteristics if appropriate, (e.g., disease epizootic), if resources could be better applied to another population. The habitat patch could be restocked when desired.

Action 2:	Introduce desert bighorn from sources outside of NM.
Responsible party:	NMDGF

Action 3:	Develop and implement genetic management plan for all populations re: Problem 7, Strategy 7 from RR Mgmt. Plan.
Responsible party:	NMDGF
Timeline:	As soon as possible

Action 4:	Determine heterozygosity whenever bighorn are handled and evaluate with respect to existing and future samples (e.g. Red Rock).
Responsible party:	NMDGF
Timeline:	On-going

Action 5:	Determine whether theoretical risks associated with genetics and demographic problems pose a real risk to populations.
Responsible party:	NMDGF
Timeline:	As soon as possible

Goal 2: Acknowledge habitat limitations on demographics.

Action 1:	Communicate to public and agency leaders that limited bighorn habitat in NM will limit growth of populations even when all bighorn ranges are occupied.
Responsible party:	NMDGF and other relevant agencies
Timeline:	At onset of program.

Comment: Bighorn populations in NM will require active management to maintain viability. Managers should monitor the demographic effects on small populations. Furthermore, managers must clarify within their agencies and the public sector the need for long term, intensive, active management. This is a necessary component of public education, as stated in Predation Goal 3.

4. Science issues

Science Issues discussed by the Threats Working Group included: the lack of scientific knowledge, lack of monitoring, conflicting expert opinion, and lack of reliable biological knowledge. Participants commonly come to the table with solutions before the problems are identified and systematically analyzed. Often, scientists do not identify high priority problems to work on, and there is a lack of scientific method or poor scientific design used. Managers should identify scientific research needs. Lack of funding can preclude researching priority problems. Managers and scientists need to clearly articulate their research needs and sell them to their agencies. Proactive/adaptive management should be implemented

<u>Goal 1: Agencies should identify important problems and conduct appropriate research to determine level of impact.</u>

Action 1:	Assess limiting factors for juvenile survival in wild populations.
Responsible party:	NMDGF, other agencies, and interested parties
Timeline:	As soon as possible

<u>Goal 2: Desert bighorn states should collaborate in scientific research projects.</u>

Action 1:	Formalize a committee to meet annually at Desert Bighorn Council (DBC) Meeting to share results and prioritize research.
Responsible party:	DBC Technical Advisory Committee
Timeline:	Prior to the next DBC annual meeting in April 2000.
Action 2:	The committee formed in Action 1 should explore possibilities, feasibility, desirability of joint venture style of management approach across states. (This issue was also addressed by the Management Working Group.)
Action 3:	Pool financial and personnel resources and expertise among states and agencies.
Responsible party:	Sheep managers
Timeline:	As soon as possible and on-going
Action 4:	Plan and conduct major research projects at landscape levels with adjoining desert bighorn states.
Responsible party:	NMDGF
Timeline:	As soon as possible and on-going

<u>Goal 3: Ensure good communication between scientific community and managers.</u>

Action 1:	Facilitate annual meetings between agencies, scientists, and other interested parties to share latest research and other information with the emphasis on science.
Responsible party:	NMDGF
Timeline:	As soon as possible, then annually
Action 2:	Continue meeting with existing advisory groups (i.e., Central Desert Bighorn Advisory Council) but expand focus and promote existence and participation.
Responsible party:	NMDGF
Timeline:	On-going

Action 3:	Create a science advisory committee to make scientific recommendations to managing agencies, administrators, and decision makers.
Responsible party:	NMDGF
Timeline:	Within next 6 months

5. Competition of exotics and livestock (non-disease issues)
Although it is difficult to demonstrate that livestock and exotic ungulates compete with bighorns and influence viability, potential for competition exists where habitats and diets overlap. There is an on-going need for research that studies competition between bighorn and exotic ungulates and domestic livestock.

<u>Goal 1: Eliminate all deleterious impacts of exotic wild ungulates from bighorn ranges in New Mexico.</u>

Action 1:	Implement guidelines in New Mexico Long-range plan for desert bighorn sheep.
Responsible party:	NMDGF
Timeline:	
Action 2:	Evaluate the benefits of restoring the Florida Mountains to bighorn habitat by eradicating ibex.
Responsible party:	NMDGF
Timeline:	
Action 3:	Consider implementing year round depredation hunts on oryx in suitable, as well as occupied, bighorn habitat when adverse impacts are noted relating to oryx occupation of bighorn range.
Responsible party:	Appropriate agencies
Timeline:	
Action 4:	Consider implementing an exotic “shoot on site” policy for oryx and barbary sheep in suitable, as well as occupied, bighorn habitat.
Responsible party:	Appropriate agencies
Timeline:	
Action 5:	Continue to make agencies aware of critical importance of bighorn habitat in the restoration of the species.
Responsible party:	NMDGF
Timeline:	

Comments: The current oryx plan does not address bighorn management goals (applies to Actions 3 & 4 only). Refer to research section of Threats Working Group (TWG). Actions listed under disease section apply to competition issues (e.g., allotment acquisition, retirement, etc.). There was concern within the TWG that public input was not included in this workshop. Additionally, we recognized that all cattle grazing practices are not equal. Land use practices differ among landowners and agencies. The potential impact of competition between livestock should be evaluated on a site-specific basis.

6. Environmental Issues

Issues discussed include: global climate change, unexpected catastrophes and changes in equilibrium states of habitat (i.e., evidence that historical sheep habitat were grasslands before domestic livestock grazing). It is likely that there will be significant future changes in climate. Toxic plant ingestion, invasive exotics and conversions of habitat types are all potential problems.

<u>Goal: Focus on things managers can influence.</u>

Managers need to agree on what ecological state they want to manage for, have realistic expectations and evaluate potential consequences of environmental changes on management action taken today (consider potential future problems now, don't wait until too late). Managers should use models to predict change over time (not highest resource funding priority).

Comment: Environmental issues were addressed in the scientific and habitat sections of this document. However, the following important points should be considered: winter season rains have increased in relation to climate change. Summer rainfall has decreased facilitating changes in habitat and woody vegetation structure. The change in vegetative community is important and land management agencies need to determine which vegetative community is important to bighorn restoration. Furthermore, habitat and climate changes should be evaluated and monitored over time.

Working group members: Chuck Hayes, Walter Boyce, Dave Hunter, Rachelle Huddleston-Lorton, Laurel Kagan Wiley, Kenneth Logan, Anthony Wright, Mara Weisenberger and Nina Fascione, facilitator.

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Section 5
Management Working Group Report

Management Working Group Report

The Management Working Group began by brainstorming a list of issues and problems related to management of bighorn sheep in New Mexico. The list was then sorted into 5 categories of concerns: population management issues, habitat issues, public issues, research needs and broad issues (those that fell into more than one of the other categories). After a brief discussion, we decided that research needs should be considered for each of the other identified problems. It was therefore omitted as a separate issue. Using the paired ranking technique (Jones, M.D. 1995. *The Thinker's Toolkit: Fourteen Skills for Making Smarter Decisions in Business and in Life*. Random House, Inc. New York), the issues were then prioritized within categories based on which issue was most important for the survival of bighorn sheep in New Mexico. The ranked issues are listed below.

Population Management Issues
1. Small population sizes
2. Population monitoring and measurement
3. Management of captive populations: Red Rock production inadequate
4. Release, reintroduction, and post-release strategies
5. Predator/prey dynamics: buffer species issue or alternative prey
6. Identify sources of bighorn mortality
7. Interspecific competition/ native animals
8. Feasibility of metapopulations in current plan
9. Bighorn harvest strategies

Habitat Issues
1. Habitat loss/ protection
2. Habitat fragmentation/ degradation and mitigation of degraded areas
3. Beneficial habitat modifications
4. Habitat evaluation of all potential sites to maximize transplant success
5. Prioritize existing sites for augmentation/ reintroduction.
6. Management response to periodic drought

Public Issues
1. Funding for management
2. Human disturbance
3. Determination of public acceptance/support or opposition to management activities
4. Promote public acceptance/support
4. Predator control
6. Poaching, law enforcement

Broad Issues
1. Management response to disease (also a habitat and public issue)
2. Lack of experimental, adaptive management to produce reliable knowledge
3. Compatibility with livestock (also a habitat and public issue)
4. Re-evaluate management goals

Early in the workshop process, we recognized that the Threats Working Group had identified several of the same issues that the Management Working Group was working on and that there was considerable overlap in discussion and resulting goals. The groups met and decided upon a division of issues that suited the expertise of the group members. Therefore, several issues the Management Working Group identified as important for the survival of the bighorn sheep in New Mexico, such as small population size and disease, are covered in the Threats Working Group Report.

Population Management Issues

1. Population Monitoring and Measurement

<u>Goal 1: For each population, annually measure the number of sheep, age and sex structure, recruitment, and mortality (with confidence intervals).</u>

Action 1:	Evaluate precision of current techniques
Responsible party:	NMDGF Program Manager
Timeline:	Contracted by September 1999
Resource needs:	NMDGF contractor, funding.

Action 2:	Implement techniques to increase the precision of population estimates (e.g. sightabililty, mark and recapture).
Responsible party:	NMDGF contractor
Timeline:	After results of Action 1 are analyzed; Fall 2000
Resource needs:	Additional personnel and effort
Measurable outcome:	Increased precision of estimates

<u>Goal 2: Monitor inter-mountain movements of bighorn sheep within metapopulations.</u>

Action 1:	Place satellite collars on all transplanted individuals and an adequate number of sheep in all populations of interest.
Responsible party:	NMDGF Program Manager
Resource needs:	Estimated $1,000,000

Comment: Recognizing that Action 1 is ideal but economically unrealistic, the group suggested Action 2 as an alternative.

Action 2:	Place radiocollars on all transplanted individuals and an adequate number of sheep in all populations of interest and locate them regularly.
Responsible party:	NMDGF Program Manager
Resource needs:	Estimated $25,000

Action 3:	If Action 1 and 2 can not be achieved, promote field observation with a representative field person for each metapopulation.
Responsible party:	NMDGF Program Manager
Resource needs:	$25,000 annually

2. Management of captive populations; Red Rock production inadequate

Goal 1: Increase production of captive bighorn sheep to meet management goals established at this workshop.

Action 1: Manage Red Rock for maximum production with an adult breeding population of at least 60 females and 15 males by implementing the following sub-actions:

- Alter sex ratio by releasing rams to achieve and maintain a 1:5 ram:ewe ratio.
- Isolate rams during lambing season.
- Add supplemental feed ad libitum if food quantity or quality is shown to be limiting.
- Rotate breeding rams approximately every 5 years, supplement female breeding stock (with external *o.c. mexicana* stock) on a regular basis.
- Consider releasing both male and female yearlings (current practice is to release only females).
- Evaluate possibility of inbreeding effect by supplementing with females for outbreeding and comparing production of inbred vs. outbred females.
- Evaluate strategies to minimize predation: consider metal fence posts, hotwires on wooden fence posts, and bottom fencing to deter coyotes and mountain lions.
- Supplement current manager with predator specialist.
- Remove deer from pen during capture operation.

Responsible party: NMDGF
Timeline: As soon as possible
Resources: Additional personnel and funding.
Measurable outcome: Increased production

Action 2: Consider establishing additional captive population(s), including exclosures.
Responsible party: NMDGF
Timeline: If Red Rock is unable to meet production goals.
Resources: Seek outside funds and cooperation.

Goal 2: Maximize post-release success of sheep from Red Rock or other captive facilities.

Action 1: If deemed necessary, consider conditioning sheep by harassing with domestic dogs, or de-clawed/de-fanged lions.

Action 2: Release sheep into most ideal habitat

Action 3: Feed sheep in typical sheep habitat.

Action 4: See release, reintroduction, and augmentation strategies issue below.

3. Release/Reintroduction/Augmentation strategies and post-release strategies for Bighorn Sheep in New Mexico are unclear.
Goal 1: Design transplants for optimum production.

Action 1:	Review success of New Mexico and other states' transplant strategies.
Responsible party:	NMDGF Program Manager
Timeline:	Whenever considering a transplant
Action 2:	Determine sex/age structure of transplant to optimize success.
Responsible party:	NMDGF Program Manager
Timeline:	Whenever considering a transplant
Action 3:	Consider pre-release predator control.
Responsible party:	NMDGF Contractor
Timeline:	Whenever considering a transplant
Action 4:	Use modeling tools to assist in reintroduction/augmentation decisions.

Goal 2: Determine reintroduction versus augmentation balance.

Action 1:	Review success of other state's transplant strategies.
Action 2:	Use modeling tools to assist in reintroduction/augmentation decisions.

4. Identification of sources of mortality
Goal 1: Determine causes of death for each individual mortality in all age classes for each metapopulation (or population).

Action 1:	Monitor all radiocollared animals with sufficient frequency to determine cause of death.
Action 2:	Develop research to identify causes of lamb mortality.

Habitat Issues

1. Habitat loss and protection, minimizing and avoiding fragmentation
Goal 1: No net loss of bighorn sheep habitat

Action 1:	Create a 'BHS Habitat Group' (members from all action agencies).
Responsible party:	NMDGF

Action 2:	BHS Habitat Group and action agencies to work with county zoning boards to coordinate zoning with BHS values.
Responsible party:	BHS Habitat Group and action agencies.
Action 3:	Make BHS a priority in Department's Habitat Conservation Program. Area habitat specialists should become pro-active in working with agencies and land mangers to develop habitat-management and prescribed-fire plans.
Responsible party:	Assistant Chief Environmental Review, Area Chiefs
Action 4:	Maintain corridors between populations of BHS.
Responsible party:	BHS Habitat Group and action agencies.
Action 5:	Increase level of protection for suitable BHS habitat that currently has no protection.
Responsible party:	BHS Habitat Group.
Action 6:	Improve maps for identifying existing and potential BHS habitat (including corridors). This is a key step which needs to be done before the other actions can be undertaken and thus should be given high priority.

2. Habitat management

<u>Goal 1: Optimize BHS habitat.</u>

Action 1:	Evaluate effectiveness of water developments.
Responsible party:	Action agencies
Action 2:	Use prescribed fire to restore and maintain BHS habitat. Where necessary, manage livestock to assure availability of fire fuels to achieve fire objectives.
Responsible party:	Action agencies
Action 3:	Use mechanical treatment to restore and maintain habitat where appropriate.
Responsible party:	Action agencies.
Action 4:	Use chemical treatment to restore and maintain habitat conditions where appropriate.
Responsible party:	Action agencies
Action 5:	Provide food/mineral supplements where appropriate.

Comment: It is important that these actions be undertaken using an experimental approach so the effects of each action can be measured. This measurement should include the impact on bighorn sheep populations and also the impact on other species.

3. Habitat evaluation of all potential sites to maximize transplant success

<u>Goal 1: Evaluate habitat and corridors of all potential sites to maximize transplant success.</u>

Action 1:	Form group to revise habitat evaluation procedure.
Responsible party:	NMDGF Program Leader in conjunction with BHS Habitat Group.
Action 2:	Use habitat evaluation procedure to plan future transplants.

4. Re-evaluate and prioritize existing sites and potential sites for augmentation and reintroduction.

<u>Goal 1: Evaluate success of reintroductions to date and evaluate prior models used to evaluate sites.</u>

Action 1:	Analyze reintroductions to identify characteristics of success/failure.
Responsible party:	BHS Program Manager
Action 2:	Re-evaluate previous evaluations.
Responsible party:	BHS Program Manager

5. Management response to periodic drought.

<u>Goal: Ensure that sufficient water and forage exist to meet nutritional requirements of BHS.</u>

Action 1:	Develop wildlife drought response team.
Action 2:	Provide water sources or allow for sufficient movement of animals to reach these sources. Assess security of habitat (visibility and proximity to escape terrain) at all water sources. Manage habitat or locations of water sources as indicated by assessment.
Action 3:	Monitor forage conditions and livestock competition and take appropriate action.

Public Issues

1. Funding for Management

<u>Goal 1: Ensure adequate funding for all agencies to accomplish goals of the management plans.</u>

Action 1:	Devise new/additional, stable funding mechanisms and alternate funding sources for BHS management.
Responsible party:	BHS Program Manager to coordinate
Timeline:	As soon as possible
Action 2:	Acquire general tax fund money

Responsible party:	NMDGF in conjunction with advisory groups (e.g. BHS advisory council).
Timeline:	As soon as possible

Action 3:	Consider auctioning another hunting permit.
Responsible party:	NMDGF
Timeline:	As soon as possible

Action 4:	Devise coordinated approach to grant proposal and other funding sources.
Responsible party:	BHS Program Manager in cooperation with other related agencies.
Timeline:	As soon as possible

2. Human Disturbance

Goal 1: Minimize human disturbance to BHS populations.

Action 1:	Where conflicts are identified, consider seasonal trail closures on public lands, particularly during lambing periods and near lambing areas.

Action 2:	Where conflicts are identified, consider seasonal road closures on public lands, particularly during lambing periods and near lambing areas.

Action 3:	If conflicts develop near urban areas or on popular public trails, consider imposing "leash laws" to prevent dogs from harassing BHS.

3. Determination of public opinion (support/acceptance/opposition) regarding management activities.

Goal 1: Determine level of public support/acceptance/opposition to management activities for each issue.

Action 1:	Schedule regular public meetings (at least twice/year)
Responsible party:	BHS Program Manager /BHS advisory council
Timeline:	As needed

Action 2:	Conduct surveys when trying to assess public opinion on key issues.
Responsible party:	Contractor
Timeline:	As needed

Action 3:	Identify key issues and key people involved.
Responsible party:	BHS Program Manager
Timeline:	As needed

Action 4:	Make maximum use of NMDGF web site
Responsible party:	NMDGF Webmaster and BHS Program Manager

4. Promote and Maintain Support for BHS management activities.

<u>Goal 1: Develop and maintain effective mechanisms for inter-agency communication and support</u>

Action 1:	Increase inter-agency support by conducting quarterly interagency meetings
Responsible party:	BHS Program Leader
Action 2:	Ensure BHS Program goals are incorporated into key agency management plans. Take BHS goals to agency meetings.
Responsible party:	NMDGF Program Manager and Area Habitat Specialists

<u>Goal 2: Garner broad public support for BHS program.</u>

Action 1:	Work one-on-one with individuals.
Responsible party:	BHS Program Manager
Action 2:	Consider developing a regional bighorn sheep website/bulletin board.
Responsible party:	Ray Lee to mention issue at Desert Bighorn Council
Timeline:	April, 2000
Action 3:	Develop public outreach program designed to widen involvement of all stakeholders.
Responsible party:	BHS Program Manager
Action 4:	Agencies should recognize that decisions are made in the public arena, be aware of emerging publics, and ensure that public decision-makers are well informed of agency analyses of management options.
Comment:	This action is meant to address the fact that decisions are often made reactively in a political arena without due consideration of the scientific data. There are conflicting jurisdictions, mandates and public demands that drive decisions; NMGFD manages sheep, BLM and USFS manage multiple-use lands, the FWS and DOE have their own operational directives and Indians are sovereign. In all cases, public opinion is part of the mix.
Action 5:	Use NMDGF web site to publicize bighorn programs

5. Public support for predator control

<u>Goal 1: Design an effective decision tree to determine when predator control is appropriate.</u>

Action: Develop decision criteria to include:

- Implement guidelines for beginning and ending of the predator control (triggers)
- Quantify the percentage of predators to be removed.
- Evaluate all other critical factors (e.g. habitat parameters) that could be effecting populations, not just the predator.
- Properly involve the public.
- Design the study to evaluate the effectiveness of the removal (including control area).

Responsible party: Chuck Hayes
Timeline: Immediately

Goal 2: Properly identify and involve the interests of all stakeholders and various publics.

Action: Develop effective means for identifying and involving all stakeholders and various publics.
Responsible party: BHS Program Manager
Timeline: As soon as possible

6. Poaching

Goal 1: Eliminate the unlawful take of any bighorn sheep.

Action 1: Implement public education, including illustrations of desert bighorn sheep and mule deer in big game proclamation.
Responsible party: BHS Program Manager with NMDGF
Action 2: Improve law enforcement and prosecution of poachers.
Responsible party: BHS Program Manager (to address agencies, chief warden)

Action 3: Work with judiciary to increase conviction rates of poachers and work with commissioners to increase poaching fines.
Responsible party: BHS Program Manager to address Justice of the Peace, Commissioners

Action 4: Where poaching is an issue, identify and address problems of public access, consider restricting road access to reduce risk of poaching.
Responsible party: NMDGF, land management agencies

Action 5: Develop an post signs warning against poaching on all roads leading to areas containing bighorn sheep.
Responsible party: BHS Program Manager

Action 7: Develop BHS-specific reward fund for “poaching tips”
Responsible party: BHS Program Manager

Action 8: Invite participation and cooperation of multiple law enforcement agencies.

Responsible party:	Interagency meeting with Conservation Officers and Chief of Law Enforcement

Action 9:	Continue prohibition of the sale of bighorn sheep parts in New Mexico.
Responsible party:	Chief of Law Enforcement

Broad Issues

1. Lack of Experimental Management

There is a lack of experimental management that is necessary to produce reliable knowledge of the effectiveness of management actions. Lack of adaptive management is a widespread failure of the wildlife profession. Management is adaptive when it develops reliable knowledge of the effectiveness of management actions and uses this knowledge to revise and improve management. Obtaining reliable knowledge of management effectiveness requires that management actions be designed as management experiments.

<u>Goal: Incorporate experimental design into management plans to provide reliable data for effective, adaptive management.</u>

Action 1:	For all issues requiring significant agency resources, management plans should be designed with control(s), randomization, and replication in order to evaluate the effectiveness of management actions. All such plans should be peer-reviewed.
Action 2:	In cases in which New Mexico has insufficient resources, numbers of sheep and sheep herds, joint management experiments should be considered with other states/countries to optimize resource utilization, especially to provide sufficient sample sizes and study areas.

2. Need for Program Manager (FTE) to administer BHS program.

<u>Goal: A dedicated person to administer program</u>

Action 1:	Build a coalition among sportspersons and other interested parties to lobby for position.

Action 2:	Identify a legislator to "carry" the legislation.
Responsible party:	David Heft to approach Wildlife Legislative Committee/FNAWS.
Resource needs:	None

Working group members: Jim Bailey, Jim DeForge, Ben Brown, Zack Parsons, Dave Verhelst, Raymond Lee, Peter Bangs, David Heft, Kevin Cobble and Onnie Byers, facilitator.

POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE DESERT BIGHORN SHEEP OF NEW MEXICO
(*Ovis canadensis*)

Sunrise Springs
Santa Fe, New Mexico
27-30 July 1999

Final Report
November 1999

Appendix I
List of Participants

DESERT BIGHORN PHVA WORKSHOP PARTICIPANTS

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Appendix II
Workshop Presentation

The Management of Bighorn Sheep in New Mexico
Eric Rominger

I want to give you the background on a very proactive bighorn sheep management program with a long history in New Mexico.

Prehistorically desert bighorn probably occurred in most if not all of the desert mountain ranges---and historical evidence for occurrence has been documented in 14 ranges. Recent genetic analyses suggest widespread exchange in desert herds which were present in Texas and Chihuahua to the east and south and west throughout Arizona. Also north in New Mexico were bighorn sheep within distances known to be traveled by bighorn.

This century saw the extirpation of desert bighorn from all but 3 mountain ranges and by 1946 when the population in the Guadalupe mountains became extinct there were just 2 populations. In 1978 these 2 populations had <15 in the Hatchets and ~180 (119 observed) in the San Andres. 1978 is the year the scabies epizootic began in the San Andres population and after the capture and salvage operation fewer than 40 bighorn remained in the San Andres and this population has further declined to what we now believe is a single ewe. In 1980 desert bighorn sheep were state listed as an endangered subspecies; in the 1990's a complete habitat evaluation and a long-range plan were produced for desert bighorn sheep.

We must note that outside the San Andres since 1978, the population has increased from <15 to approximately 220, primarily as a result of captive breeding based transplants into 4 new populations and augmentation of the hatchet population. Captive breeding facility was established in 1972 at Red Rock, north of Lordsburg with 20 founders from 2 populations...San Andres and Loma Prieta, Mexico...so why was it among the least genetically diverse in a recent manuscripts?

This population has produced >400 individuals of which 199 have been removed, ~103 are present at the facility and >100 mortalities have been documented at the facility. Bighorn were fed supplementally until 1991 and then feeding was stopped because the pen size was doubled, however the population also doubled and DGF has again begun to feed (June 1999) in this facility to ascertain whether or not a skewed sex ratio is a function of a nutritional constraint rather than inbreeding or other genetic factors.

Transplants/augmentations

Year	Herd	No.
1979	Hatchet	12
1981	Peloncillo	10
1982	Hatchet	18
1986	Alamo Hueco	21
1991	Peloncillo	6
1992	Ladron	23
1993	La/Pe	19
1995	Fra Cristobal	37
1997	Pe/HA/La/FC	45
		191

These transplants have resulted in the establishment of 1 metapopulation of >100 bighorn (Peloncillo/Hatchet/Alamo Hueco/Animas) referred to as the Bootheel metapopulation. Two other relatively isolated populations have also been established in the Ladron and Fra Cristobal mountains. The 1995 transplant from Red Rock was 12 ewes and 33 rams due to skewed sex ratio and the proposed transplant this fall will be 25-30 rams and 0-5 ewes because of continued male domination of recruitment.

Recent population trends have been down in nearly all mountain ranges. The last 106 bighorn sheep out of Red Rock have been radio-collared which has led to a very large data set on survival and cause of mortality and the fate of 101 of these bighorn is known. At least 36 of 48 known mortalities on radio-collared desert bighorn have been caused by mountain lion predation. Since the helicopter survey in October 1998, 8 of 49 (16%) radio-collared desert bighorn sheep have died (all from lion predation) suggesting that the adult population has almost certainly declined below 200 individuals.

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IUCN GUIDELINES FOR THE PLACEMENT OF CONFISCATED LIVE ANIMALS[1]

Statement of Principle:

When live animals are confiscated by government authorities, these authorities have a responsibility to dispose of them appropriately. Within the confines of national and international law, the ultimate on disposition of confiscated animals must achieve three goals: 1) to maximise conservation value of the specimens without in any way endangering the health, behavioral repertoire, genetic characteristics, or conservation status of wild or captive populations of the species[1]; 2) to discourage further illegal or irregular[2] trade in the species; and 3) to provide a humane solution, whether this involves maintaining the animals in captivity, returning them to the wild, or employing euthanasia to destroy them.

Statement of Need:

Increased regulation of trade in wild plants and animals and enforcement of these regulations has resulted in an increase in the number of wildlife shipments intercepted by government authorities as a result of non-compliance with these regulations. In some instances, the interception is a result of patently illegal trade; in others, it is in response to other irregularities. While in some cases the number of animals in a confiscated shipment is small, in many others the number is in the hundreds. Although in many countries confiscated animals have usually been donated to zoos and aquaria, this option is proving less viable with large numbers of animals and, increasingly, for common species. The international zoo community has recognized that placing animals of low conservation priority in limited cage space may benefit those individuals but may also detract from conservation efforts as a whole. They are, therefore, setting conservation priorities for cage space (IUDZG/CBSG 1993).

With improved interdiction of the illegal trade in animals there is an increasing demand for information to guide confiscating agencies in the disposal of specimens. This need has been reflected in the formulation of specific guidelines for several groups of organisms such as parrots (Birdlife International in prep) and primates (Harcourt in litt.). However, no general guidelines exists.

In light of these trends, there is an increasing demand - and urgent need - for information and advice to guide confiscating authorities in the disposition of live animals. Although specific guidelines have been formulated for certain groups of organisms, such as parrots (Birdlife International in prep.) and primates (Harcourt 1987), no general guidelines exist.

When disposing of confiscated animals, authorities must adhere to both national and international law. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) requires that confiscated individuals of species listed on the treaty's Appendices be returned to the "state of export or to a rescue centre or such other place as the Management Authority deems appropriate and consistent with the purpose of the Convention." (Article VIII). However the treaty does not elaborate on this requirement, and CITES Management Authorities must act according to their own interpretation, not only with respect to repatriation but also as regards what constitutes disposition that is "appropriate and consistent" with the treaty. Although the present guidelines are intended to assist CITES Management Authorities in making this assessment, they are designed to be of general applicability to all confiscated live animals.

[1] Although this document refers to species, in the case of species with well-defined subspecies and races, the issues addressed will apply to lower taxonomic units.

The lack of specific guidelines has resulted in confiscated animals being disposed of in a variety of ways. In some cases, release of confiscated animals into existing wild populations has been made after careful evaluation and with due regard for existing guidelines (IUCN 1987, IUCN 1995). In other cases, such releases have not been well planned and have been inconsistent with general conservation objectives and humane considerations, such as releasing animals in inappropriate habitat, dooming these individuals to starvation or certain death from other causes against which the animals are not equipped or adapted. Such releases may also have strong negative conservation value by threatening existing wild populations as a result of: 1) diseases and parasites acquired by the released animals while in captivity spreading into existing wild populations; 2) individuals released into existing populations, ro in areas near to existing populations, not being of the same race or sub-species as those in the wild population, resulting in mixing of distinct genetic lineages; 3) animals held in captivity, particularly juveniles and immatures, acquiring an inappropriate behavioral repertoire from individuals of other species, and/or either losing certain behaviors, or not developing the full behavioral repertoire, necessary for survival in the wild. Also, it is possible that release of these animals could result in inter-specific hybridisation.

Disposition of confiscated animals is not a simple process. Only on rare occasions will the optimum course to take be clear-cut or result in an action of conservation value. Options for the disposition of confiscated animals have thus far been influenced by the public's perception that returning animals to the wild is the optimal solution in terms of both animals welfare and conservation. A growing body of scientific study of re-introduction of captive animals suggests that such actions may be among the least appropriate options for many reasons. This recognition requires that the options available to confiscating authorities for disposition be carefully reviewed.

Management Options:

In deciding on the disposition of confiscated animals, priority must be given to the well-being and conservation of existing wild populations of the species involved, with all efforts made to ensure the humane treatment of the confiscated individuals. Options for disposition fall into three principal categories: 1) maintenance of the individual(s) in captivity; 2) returning the individual(s) in question to the wild; and 3) euthanasia.

Within a conservation perspective, by far the most important consideration in reviewing the options for disposition is the conservation status of the species concerned. Where the confiscated animals represent an endangered or threatened species, particular effort should be directed towards evaluating whether and how these animals might contribute to a conservation programme for the species. The decision as to which option to employ in the disposition of confiscated animals will depend on various legal, social, economic and biological factors. The "Decision Tree"[1] provided in the present guidelines is intended to facilitate consideration of these options. The tree has been written so that it may be used for both threatened and common species. However, it recognizes that the conservation status of the species will be the primary consideration affecting the options available for placement, particularly as the expense and difficulty of returning animals to the wild (see below) will often only be justified for threatened species. International networks of experts, such as the IUCN-Species Survival Commission Specialist Groups, should be able to assist confiscating authorities, and CITES Scientific and Management Authorities, in their deliberations as to the appropriate disposition of confiscated specimens.

Sending animals back automatically to the country from which they were shipped, the country in which they originated (if different), or another country m which the species exists, does not solve any problems. Repatriation to avoid addressing the question of disposition of confiscated animals is irresponsible as the authorities in these countries will face the same issues concerning placement as the authorities in the original confiscating country.

OPTION 1-- CAPTIVITY

Confiscated animals are already in captivity; there are numerous options for maintaining them in captivity. Depending on the circumstances, animals can be donated, loaned, or sold. Placement may be in zoos or other facilities, or with private individuals. Finally, placement may be either in the country of origin, the country of export (if different), the country of confiscation. or in a country with adequate and/or specialised facilities for the species in question. If animals are maintained in captivity, in preference to either being returned to the wild or euthanized, they must be afforded humane conditions and ensured proper care for their natural lives.

Zoos and aquaria are the captive facilities most commonly considered for disposition of animals, but a variety of captive situations exist where the primary aim of the institution or individuals involved is not the propagation and resale of wildlife. These include:

Rescue centres, established specifically to treat injured or confiscated animals, are sponsored by a number of humane organisations in many countries.

Life-time care facilities devoted to the care of confiscated animals have been built in a few countries.

Specialist societies or clubs devoted to the study and care of single taxa or species(e.g., reptiles, amphibians, birds) have, in some instances, provided an avenue for the disposition of confiscated animals without involving sale through intermediaries. Placement may be made directly to these organisations or to individuals who are members.

Humane Societies may be willing to ensure placement of confiscated specimens with private individuals who can provide humane life-time care.

Research laboratories (either commercial or non-commercial, e.g. universities) maintain collections of exotic animals for many kinds of research (e.g. behavioural, ecological, physiological, psychological, medical). Attitudes towards vivisection, or even towards the non-invasive use of animals in research laboratories as captive study populations, vary widely from country to country. Whether transfer of confiscated animals to research institutions is appropriate will therefore engender some debate. However, it should be noted that transfer to facilities involved in research conducted under humane conditions may offer an alternative -- and one which may eventually contribute information relevant to the species' conservation. In many cases, the lack of known provenance and the risk that the animal in question has been exposed to unknown pathogens will make transfer to a research institution an option that will be rarely exercised or desired.

CAPTIVITY - Sale, Loan or Donation

Animals can be placed with an institution or individual in a number of ways. It is critical, however. that two issues be separated: the ownership of the animals and/or their progeny, and the payment of a fee by the institution/individual receiving the animals. Paying the confiscating authority, or the country of origin, does not necessarily give the person or institution making the payment any rights (these may rest with the confiscating authority). Similarly, ownership of an animal can be transferred without payment. Confiscating authorities and individuals or organizations participating in the placement of confiscated specimens must clarify ownership. both of the specimens being transferred and their progeny. Laws dictating right of ownership of wildlife differ between nations, in some countries ownership remains with the government, in others the owner of the land inhabited by the wildlife has automatic rights over the animals.

When drawing up the terms of transfer many items must be considered, including:

-- ownership of both the animals involved and their offspring (dictated by national law) must be specified as one of the terms and conditions of the transfer (it may be necessary to insist there is no breeding for particular species, e.g. primates). Either the country of origin or the country of confiscation may wish to retain ownership of the animals and/or their progeny. Unless specific legal provisions apply, it is impossible to assure the welfare of the animals following a sale which includes a transfer of ownership.

-- sale or payment of a fee to obtain certain rights (e.g. ownership of offspring) can provide a means of placement that helps offset the costs of confiscation.
--sale and transfer of ownership should only be considered in certain circumstances, such as where the animals in question are not threatened and not subject to a legal proscription on trade (e.g., CITES Appendix I) and there is no risk of stimulating further illegal or irregular trade.

--sale to commercial captive breeders may contribute to reducing the demand for wild-caught individuals.
--sale may risk creating a public perception of the confiscating State perpetuating or benefitting from illegal or irregular trade.

--if ownership is transferred to an organization to achieve a welfare or conservation goal, the confiscating authority should stipulate what will happen to the specimens should the organization wish to sell/transfer the specimens to another organization or individual.

--confiscating authorities should be prepared to make public the conditions under which confiscated animals have been transferred and, where applicable, the basis for any payments involved.

CAPTIVITY-- **Benefits**

The benefits of placing confiscated animals in a facility that will provide life-time care under humane conditions include;

a) educational value;
b) potential for captive breeding for eventual re-introduction;
c) possibility for the confiscating authority to recoup from sale costs of confiscation;
d) potential for captive bred individuals to replace wild-caught animals as a source for trade.

CAPTIVITY- **Concerns**

The concerns raised by placing animals in captivity include:

A)**Disease.** Confiscated animals may serve as vectors for disease. The potential consequences of the introduction of alien disease to a captive facility are more serious than those of introducing disease to wild populations (see discussion page 9); captive conditions might encourage disease spread to not only conspecifics. As many diseases can not be screened for, even the strictest quarantine and most extensive screening for disease can not ensure that an animal is disease free. Where quarantine cannot adequately ensure that an individual is disease free, isolation for an indefinite period, or euthanasia, must be carried out.

B) **Escape**. Captive animals maintained outside their range can escape from captivity and become pests. Accidental introduction of exotic species can cause tremendous damage and in certain cases, such as the escape of mink from fur farms in the United Kingdom, the introduction of exotics can result from importation of animals for captive rearing.

C) **Cost of Placement**. While any payment wi11 place a value on an animal, there is little evidence that trade would be encouraged if the institution receiving a donation of confiscated animals were to reimburse the confiscating authority for costs of care and transportation. However, payments should be explicitly for reimbursement of costs of confiscation and care, and, where possible, the facility receiving the animals should bear all such costs directly.

D) **Potential to Encourage Undesired Trade**. Some (e.g., Harcourt 1987) have maintained that any transfer - whether commercial or non-commercial - of confiscated animals risks promoting a market for these species aud creating a perception of the confiscating state being involved in illegal or irregular trade.

Birdlife International (in prep.) suggests that in certain circumstances sale of confiscated animals does not necessarily promote undesired trade. They offer the following requirements that must be met for permissible sale by the confiscating authority: I) the species to be sold is already available for sale legally in the confiscating country in commercial quantities; and 2) wildlife traders under indictment for; or convicted of, crimes related to import of wildlife are prevented from purchasing the animals in question. However, experience in selling confiscated animals in the USA suggests that it is virtually impossible to ensure that commercial dealers suspected or implicated in illegal or irregular trade are excluded, directly or indirectly, in purchasing confiscated animals.

In certain circumstances sale or loan to commercial captive breeders may have a clearer potential for the conservation of the species, or welfare of the individuals, than non-commercial disposition or euthanasia. However, such breeding programmes must be carefully assessed as it may be difficult to determine the effects of these programmes on wild populations.

OPTION 2-- RETURN TO THE WILD

These guidelines suggest that return to the wild would be a desirable option in only a very small number of instances and under very specific circumstances. The rationale behind many of the decision options iii this section are discussed in greater detail in the IUCN Re-introduction Guidelines (IUCN/SSC RSG 1995) which, it is important to note, make a clear distinction between the different options for returning animals to the wild. These are elaborated below.

I) **Re-introduction**: an attempt to establish a population in an area that was once part of the range of the species but from which it has become extirpated.
Some of the best known re-introductions have been of species that had become extinct in the wild. Examples include: Pere David's deer (*Elaphurus davidanus*) and the Arabian oryx (*Oryx leucoryx*.). Other re-introduction programmes have involved species that exist in some parts of their historical range but have been eliminated from other areas; the aim of these programmes is to re-establish a population in all area, or region, from which the species has disappeared. An example of this type of r~introduction is the recent re-introduction of the swift fox (*Vulpes velox*) in Canada.

2) **Reinforcement of an Existing Population**: the addition of individuals to all existing population of the same taxon.

Reinforcement can be a powerful conservation tool when natural populations are diminished by a process which, at least in theory, can be reversed. An example of a successful reinforcement project is the golden lion tamarin *(Leontopithecus rosalia*) project in Brazil. Habitat loss, coupled with capture of live animals for pets, resulted in a rapid decline of the golden lion tamarin. when reserves were expanded, and capture for the pet trade curbed, captive-bred golden lion tamarins were then used to supplement depleted wild populations.

Reinforcement has been most commonly pursued when individual animals injured by human activity have been provided with veterinary care and released. Such activities are common in many western countries, and specific programmes exist for species as diverse as hedgehogs and birds of prey. However common an activity, reinforcement carries with it the very grave risk that individuals held in captivity, even temporarily, are potential vectors for the introduction of disease into wild populations.

Because of inherent disease risks and potential behavioural abnormalities, reinforcement should only be employed in instances where there is a direct and measurable conservation benefit (demographically and/or genetically, and/or to enhance conservation in the public's eye), for example when reinforcement will significantly add to the viability of the wild population into which an individual is being placed.

3) **Conservation Introductions:** (also referred to as Beneficial or Benign Introductions - IUCN 1995): an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within a suitable habitat in which a population can be established without predicted detriment to native species.

Extensive use of conservation introductions has been made in New Zealand, where endangered birds have been transferred to off-shore islands that were adjacent to, but not part of the animals' original range. Conservation introductions can also be a component of a larger programme of re-introduction, an example being the breeding of red wolves on islands outside their natural range and subsequent transfer to mainland range areas (Smith 1990).

RETURN TO THE WILD - CONCERNS

Before return to the wild of confiscated animals is considered, several issues of concern must be considered in general terms; welfare, conservation value, cost, and disease.

a) **Welfare**. While some consider return to the wild to be humane, ill-conceived projects may return animals to the wild which then die from starvation or suffer an inability to adapt to an unfamiliar or inappropriate environment. This is not humane. Humane considerations require that each effort to return confiscated animals to the wild be thoroughly researched and carefully planned. Such returns also require long-term commitment in terms of monitoring the fate of released individuals. Some (e.g., International Academy of Animal Welfare Sciences 1992) have advocated that the survival prospects for released animals must at least approximate those of wild animals of the same sex and age class in order for return to the wild to be seriously considered. While such demographic data on wild populations are, unfortunately, rarely available, the spirit of this suggestion should be respected -- there must be humane treatment of confiscated animals when attempting to return them to the wild.

b) **Conservation Value And Cost**. In cases where returning confiscated animals to the wild appears to be the most humane option, such action can only be undertaken if it does not threaten existing populations of conspecifics or populations of other interacting species, or the ecological integrity of the area in which they live. The conservation of the species as a whole, and of other animals already living free, must take precedent over the welfare of individual animals that are already in captivity.

Before animals are used in programmes in which existing populations are reinforced, or new populations are established, it must be determined that returning these individuals to the wild will make a significant contribution to the conservation of the species, or populations of other interacting species. Based solely on demographic considerations, large populations are less likely to go extinct, and therefore reinforcing existing very small wild populations may reduce the probability of extinction. In very small populations a lack of males or females may result in reduced population growth or population decline and, therefore, reinforcing a very small population lacking animals of a particular sex may also improve prospects for survival of that population. However, genetic and behavioural considerations, as well as the possibility of disease introduction, also play a fundamental role in determining the long term survival of a population. The cost of returning animals to the wild in an appropriate manner can be prohibitive for all but the most endangered species (Stanley Price 1989; Seal et al. 1989). The species for which the conservation benefits clearly outweigh these costs represent a tiny proportion of the species which might, potentially, be confiscated In the majority of cases, the costs of appropriate, responsible (re)introduction will preclude return to the wild. Poorly planned or executed (re)introduction programmes are no better than dumping animals in the wild and should be vigorously opposed on both conservation and humane grounds.

c) **Founders And Numbers Required**. Most re-introductions require large numbers of founders, usually released in smaller groups over a period of time. Hence, small groups of confiscated animals may be inappropriate for re-introduction programmes, and even larger groups will require careful management if they are to have any conservation value for re-introduction programmes. In reality, confiscated specimens will most often only be of potential value for reinforcing an existing population, despite the many potential problems this will entail.

c) **Source of Individuals**. If the precise provenance of the animals is not known (they may be from several different provenances), or if there is any question of the source of animals, supplementation may lead to inadvertent pollution of distinct genetic races or sub~species. If particular local races or sub-species show specific adaptation to their local environments mixing in individuals from other races or sub-species may be damaging to the local population. Introducing an individual or individuals into the wrong habitat type may also doom that individual to death.

a) **Disease**. Animals held in captivity and/or transported, even for a very short time, may be exposed to a variety of pathogens. Release of these animals to the wild may result in introduction of disease to con-specifics or unrelated species with potentially catastrophic effects. Even if there is a very small risk that confiscated animals have been infected by exotic pathogens, the potential effects of introduced diseases on wild populations are so great that this will often prevent returning confiscated animals to the wild (Woodford and Rossiter 1993, papers in *J Zoo and Wildlife Medicine* 24(3), 1993).

Release of any animal into the wild which has been held in captivity is risky. Animals held in captivity are more likely to acquire diseases and parasites. While some of these diseases can be tested for, tests do not exist for many animal diseases. Furthermore, animals held in captivity are frequently exposed to diseases not usually encountered in their natural habitat. Veterinarians and quarantine officers, taking that the species in question is only susceptible to certain diseases, may not test for the diseases picked up in captivity. It should be assumed that all diseases are potentially contagious.

Given that any release incurs some risk, the following “precautionary principle" must be adopted: *if there is no conservation value in releasing confiscated specimens, the possibility of accidentally introducing a disease, or behavioural and genetic aberrations into the environment which are not already present, however unlikely, may rule out returning confiscated specimens to the wild as a placement option.*

RETURN TO THE WILD: BENEFITS

There are several benefits of returning animals to the wild, either through re-introduction for the establishment of a new population or reinforcement of an existing population.
a) **Threatened Populations**: In situations where the existing population is severely threatened, such an action might improve the long-term conservation potential of the species as a whole, or of a local population of the species (e.g., golden lion tamarins).

b) **Public Statement**: Returning animals to the wild makes a strong political/educational statement concerning the fate of animals (e.g., orangutans (*Pongo pygmaeus*) and chimpanzees *(Pan troglodytes*) - Aveling & Mitchell 1982, but see Rijksen & Rijksen-Graatsma 1979) and may serve to promote local conservation values. However, as part of any education or public awareness programmes, the costs and difficulties associated with the return to the wild must be emphasized.

OPTION 3- EUTHANASIA

Euthanasia: the killing of animals carried out according to humane guidelines -- is unlikely to be a popular option amongst confiscating authorities for disposition of confiscated animals. However, it cannot be over-stressed that euthanasia may frequently be the most feasible option available for economic, conservation and humane reasons. hi many cases, authorities confiscating live animals will encounter the following situations:

a) Return to the wild in some manner is either unnecessary (e.g., in the case of a very common species), impossible, or prohibitively expensive as a result of the need to conform to biological (IUCN/SSC RSG ~995) and animal welfare guidelines (International Academy of We1fare Sciences 1992).

b) Placement in a captive facility is impossible, or there are serious concerns that sale will be problematic or controversial.

c) During transport, or while held in captivity, the animals have contracted a chronic disease that is incurable and, therefore, are a risk to any captive or wild population. hi such situations, there may be no practical alternative to euthanasia.

EUTHANASIA -ADVANTAGES:

a) From the point of view of conservation of the species involved, and of protection of existing captive and wild populations of animals, euthanasia carries far fewer risks (e.g. loss of any unique behavioural/genetic/ecological variations within an individual representing variation within the species) when compared to returning animals to the wild.

b) Euthanasia will also act to discourage the activities that gave rise to confiscation, be it smuggling or other patently illegal trade, incomplete or irregular paperwork, poor packing, or other problems, as the animals in question are removed entirely from trade.

c) Euthanasia may be in the best interest of the welfare of the confiscated animals. Release to the wild will carry enormous risks for existing wild populations and may pose severe challenges to the survival prospects of the individual animals, who may, as a result, die of starvation, disease or predation.

d) Cost: euthanasia is cheap compared to other options. There is potential for diverting resources which might have been used for re-introduction or lifetime care to conservation of the species in the wild.

When animals are euthanized, or when they die a natural death while in captivity, the dead specimen should be placed in the collection of a natural history museum, or another reference collection in a university or research institute. Such reference collections are of great importance to studies of biodiversity. if such placement is impossible, carcasses should be incinerated to avoid illegal trade in animal parts or derivatives.

EUTHANASIA- RISKS

a) There is a risk of losing unique behavioural, genetic and ecological material within an individual or group of individuals that represents variation within a species.

DECISION TREE ANALYSIS

For decision trees dealing with "Return to the Wild" and "Captive Options" the confiscating party must first ask the question:

Question 1: Will "Return to the Wild" make a significant contribution to the conservation of the species?

The most important consideration in deciding on placement of confiscated specimens is the conservation of the species in question. Conservation interests are best served by ensuring the survival of as many individuals as possible. The release of confiscated animals therefore must improve the prospects for survival of the existing wild population. Returning an individual to the wild that has benn held in captivity will always involve some level of risk to existing populations of the same or other species in the ecosystem to which the animal is returned because there can never be absolute certainty that a confiscated animal is disease- and parasite-free. In most instances, the benefits of return to the wild will be outweighed by the costs and risks of such an action. If returning animals to the wild is not of conservation value, captive options pose fewer risks and may offer more humane alternatives.

Q1 Answer: No: Investigate "Captive Options"
Yes: Investigate "Return to the Wild Options"

DECISION TREE ANALYSIS: CAPTIVITY

The decision to maintain confiscated animals in captivity involves a simpler set of considerations than that involving attempts to return confiscated animals to the wild.

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Animals that may be transferred to captive facilities must have a clean bill of health because of the risk of introducing disease to captive populations.

Theses animals must be placed in quarantine to determine if they are disease-free before being transferred to a captive-breeding facility.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen and move to Question 3.

Question 3: Have animals been found to be disease-free by comprehensive veterinary screening and quarantine or can they be treated for any infection discovered?

If; during quarantine animals are found to harbour diseases that cannot reasonably be cured, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: If chronic and incurable infection, first offer animals to research institutions. impossible to place in such institutions, euthanize.

Question 4: Are there grounds for concern that sale will stimulate further illegal or irregular trade?

Commercial sale of Appendix I species is not permitted under the Convention as it is undesirable to stimulate trade in these species. Species not listed in any CITES appendix, but which are nonetheless seriously threatened with extinction, should be afforded the same caution.

Sale of confiscated animals, where legally permitted, is a difficult option to consider. while the benefits of sale -- income and quick disposition -- are clear, there are many problems that may arise as a result of further commercial transactions of the specimens involved. Equally, it should be noted that there may be circumstances where such problems arise as a result of a non-commercial transaction or that, conversely, sale to commercial captive breeders may contribute to production of young offsetting the capture from the wild.

More often than not, sale of threatened species should not take place. Such sales or trade in threatened species may be legally proscribed in some countries, or by CITES. There may be rare cases where a commercial captive breeding operation may purchase or receive individuals for breeding, which may reduce pressure on wild populations subject to trade. In all circumstances, the confiscating authority should be satisfied that:

1) those involved in the illegal or irregular transaction that gave rise to confiscation cannot obtain the animals;
2) the sale does not compromise the objective of confiscation; and, finally,

3) the sale will not increase illegal, irregular or otherwise undesired trade in the species.

Previous experience with sale in some countries (e.g., the USA) has indicated that selling confiscated animals is beset by both logistic and political problems and that, in addition to being controversial, it may also be counter-productive to conservation objectives.

Q4 Answer: Yes: Proceed to Question 5a.
No: Proceed to Question 5b.

Question 5a: Is space available in a non-commercial captive facility (e.g., life-time care facility, zoo, rescue centre, specialist society, their members or private individuals)?

Question 5b: Is space available in a non-commercial captive facility (e.g., life-time care facility, zoo, rescue centre, specialist society, their members or private individuals) or is there a commercial facility breeding this species, and is the facility interested in the animals?

Transfer of animals to non-commercial captive-breeding facilities, if sale may stimulate further illegal or irregular trade, or commercial captive breeding facilities, an option only if sale will not stimulate further illegal or irregular trade, should generally provide a safe and acceptable means of disposition of confiscated animals. when a choice must be made between several such institutions, the paramount consideration should be which facility can:

1) offer the opportunity for the animals to participate in a captive breeding programme;
2) provide the most consistent care; and
3) ensure the welfare of the animals.

The terms and conditions of the transfer should be agreed between the confiscating authority and the recipient institution. Terms and conditions for such agreements should include:

I) a clear commitment to ensure life-time care or, in the event that this becomes impossible, transfer to another facility that can ensure life-time care, or euthanasia;
2) clear specification of ownership of the specimens concerned (as determined by national law) and, where breeding may occur, the offspring. Depending on the circumstances, ownership may be vested with the confiscating authority, the country of origin or export, or with the recipient facility.
3) clear specification of conditions under which the animal(s) or their progeny may be sold.

In the majority of instances, there will be no facilities or zoo or aquarium space available in the country in which animals are confiscated. Where this is the case other captive options should be investigated. This could include transfer to a captive facility outside the country of confiscation particularly in the country of origin, or, if transfer will not stimulate further illegal trade, placement in a commercial captive breeding facility. However, these breeding programmes must be carefully assessed and approached with caution. It may be difficult to monitor these programmes and such programmes may unintentionally, or intentionally, stimulate trade in wild animals. The conservation potential of this transfer, or breeding loan, must be carefully weighed against even the smallest risk of stimulating trade which would further endanger the wild population of the species.

In many countries, there are active specialist societies or clubs of individuals with considerable expertise in the husbandry and breeding of individual Species or groups of Species. Such societies can assist in finding homes for confiscated animals without involving sale through intermediaries. In this case, individuals receiving confiscated animals must have demonstrated expertise in the husbandry of the species concerned and must be provided with adequate information and advice by the club or society concerned. Transfer to specialist societies or individual members must be made according to terms and conditions agreed with the confiscating authority. Such agreements may be the same or similar to those executed with Lifetime Care facilities or zoos. Placement with these societies or members is an option if sale of the confiscated animals may or may not stimulate trade.

Q5 Answer: Yes: Execute agreement and Sell
No: Proceed to Question 6.

Question 6: Are institutions interested in animals for research under humane conditions?

Many research laboratories maintain collections of exotic animals for research conducted under humane conditions. If these animals are kept in conditions that ensure their welfare, transfer to such institutions may provide an acceptable alterative to other options, such as sale or euthanasia. As in the preceding instances, such transfer should be subject to terms and conditions agreed with the confiscating authority; in addition to those already suggested, it may be advisable to include terms that stipulate the types of research the confiscating authority considers permissible. If no placement is possible, the animals should be euthanized.

Q6 Answer: Yes: Execute Agreement and Transfer.
No: Euthanize.

DECISION TREE ANALYSIS -- RETURN TO THE WILD

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Because of the risk of introducing disease to wild populations, animals that may be released must have a clean bill of health. These animals must be placed in quarantine to determine if they are disease free before being considered for released.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen and move to Question 3

Question 3: Have animals been found to be disease free by comprehensive veterinary screening and quarantine or can they be treated for any infection discovered?
1. If during quarantine, the animals are found to harbour diseases that cannot reasonably be cured, unless any institutions are interested in the animals for research under humane conditions, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: if chronic and incurable infection, first offer animals to research institutions. if impossible to place in such institutions, euthanize.

Question 4: Can country of origin and site of capture be confirmed?

The geographical location from which confiscated individuals have been removed from the wild must be determined if these individuals are to be re-introduced or used to supplement existing populations. In most cases, animals should only be returned to the population from which they were taken, or from populations which are known to have natural exchange of individuals with this population.

If provenance of the animals is not known, release for reinforcement may lead to inadvertent hybridisation of distinct genetic races or sub-species. Related species of animals that may live in sympatry in the wild and never hybridise have been known to hybridise when held in captivity or shipped in multi-Species groups. This type of generalisation of species recognition under abnormal conditions can result in behavioural problems compromising the success of any future release and can also pose a threat to wild populations by artificially destroying reproductive isolation that is behaviourally mediated.

Q4 Answer: Yes: Proceed to Question 5.
No: Pursue 'Captive Options'.

Question 5: Do the animals exhibit behavioural abnormalities which might make them unsuitable for return to the wild?

Behavioural abnormalities as a result of captivity can result in animals which are not suitable for release into the wild. A wide variety of behavioural traits and specific behavioural skills are necessary for survival, in the short-term for the individual, and in the long-term for the population. Skills for hunting, avoiding predators, food selectivity etc. are necessary to ensure survival.

Q5 Answer: Yes: Pursue 'Captive Options'.
No; Proceed to Question 6.

Question 6:Can individuals be returned expeditiously to origin (specific location), and will benefits to conservation of the species outweigh any risks of such action?

Repatriation of the individual and reinforcement of the population will only be options under certain conditions and following the IUCN/RSG 1995 guidelines:
1) Appropriate habitat for such an operation still exists in the specific location that the individual was removed from; and
2) sufficient funds are available, or can be made available.

Q6 Answer: Yes: Repatriate and reinforce at origin (specific location) following IUCN guidelines.
No: Proceed to Question 7.

Question 7: For the species in question, does a generally recognized programme exist whose aim is conservation of the species and eventual return to the wild of confiscated individuals and or their progeny? Contact IUCN/SSC, IUDZG, Studbook Keeper, or Breeding Programme Coordinator.

In the case of Species for which active captive breeding and or re-introduction programmes exist, and for which further breeding stock/founders are required, confiscated animals should be transferred to such programmes after consultation with the appropriate scientific authorities. If the Species in question is part of a captive breeding programme, but the taxon (sub-species or race) is not part of this programme (e.g. Maguire & Lacy 1990), other methods of disposition must be considered. Particular attention should be paid to genetic screening to avoid jeopardizing captive breeding programmes through inadvertent hybridisation.

Q7 Answer: Yes: Executer agreement and transfer to existing programme.
No: Proceed to Question 8.

Question 8: Is there a need and is it feasible to establish a new r~introduction programme following IUCN Guidelines?

In cases where individuals cannot be transferred to existing r~introduction programmes, return to the wild, following appropriate guidelines, will only be possible under the following circumstances:
1) appropriate habitat exists for such an operation; 2) sufficient funds are available, or can be made available, to support a programme over the many years that (re)introduction will require; and 3) either sufficient numbers of animals are available so that re-introduction efforts are potentially viable, or only reinforcement of existing populations is considered. In the majority of cases, at least one, if not all, of these requirements will fail to be met. In this instance, either conservation introductions outside the historical range of the Species or other options for disposition of the animals must be considered.

It should be emphasized that if a particular species or taxon is confiscated with some frequency, consideration should be made as to whether to establish a re-introduction, reinforcement, or introduction programme. Animals should not be held by the confiscating authority indefinitely while such programmes are planned, but should be transferred to a holding facility after consultation with the organization which is establishing the new programme.

Q8 Answer: Yes: Execute agreement and transfer to holding facility or new programme.
No: Pursue 'Captive Options'.

References

Aveling, R. & Mitchell A.H. (1982). Is rehabilitating orang utans worthwhile? Oryx 16: 263-271.

BirdLife International (in prep). Parrots: An Action Plan for their Conservation. (BirdLife International, Cambridge: England).

Harcourt, A. H. (1987). *Options for unwanted or confiscated primates*. Primate Conservation 8:111-113.

International Academy of Animal Welfare Sciences (1992). *Welfare guidelines for the re-introduction of captive-bred mammals to the wild*. (Universities Federation for Animal Welfare, Potters Bar: United Kingdom).

IUCN (1987). *The IUCN position statement on translocation of living organisms: introductions, re-introductions and restocking*. (IUCN, Gland: Switzerland).

IUCN/SSC RSG (1995). *Draft guidelines for re-introductions*. Species Survival Commission Re-introduction Specialist Group, IUCN - The World Conservation Union.

IUDZG/CBSG (IUCN/SSC) 1993. *The World Zoo Conservation Strategy. The Role of Zoos and Aquaria of the World in Global Conservation*. IUDZG - the World Zoo Organization.

Maguire, L.A. and Lacy, W. C. (1990). Allocating scarce resources for conservation of endangered sub-Species: partitioning zoo space for tigers. Conservation Biology 4, 156-157.

Rijksen, H. D. & Rijksen-Graatsma, A. (1979). Rehabilitation, a new approach is needed. Tigerpaper 6:16-18.

Seal, U.S. & Foose, T. (1992). Captive Animal Management Program (CAMP) Summary Report. (IUCN-CBSG, Apple Valley, Minnesota: USA).

Smith, R. (1990). Island Update. Red Wolf Newsletter 2(1): 2-3.

Stanley Price, M. W. (1989) *Animal re-introduction: the Arabian oryx in Oman*. Cambridge studies in applied ecology and resource management. (Cambridge University Press, Cambridge).

IUCN Position Statement on Translocation of Living Organisms:

INTRODUCTIONS, REINTRODUCTIONS AND RE-STOCKING

Prepared by the Species Survival Commission in collaboration with the Commission on Ecology, and the Commission on Environmental Policy, Law and Administration
Approved by the 22nd Meeting of the IUCN Council, Gland, Switzerland, 4 September 1987

FOREWORD

This statement sets out IUCN's position on translocation of living organisms, covering introductions, re-introductions and re-stocking. The implications of these three sorts of translocation are very different so the paper is divided into four parts dealing with Introductions, Re-introductions, Re-stocking and Administrative Implications, respectively.

DEFINITIONS:

Translocation is the movement of living organisms from one area with free release in another. The three main classes of translocation distinguished in this document are defined as follows:

- **Introduction** of an organism is the intentional or accidental dispersal by human agency of a living organism outside its historically known native range.
- **Re-introduction** of an organism is the intentional movement of an organism into a part of its native range from which it has disappeared or become extirpated in historic times as a result of human activities or natural catastrophe.
- **Re-stocking** is the movement of numbers of plants or animals of a species with the intention of building up the number of individuals of that species in an original habitat.

Translocations are powerful tools for the management of the natural and man made environment which, properly used, can bring great benefits to natural biological systems and to man, but like other powerful tools they have the potential to cause enormous damage if misused. This IUCN statement describes the advantageous uses of translocations and the work and precautions needed to avoid the disastrous consequences of poorly planned translocations.

PART I

INTRODUCTIONS

BACKGROUND

Non-native (exotic) species have been introduced into areas where they did not formerly exist for a variety of reasons, such as economic development, improvement of hunting and fishing, ornamentation, or maintenance of the cultures of migrated human communities. The damage done by harmful introductions to natural systems far outweighs the benefit derived from them. The introduction and establishment of alien species in areas where they did not formerly occur, as an accidental or intended result of human activities, has often been directly harmful to the native plants and animals of many parts of the world and to the welfare of mankind.

The establishment of introduced alien species has broken down the genetic isolation of communities of co-evolving species of plants and animals. Such isolation has been essential for the evolution and maintenance of the diversity of plants and animals composing the biological wealth of our planet. Disturbance of this isolation by alien species has interfered with the dynamics of natural systems causing the premature extinction of species. Especially successful and aggressive invasive species of plants and animals increasingly dominate large areas having replaced diverse autochthonous communities. Islands, in the broad sense, including isolated biological systems such as lakes or isolated mountains, are especially vulnerable to introductions because their often simple ecosystems offer refuge for species that are not aggressive competitors. As a result of their isolation they are of special value because of high endemism (relatively large numbers of unique local forms) evolved under the particular conditions of these islands over a long period of time. These endemic species are often rare and highly specialised in their ecological requirements and may be remnants of extensive communities from bygone ages, as exemplified by the Pleistocene refugia of Africa and Amazonia.

The diversity of plants and animals in the natural world is becoming increasingly important to man as their demands on the natural world increase in both quantity and variety, notwithstanding their dependence on crops and domestic animals nurtured within an increasingly uniform artificial and consequently vulnerable agricultural environment.

Introductions, can be beneficial to man. Nevertheless the following sections define areas in which the introduction of alien organisms is not conducive to good management, and describe the sorts of decisions that should be made before introduction of an alien species is made.

To reduce the damaging impact of introductions on the balance of natural systems, governments should provide the legal authority and administrative support that will promote implementation of the following approach.

Intentional Introduction

General

1. Introduction of an alien species should only be considered if clear and well defined benefits to man or natural communities can be foreseen.
2. Introduction of an alien species should only be considered if no native species is considered suitable for the purpose for which the introduction is being made.

Introductions to Natural Habitats

3. No alien species should be deliberately introduced into any natural habitat, island, lake, sea, ocean or centre of endemism, whether within or beyond the limits of national jurisdiction. A natural habitat is defined as a habitat not perceptibly altered by man. Where it would be effective, such areas should be surrounded by a buffer zone sufficiently large to prevent unaided spread of alien species from nearby areas. No alien introduction should be made within the buffer zone if it is likely to spread into neighbouring natural areas.

Introduction into Semi-natural Habitat

4. No alien species should be introduced into a semi-natural habitat unless there are exceptional reasons for doing so , and only when the operation has been comprehensively investigated and carefully planned in advance. A semi-natural habitat is one which has been detectably changed by man's actions or one which is managed by man, but still resembles a natural habitat in the diversity of its species and the complexity of their interrelationships. This excludes arable farm land, planted ley pasture and timber plantations.

Introductions into Man-made Habitat

5. An assessment should be made of the effects on surrounding natural and semi-natural habitats of the introduction of any species, sub-species, or variety of plant to artificial, arable, ley pasture or other predominantly monocultural forest systems. Appropriate action should be taken to minimise negative effects.

Planning a Beneficial introduction

6. Essential features of investigation and planning consist of:
    - an assessment phase culminating in a decision on the desirability of the introduction;

- an experimental, controlled trial;
- the extensive introduction phase with monitoring and follow-up.

THE ASSESSMENT PHASE

Investigation and planning should take the following factors into account:

a) No species should be considered for introduction to a new habitat until the factors which limit its distribution and abundance in its native range have been thoroughly studied and understood by competent ecologists and its probable dispersal pattern appraised.

Special attention should be paid to the following questions:

- What is the probability of the exotic species increasing in numbers so that it causes damage to the environment, especially to the biotic community into which it will be introduced?
- What is the probability that the exotic species will spread and invade habitats besides those into which the introduction is planned? Special attention should be paid to the exotic species' mode of dispersal.
- How will the introduction of the exotic proceed during all phases of the biological and climatic cycles of the area where the introduction is planned? It has been found that fire, drought and flood can greatly alter the rate of propagation and spread of plants.
- What is the capacity of the species to eradicate or reduce native species by interbreeding with them?
- Will an exotic plant interbreed with a native species to produce new species of aggressive polyploid invader? Polyploid plants often have the capacity to produce varied offspring some of which quickly adapt to and dominate, native floras and cultivars alike.
- Is the alien species the host to diseases or parasites communicable to other flora and fauna, man, their crops or domestic animals, in the area of introduction?
- What is the probability that the species to be introduced will threaten the continued existence or stability of populations of native species, whether as a predator, competitor for food, cover, breeding sites or in any other way? If the introduced species is a carnivore, parasite or specialised herbivore, it should not be introduced if its food includes rare native species that could be adversely affected.

b) There are special problems to be considered associated with the introduction of aquatic species. These species have a special potential for invasive spread.

- Many fish change trophic level or diet preference following introduction, making prediction of the results of the re-introduction difficult. Introduction of a fish or other species at one point on a river system or into the sea may lead to the spread of the species throughout the system or area with unpredictable consequences for native animals and plants. Flooding may transport introduced species from one river system to another.
- introduced fish and large aquatic invertebrates have shown a great capacity to disrupt natural systems as their larval, sub-adult and adult forms often use different parts of the same natural system.

c) No introduction should be made for which a control does not exist or is not possible. A risk-and-threat analysis should be undertaken including investigation of the availability of methods for the control of the introduction should it expand in a way not predicted or have unpredicted undesirable effects, and the methods of control should be socially acceptable, efficient, should not damage vegetation and fauna, man, his domestic animals or cultivars.

d)When the questions above have been answered and the problems carefully considered, it should be decided if the species can reasonably be expected to survive in its new habitat, and if so, if it can reasonably be expected to enhance the flora and fauna of the area, or the economic or aesthetic value of the area, and whether these benefits outweigh the possible disadvantages revealed by the investigations.

THE EXPERIMENTAL CONTROLLED TRIAL

Following a decision to introduce a species, a controlled experimental introduction should be made observing the following advice:

- Test plants and animals should be from the same stock as those intended to be extensively introduced.
- They should be free of diseases and parasites communicable to native species, man, his crops and domestic livestock.
- The introduced species' performance on parameters in 'the Assessment Phase' above should be compared with the pre-trial assessment, and the suitability of the species for introduction should be reviewed in light of the comparison.

THE EXTENSIVE INTRODUCTION

If the introduced species behaves as predicted under the experimental conditions, then extensive introductions may commence but should be closely monitored. Arrangements should be made to apply counter measures to restrict, control, or eradicate the species if necessary.

The results of all phases of the introduction operation should be made public and available to scientists and others interested in the problems of introductions.

The persons or organisation introducing the species, not the public, should bear the cost of control of introduced organisms and appropriate legislation should reflect this.

ACCIDENTAL INTRODUCTIONS

1. Accidental introductions of species are difficult to predict and monitor, nevertheless they "should be discouraged where possible. The following actions are particularly important:
    - On island reserves, including isolated habitats such as lakes, mountain tops and isolated forests, and in wilderness areas, special care should be taken to avoid accidental introductions of seeds of alien plants on shoes and clothing and the introduction of animals especially associated with man, such as cats, dogs, rats and mice.
    - Measures, including legal measures, should be taken to discourage the escape of farmed, including captive-bred, alien wild animals and newly-domesticated species which could breed with their wild ancestors if they escaped.
    - In the interest of both agriculture and wildlife, measures should be taken to control contamination of imported agricultural seed with seeds of weeds and invasive plants.
    - Where large civil engineering projects are envisaged, such as canals, which would link different biogeographical zones, the implications of the linkage for mixing the fauna and flora of the two regions should be carefully considered. An example of this is the mixing of species from the Pacific and Caribbean via the Panama Canal, and the mixing of Red Sea and Mediterranean aquatic organisms via the Suez Canal. Work needs to be done to consider what measures can be taken to restrict mixing of species from different zones through such large developments.

2. Where an accidentally introduced alien successfully and conspicuously propagates itself, the balance of its positive and negative economic and ecological effects should be investigated. If the overall effect is negative, measures should be taken to restrict its spread.

WHERE ALIEN SPECIES ARE ALREADY PRESENT

1. In general, introductions of no apparent benefit to man, but which are having a negative effect on the native flora and fauna into which they have been introduced, should be removed or eradicated. The present ubiquity of introduced species will put effective action against the majority of invasives beyond the means of many States but special efforts should be made to eradicate introductions on:
   - islands with a high percentage of endemics in the flora and fauna;
   - areas which are centres of endemism;
   - areas with a high degree of species diversity;
   - areas with a high degree of other ecological diversity;
   - areas in which a threatened endemic is jeopardised by the presence of the alien.
2. Special attention should be paid to feral animals. These can be some of the most aggressive and damaging alien species to the natural environment, but may have value as an economic or genetic resource in their own right, or be of scientific interest. Where a feral population is believed to have a value in its own right, but is associated with changes in the balance of native vegetation and fauna, the conservation of the native flora and fauna should always take precedence. Removal to captivity or domestication is a valid alternative for the conservation of valuable feral animals consistent with the phase of their evolution as domestic animals.

   Special attention should be paid to the eradication of mammalian feral predators from areas where there are populations of breeding birds or other important populations of wild fauna. Predatory mammals are especially difficult, and sometimes impossible to eradicate, for example, feral cats, dogs, mink, and ferrets.
3. In general, because of the complexity and size of the problem, but especially where feral mammals or several plant invaders are involved, expert advice should be sought on eradication.

BIOLOGICAL CONTROL

1. Biological control of introductions has shown itself to be an effective way of controlling and eradicating introduced species of plants and more rarely, of animals. As biological control involves introduction of alien species, the same care and procedures should be used as with other intentional introductions.

MICRO-ORGANISMS

1. There has recently been an increase of interest in the use of micro-organisms for a wide variety of purposes including those genetically altered by man.
   Where such uses involve the movement of micro-organisms to areas where they did not formerly exist, the same care and procedures should be used as set out above for other species.

PART II

THE RE-INTRODUCTION OF SPECIES*

Re-introduction is the release of a species of animal or plant into an area in which it was indigenous before extermination by human activities or natural catastrophe. Re-introduction is a particularly useful tool for restoring a species to an original habitat where it has become extinct due to human persecution, over-collecting, over-harvesting or habitat deterioration, but where these factors can now be controlled. Re-introductions should only take place where the original causes of extinction have been removed. Re-introductions should only take place where the habitat requirements of the species are satisfied. There should be no re-introduction if a species became extinct because of habitat change which remains unremedied, or where significant habitat deterioration has occurred since the extinction.

The species should only be re-introduced if measures have been taken to reconstitute the habitat to a state suitable for the species.

The basic programme for re-introduction should consist of:

- a feasibility study;
- a preparation phase;
- release or introduction phase; and a
- follow-up phase.

THE FEASIBILITY STUDY

An ecological study should assess the previous relationship of the species to the habitat into which the re-introduction is to take place, and the extent that the habitat has changed since the local extinction of the species. If individuals to be re-introduced have been captive-bred or cultivated, changes in the species should also be taken into account and allowances made for new features liable to affect the ability of the animal or plant to re-adapt to its traditional habitat.

The attitudes of local people must be taken into account especially if the reintroduction of a species that was persecuted, over-hunted or over collected , is proposed. If the attitude of local people is unfavorable an education and interpretive programme emphasizing the benefits to them of the re-introduction, or other inducement, should be used to improve their attitude before re-introduction takes place.

The animals or plants involved in the re-introduction must be of the closest available race or type to the original stock and preferably be the same race as that previously occurring in the area.

Before commencing a re-introduction project, sufficient funds must be available to ensure that the project can be completed, including the follow-up phase.

THE PREPARATION AND RELEASE OR INTRODUCTORY PHASES

The successful re-introduction of an animal or plant requires that the biological needs of the species be fulfilled in the area where the release is planned. This requires a detailed knowledge of both the needs of the animal or plant and the ecological dynamics of the area of re-introduction. For this reason the best available scientific advice should be taken at all stages of a species re-introduction.

This need for clear analysis of a number of factors can be clearly seen with reference to introductions of ungulates such as ibex, antelope and deer where re-introduction involves understanding and applying the significance of factors such as the ideal age for re-introducing individuals, ideal sex ratio, season, specifying capture techniques and mode of transport to re-introduction site, freedom of both the species and the area of introduction from disease and parasites, acclimatisation, helping animals to learn to forage in the wild, adjustment of the gut flora to deal with new forage, 'imprinting' on the home range, prevention of wandering of individuals from the site of re-introduction, and on-site breeding in enclosures before release to expand the released population and acclimatise the animals to the site. The re-introduction of other taxa of plants and animals can be expected to be similarly complex.

FOLLOW-UP PHASE

Monitoring of released animals must be an integral part of any re-introduction programme. Where possible there should be long-term research to determine the rate of adaptation and dispersal, the need for further releases and identification of the reasons for success or failure of the programme.

The species impact on the habitat should be monitored and any action needed to improve conditions identified and taken.

Efforts should be made to make available information on both successful and unsuccessful re-introduction programmed through publications, seminars and other communications.

PART III

RESTOCKING

1. Restocking is the release of a plant or animal species into an area in which it is already present. Restocking may be a useful tool where:
   - it is feared that a small reduced population is becoming dangerously inbred; or
   - where a population has dropped below critical levels and recovery by natural growth will be dangerously slow; or
   - where artificial exchange and artificially-high rates of immigration are required to maintain outbreeding between small isolated populations on biogeographical islands.
2. In such cases care should be taken to ensure that the apparent nonviability of the population, results from the genetic institution of the population and not from poor species management which has allowed deterioration in the habitat or over-utilisation of the population. With good management of a population the need for re-stocking should be avoidable but where re-stocking is contemplated the following points should be observed:

   a) Restocking with the aim of conserving a dangerously reduced population should only be attempted when the causes of the reduction have been largely removed and natural increase can be excluded.

   b) Before deciding if restocking is necessary, the capacity of the area it is proposed to restock should be investigated to assess if the level of the population desired is sustainable. If it is, then further work should be undertaken to discover the reasons for the existing low population levels. Action should then be taken to help the resident population expand to the desired level. Only if this fails should restocking be used.
3. Where there are compelling reasons for restocking the following points should be observed.

   a) Attention should be paid to the genetic constitution of stocks used for restocking.

   - In general, genetic manipulation of wild stocks should be kept to a minimum as it may adversely affect the ability of a species or population to survive. Such manipulations modify the effects of natural selection and ultimately the nature of the species and its ability to survive.

- Genetically impoverished or cloned stocks should not be used to re-stock populations as their ability to survive would be limited by their genetic homogeneity.

b) The animals or plants being used for re-stocking must be of the same race as those in the population into which they are released.

c) Where a species has an extensive natural range and restocking has the aim of conserving a dangerously reduced population at the climatic or ecological edge of its range, care should be taken that only individuals from a similar climatic or ecological zone are used since interbreeding with individuals from an area with a milder climate may interfere with resistant and hardy genotypes on the population's edge.

d) Introduction of stock from zoos may be appropriate, but the breeding history and origin of the animals should be known and follow as closely as possible Assessment Phase guidelines a, b, c and d (see pages 5-7). In addition the dangers of introducing new diseases into wild populations must be avoided: this is particularly important with primates that may carry human zoonoses.

e) Restocking as part of a sustainable use of a resource (e.g. release of a proportion of crocodiles hatched from eggs taken from farms) should follow guidelines a and b (above).

f) Where restocking is contemplated as a humanitarian effort to release or rehabilitate captive animals it is safer to make such releases as re-introductions where there is no danger of infecting wild populations of the same species with new diseases and where there are no problems of animals having to be socially accepted by wild individuals of the species.

PART IV

NATIONAL, INTERNATIONAL AND SCIENTIFIC IMPLICATIONS OF TRANSLOCATIONS

NATIONAL ADMINISTRATION

1. Pre-existing governmental administrative structures and frameworks already in use to protect agriculture, primary industries, wilderness and national parks should be used by governments to control both intentional and unintentional importation of organisms, especially through use of plant and animal quarantine regulations.
2. Governments should set up or utilise pre-existing scientific management authorities or experts in the fields of biology, ecology and natural resource management to advise them on policy matters concerning translocations and on individual cases where an introduction, re-introduction or restocking or farming of wild species is proposed.
3. Governments should formulate national policies on:
    - translocation of wild species;
    - capture and transport of wild animals;
    - artificial propagation of threatened species;
    - selection and propagation of wild species for domestication; and
    - prevention and control of invasive alien species.
4. At the national level legislation is required to curtail introductions:

Deliberate introductions should be subject to a permit system. The system should apply not only to species introduced from abroad but also to native species introduced to a new area in the same country. It should also apply to restocking.

Accidental introductions

- for all potentially harmful organisms there should be a prohibition to import them and to trade in them except under a permit and under very stringent conditions. This should apply in particular to the pet trade;
- where a potentially harmful organism is captive bred for commercial purposes (e.g. mink) there should be established by legislation strict standards for the design and operation of the captive breeding facilities. In particular, procedures should be established for the disposal of the stock of animals in the event of a discontinuation of the captive breeding operation;
- there should be strict controls on the use of live fish bait to avoid inadvertent introductions of species into water where they do not naturally occur.

Penalties

5. Deliberate introductions without a permit as well as negligence resulting in the escape or introduction of species harmful to the environment should be considered criminal offences and punished accordingly. The author of a deliberate introduction without a permit or the person responsible for an introduction by negligence should be legally liable for the damage incurred and should in particular bear the costs of eradication measures and of habitat restoration where required.

INTERNATIONAL ADMINISTRATION

Movement of Introduced Species Across International Boundaries

1. Special care should be taken to prevent introduced species from crossing the borders of a neighboring state. When such an occurence is probable, the neighboring state should be promptly warned and consultations should be held in order to take adequate measures.

The Stockholm Declaration

2. According to Principle 21 of the Stockholm Declaration on the Human Environment, states have the responsibility 'to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states'.

International Codes of Practice, Treaties and Agreements

3. States should be aware of the following international agreements and documents relevant to translocation of species:
    - ICES, Revised Code of Practice to Reduce the Risks from introduction of Marine Species, 1982.
    - FAO, Report of the Expert Consultation on the Genetic Resources of Fish, Recommendations to Governments No L 1980.
    - EIFAC (European Inland Fisheries Advisory Commission), Report of the Working Party on Stock Enhancement, Hamburg, FRG 1983.
    - The Bonn Convention MSC: Guidelines for Agreements under the Convention.
    - The Berne Convention: the Convention on the Conservation of European wildlife and Natural Habitats.

- The ASEAN Agreement on the Conservation of Nature and Natural Resources.
- Law of the Sea Convention, article 196.
- Protocol on Protected Areas and Wild Fauna and Flora in Eastern African Region.

In addition to the international agreements and documents cited, States also should be aware of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). International shipments of endangered or threatened species listed in the Appendices to the Convention are subject to CITES regulation and permit requirements. Enquiries should be addressed to: CITES Secretariat**, Case Postale 456, CH-1219 Chatelaine, Genève, Switzerland; telephone: 41/22/979 9149, fax: 41/22/797 3417.

Regional Development Plans

4. International, regional or country development and conservation organisations, when considering international, regional or country conservation strategies or plans, should include in-depth studies of the impact and influence of introduced alien species and recommend appropriate action to ameliorate or bring to an end their negative effects.

Scientific Work Needed

5. A synthesis of current knowledge on introductions, re-introductions and re-stocking is needed.

6. Research is needed on effective, target specific, humane and socially acceptable methods of eradication and control of invasive alien species.

7. The implementation of effective action on introductions, re-introductions and re-stocking frequently requires judgements on the genetic similarity of different stocks of a species of plant or animal. More research is needed on ways of defining and classifying genetic types.

8. Research is needed on the way in which plants and animals are dispersed through the agency of man (dispersal vector analysis).

   A review is needed of the scope, content and effectiveness of existing legislation relating to introductions.

IUCN Responsibilities

International organisations, such as UNEP, UNESCO and FAO, as well as states planning to introduce, re-introduce or restock taxa in their territories, should provide sufficient funds, so that IUCN as an international independent body, can do the work set out below and accept the accompanying responsibilities.

9. IUCN will encourage collection of information on all aspects of introductions, re-introductions and restocking, but especially on the case histories of re-introductions; on habitats especially vulnerable to invasion; and notable aggressive invasive species of plants and animals.

   Such information would include information in the following categories:

   - a bibliography of the invasive species;
   - the taxonomy of the species;
   - the synecology of the species; and
   - methods of control of the species.

10. The work of the Threatened Plants Unit of IUCN defining areas of high plant endemism, diversity and ecological diversity should be encouraged so that guidance on implementing recommendations in this document may be available.

11. A list of expert advisors on control and eradication of alien species should be available through IUCN.

Note:
* The section on re-introduction of species has been enhanced by the Guidelines For Re-Introductions
** The address of the CITES Secretariat has been updated.

IUCN Policy Statement on Captive Breeding

Prepared by the SSC Captive Breeding Specialist Group *
Approved by the 22nd Meeting of the IUCN Council, Gland Switzerland, 4 September 1987

SUMMARY: Habitat protection alone is not sufficient if the expressed goal of the World Conservation Strategy, the maintenance of biotic diversity, is to be achieved. Establishment of self-sustaining captive populations and other supportive intervention will be needed to avoid the loss of many species, especially those at high risk. In greatly reduced, highly fragmented, and disturbed habitats Captive breeding programmes need to be established before species are reduced to critically low numbers, and thereafter need to be co-ordinated internationally according to sound biological principles, with a view to the maintaining or re-establishment of viable populations in the wild.

PROBLEM STATEMENT

IUCN data indicate that abut three per cent of terrestrial Earth is gazetted for protection. Some of this and much of the other 97 per cent is becoming untenable for many species and remaining populations are being greatly reduced and fragmented. From modern population biology one can predict that many species will be lost under these conditions. On average more than one mammal, bird, or reptile species has been lost in each year this century. Since extinctions of most taxa outside these groups are not recorded, the loss rate for all species is much higher.

Certain groups of species are at particularly high risk, especially forms with restricted distribution, those of large body size, those of high economic value, those at the top of food chains, and those which occur only in climax habitats. Species in these categories are likely to be lost first, but a wide range of other forms are also at risk. Conservation over the long term will require management to reduce risk, including ex situ populations which could support and interact demographically and genetically with wild populations.

FEASIBILITY

Over 3,000 vertebrate species are being bred in zoos and other captive animal facilities. When a serious attempt is made, most species breed in captivity, and viable populations can be maintained over the long term. A wealth of experience is available in these institutions, including husbandry, veterinary medicine, reproductive biology, behaviour, and genetics. They offer space for supporting populations of many threatened taxa, using resources not competitive with those for in situ conservation. Such captive stocks have in the past provided critical support for some wild populations (e.g. American bison, *Bison bison*), and have been the sole escape from extinction for others which have since been re-introduced to the wild (e.g. Arabian oryx, *Oryx leucoryx*).

RECOMMENDATION

IUCN urges that those national and international organizations and those individual institutions concerned with maintaining wild animals in captivity commit themselves to a general policy of developing demographically self-sustaining captive populations of endangered species wherever necessary.

SUGGESTED PROTOCOL

WHAT: The specific problems of the species concerned need to be considered, and appropriate aims for a captive breeding programme made explicit.

WHEN: The vulnerability of small populations has been consistently under estimated. This has erroneously shifted the timing of establishment of captive populations to the last moment, when the crisis is enormous and when extinction is probable. Therefore, timely recognition of such situations is critical, and is dependent on information on wild population status, particularly that provided by the IUCN/Conservation Monitoring Centre**. Management to best reduce the risk of extinction requires the establishment of supporting captive populations much earlier, preferably when the wild population is still in the thousands. Vertebrate taxa with a current census below one thousand individuals in the wild require close and swift cooperation between field conservationists and captive breeding specialists, to make their efforts complementary and minimize the likelihood of the extinction of these taxa.

HOW: Captive populations need to be founded and managed according to sound scientific principles for the primary purpose of securing the survival of species through stable, self-sustaining captive populations. Stable captive populations preserve the options of reintroduction and/or supplementation of wild populations. A framework of international cooperation and coordination between captive breeding institutions holding species at risk must be based upon agreement to cooperatively manage such species for demographic security and genetic diversity. The IUCN/SSC Captive Breeding Specialist Group* is an appropriate advisory body concerning captive breeding science and resources.

Captive programmes involving species at risk should be conducted primarily for the benefit of the species and without commercial transactions. Acquisition of animals for such programmed should not encourage commercial ventures or trade. Whenever possible, captive programmed should be carried out in parallel with field studies and conservation efforts aimed at the species in its natural environment.

Notes:
Currently the *Conservation Breeding Specialist Group and the
** World Conservation Monitoring Centre

IUCN/SSC Guidelines For Re-Introductions

Prepared by the SSC Re-introduction Specialist Group *
Approved by the 41st Meeting of the IUCN Council, Gland Switzerland, May 1995

INTRODUCTION

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission (1), in response to the increasing occurrence of re-introduction projects worldwide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although IUCN developed a Position Statement on the Translocation of Living Organisms in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re-introduction exercises.

These guidelines are intended to act as a guide for procedures useful to re-introduction programmes and do not represent an inflexible code of conduct. Many of the points are more relevant to re-introductions using captive-bred individuals than to translocations of wild species. Others are especially relevant to globally endangered species with limited numbers of founders. Each re-introduction proposal should be rigorously reviewed on its individual merits. It should be noted that re-introduction is always a very lengthy, complex and expensive process.

Re-introductions or translocations of species for short-term, sporting or commercial purposes - where there is no intention to establish a viable population - are a different issue and beyond the scope of these guidelines. These include fishing and hunting activities.

This document has been written to encompass the full range of plant and animal taxa and is therefore general. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

CONTEXT

The increasing number of re-introductions and translocations led to the establishment of the IUCN/SSC Species Survival Commission's Re-introduction Specialist Group. A priority of the Group has been to update IUCN's 1987 Position Statement on the Translocation of Living Organisms, in consultation with IUCN's other commissions.

It is important that the Guidelines are implemented in the context of IUCN's broader policies pertaining to biodiversity conservation and sustainable management of natural resources. The philosophy for environmental conservation and management of IUCN and other conservation bodies is stated in key documents such as "Caring for the Earth" and "Global Biodiversity Strategy" which cover the broad themes of the need for approaches with community involvement and participation in sustainable natural resource conservation, an overall enhanced quality of human life and the need to conserve and, where necessary, restore ecosystems. With regards to the latter, the re-introduction of a species is one specific instance of restoration where, in general, only this species is missing. Full restoration of an array of plant and animal species has rarely been tried to date.

Restoration of single species of plants and animals is becoming more frequent around the world. Some succeed, many fail. As this form of ecological management is increasingly common, it is a priority for the Species Survival Commission's Re-introduction Specialist Group to develop guidelines so that re-introductions are both justifiable and likely to succeed, and that the conservation world can learn from each initiative, whether successful or not. It is hoped that these Guidelines, based on extensive review of case - histories and wide consultation across a range of disciplines will introduce more rigour into the concepts, design, feasibility and implementation of re-introductions despite the wide diversity of species and conditions involved.

Thus the priority has been to develop guidelines that are of direct, practical assistance to those planning, approving or carrying out re-introductions. The primary audience of these guidelines is, therefore, the practitioners (usually managers or scientists), rather than decision makers in governments. Guidelines directed towards the latter group would inevitably have to go into greater depth on legal and policy issues.

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1. DEFINITION OF TERMS

"Re-introduction": an attempt to establish a species(2) in an area which was once part of its historical range, but from which it has been extirpated or become extinct (3) ("Re-establishment" is a synonym, but implies that the re-introduction has been successful).

"Translocation": deliberate and mediated movement of wild individuals or populations from one part of their range to another.

"Re-inforcement/Supplementation": addition of individuals to an existing population of conspecifics.

"Conservation/Benign Introductions": an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area. This is a feasible conservation tool only when there is no remaining area left within a species' historic range.

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2. AIMS AND OBJECTIVES OF RE-INTRODUCTION

a. Aims:
The principle aim of any re-introduction should be to establish a viable, free-ranging population in the wild, of a species, subspecies or race, which has become globally or locally extinct, or extirpated, in the wild. It should be re-introduced within the species' former natural habitat and range and should require minimal long-term management.

b. Objectives:
The objectives of a re-introduction may include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain and/or restore natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of these.

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3. MULTIDISCIPLINARY APPROACH

A re-introduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. As well as government personnel, they may include persons from governmental natural resource management agencies; non-governmental organisations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

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4. PRE-PROJECT ACTIVITIES

4a. BIOLOGICAL

(i) Feasibility study and background research

- An assessment should be made of the taxonomic status of individuals to be re-introduced. They should preferably be of the same subspecies or race as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re-introduction area, as well as molecular genetic studies, should be undertaken in case of doubt as to individuals' taxonomic status. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.
- Detailed studies should be made of the status and biology of wild populations(if they exist) to determine the species' critical needs. For animals, this would include descriptions of habitat preferences, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases. For migratory species, studies should include the potential migratory areas. For plants, it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators), insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re-introduction scheme.
- The species, if any, that has filled the void created by the loss of the species concerned, should be determined; an understanding of the effect the re-introduced species will have on the ecosystem is important for ascertaining the success of the re-introduced population.
- The build-up of the released population should be modelled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.
- A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

(ii) Previous Re-introductions

- Thorough research into previous re-introductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing re-introduction protocol.

(iii) Choice of release site and type

- Site should be within the historic range of the species. For an initial re-inforcement there should be few remnant wild individuals. For a re-introduction, there should be no remnant population to prevent disease spread, social disruption and introduction of alien genes. In some circumstances, a re-introduction or re-inforcement may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range.
- A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist and only when a significant contribution to the conservation of the species will result.
- The re-introduction area should have assured, long-term protection (whether formal or otherwise).

(iv) Evaluation of re-introduction site

- Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. Likewise, a change in the legal/ political or cultural environment since species extirpation needs to be ascertained and evaluated as a possible constraint. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.
- Identification and elimination, or reduction to a sufficient level, of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal. Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the re-introduction is carried out.

(v) Availability of suitable release stock

- It is desirable that source animals come from wild populations. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics (morphology, physiology, behaviour, habitat preference) to the original sub-population.
- Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.
- Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.
- If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.
- Re-introductions should not be carried out merely because captive stocks exist, nor solely as a means of disposing of surplus stock.
- Prospective release stock, including stock that is a gift between governments, must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for non-endemic or contagious pathogens with a potential impact on population levels, must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.
- Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.
- Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

(vi) Release of captive stock

- Most species of mammal and birds rely heavily on individual experience and learning as juveniles for their survival; they should be given the opportunity to acquire the necessary information to enable survival in the wild, through training in their captive environment; a captive bred individual's probability of survival should approximate that of a wild counterpart.

- Care should be taken to ensure that potentially dangerous captive bred animals (such as large carnivores or primates) are not so confident in the presence of humans that they might be a danger to local inhabitants and/or their livestock.

4b. SOCIO-ECONOMIC AND LEGAL REQUIREMENTS

- Re-introductions are generally long-term projects that require the commitment of long-term financial and political support.
- Socio-economic studies should be made to assess impacts, costs and benefits of the re-introduction programme to local human populations.
- A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss or alteration of habitat). The programme should be fully understood, accepted and supported by local communities.
- Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimise these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.
- The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing provincial, national and international legislation and regulations, and provision of new measures and required permits as necessary.
- Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state or when a re-introduced population can expand into other states, provinces or territories.
- If the species poses potential risk to life or property, these risks should be minimised and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered. In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.

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5. PLANNING, PREPARATION AND RELEASE STAGES

- Approval of relevant government agencies and land owners, and coordination with national and international conservation organizations.
- Construction of a multidisciplinary team with access to expert technical advice for all phases of the programme.
- Identification of short- and long-term success indicators and prediction of programme duration, in context of agreed aims and objectives.
- Securing adequate funding for all programme phases.
- Design of pre- and post- release monitoring programme so that each re-introduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data.

Monitoring the health of individuals, as well as the survival, is important; intervention may be necessary if the situation proves unforseeably favourable.

- Appropriate health and genetic screening of release stock, including stock that is a gift between governments. Health screening of closely related species in the re-introduction area.
- If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.
- If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.
- Appropriate veterinary or horticultural measures as required to ensure health of released stock throughout the programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to the release site.
- Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.
- Determination of release strategy (acclimatization of release stock to release area; behavioural training - including hunting and feeding; group composition, number, release patterns and techniques; timing).
- Establishment of policies on interventions (see below).
- Development of conservation education for long-term support; professional training of individuals involved in the long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.
- The welfare of animals for release is of paramount concern through all these stages.

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6. POST-RELEASE ACTIVITIES

- Post release monitoring is required of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.
- Demographic, ecological and behavioural studies of released stock must be undertaken.
- Study of processes of long-term adaptation by individuals and the population.
- Collection and investigation of mortalities.
- Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.
- Decisions for revision, rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage.
- Evaluation of cost-effectiveness and success of re- introduction techniques.
- Regular publications in scientific and popular literature.

Footnotes:

1. Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN.
2. The taxonomic unit referred to throughout the document is species; it may be a lower taxonomic unit (e.g. subspecies or race) as long as it can be unambiguously defined.
3. A taxon is extinct when there is no reasonable doubt that the last individual has died

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The IUCN/SSC Re-introduction Specialist Group

The IUCN/SSC Re-introduction Specialist Group (RSG) is a disciplinary group (as opposed to most SSC Specialist Groups which deal with single taxonomic groups), covering a wide range of plant and animal species. The RSG has an extensive international network, a re-introduction projects database and re-introduction library. The RSG publishes a bi-annual newsletter RE-INTRODUCTION NEWS.
If you are a re-introduction practitioner or interested in re-introductions please contact:

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