Wyoming Toad (*Bufo baxteri*)

Population and Habitat Viability Assessment

February, 2001
Laramie, Wyoming

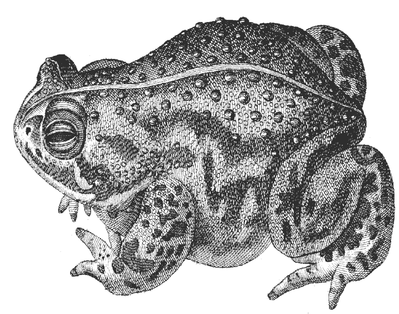
POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)

for the

WYOMING TOAD
(*Bufo baxteri*)

12 – 15 February 2001
Laramie, Wyoming

FINAL WORKSHOP REPORT



A contribution of the IUCN/SSC Conservation Breeding Specialist Group, in collaboration with the United States Fish and Wildlife Service (U.S. Department of the Interior).

Cover photograph of Wyoming toad courtesy of S. Roberts, USFWS.
Cover photograph of Mortenson Lake courtesy of A. Anderson.

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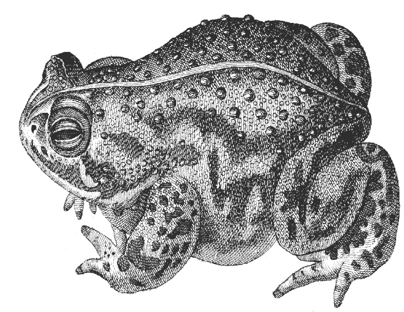

SECTION I
EXECUTIVE SUMMARY

Wyoming Toad (*Bufo baxteri*) Population and Habitat Viability Assessment (PHVA) Workshop Executive Summary

Introduction

The Wyoming toad was discovered by Dr. George Baxter in 1946 and was originally known as *Bufo hemiophrys baxteri* until 1998 when it was given full species status as *Bufo baxteri*. The toad is thought to be a glacial relic always found only in the Laramie Basin. It was originally known from many breeding sites in the floodplains of the Big and Little Laramie Rivers. Later, after irrigation practices changed the nature of the floodpains, it was found along margins of ponds and small seepage lakes between 7,000 and 7,500 feet. Baxter and others monitored breeding sites for more than 30 years, with few toads seen or heard from 1975 to 1979. An extensive survey of the Laramie Basin in 1980 found only one population.

The Wyoming toad was listed as an endangered species under the Endangered Species Act on January 17, 1984, with a recovery plan approved in 1991. Currently the total population of the Wyoming toad includes approximately 200 animals in the captive breeding program and as few as 62 toads surviving at reintroduction sites in the Laramie Basin based upon fall 2000 survey data (after releases of more than 10,000 toads and tadpoles since 1995). Necessary conservation measures include improving reproduction and survival in the captive breeding program, improving survival at reintroduction sites, developing techniques to control the effects of the amphibian chytrid fungus, and eliminating threats and further habitat degradation in the wild.

The PHVA Workshop Process

In order to better understand the factors leading to the precipitous decline of the Wyoming toad, and to develop a set of alternative population management options, The United States Fish and Wildlife Service (US Department of the Interior) requested a Population and Habitat Viability Assessment (PHVA) Workshop. This workshop was held in Laramie, Wyoming 12-15 February 2001. Thirty-five people attended the workshop, which was facilitated by the Conservation Breeding Specialist Group (CBSG) of the IUCN Species Survival Commission. Workshop participants included federal and state agency biologists, university researchers, private landowners, and zoo biologists working together closely throughout the duration of the meeting to discuss issues and assess the available biological and social information relevant to Wyoming toad conservation. Workshop sponsors included the Fish and Wildlife Service, Denver Zoo, the John Ball Zoological Society, and the Zoological Society of Cincinnati.

At the beginning of each PHVA workshop, the participants derive a shared vision that guides their activities throughout the duration of the meeting: To prevent extinction of the species by maintaining viable populations in the wild. The workshop process then takes a detailed look at the species' life history and population dynamics, current and historical distribution and status, and uses this information to assess the impact of the various threats that are thought to place the species at risk.

A crucial outcome of a PHVA workshop is that a substantial amount of information – much of which has not been published or subjected to external review – can be assembled and assessed through expert analysis. This information can be from many sources; those with a wide variety of expertise as well as those having a particular stake in the future of the species are encouraged to contribute their knowledge. In this way, all the data are given equal importance and consideration.

Once assessed for relevance and accuracy, the appropriate data are used to develop a computer simulation model of the growth dynamics of the population(s) under consideration. The general purpose of the model is to determine: i) the risk of population decline or perhaps even extinction under current environmental conditions; ii) those factors most responsible for generating this risk; iii) those aspects of a population's biology and ecology that tend to drive its projected growth. In effect, these modeling techniques provide an objective, neutral platform for assessing information, testing hypotheses, and assisting managers in the conservation decision-making process.
Complimentary to the population modeling effort is a deliberative process that forms the foundation of the workshop activities. Participants work together to identify the key issues affecting the conservation of the species and then tackle their implications within topic-based working groups. Each working group produces a report of their deliberations, which are assembled along with other information to produce this report. A successful PHVA workshop depends on determining an outcome where all participants, many coming to the meeting with different interests and needs, gain added benefits through the development of a management strategy for the species in question. Most importantly, local solutions take priority; working group recommendations are developed by, and therefore become the property of, the local participants.

The Wyoming Toad PHVA Workshop

At the beginning of this workshop, the participants were asked to give individual answers to the following three questions:

- What do you hope this workshop will accomplish?
- What, in your judgement, is the primary problem affecting Wyoming toad survival and recovery?
- What do you bring to the workshop to assist conservation or recovery of the Wyoming toad?

(See Appendix A for detailed responses.) Much of the information presented in the individual responses centered around four primary topics, which then became the focus of the following topic-based working groups: Disease Issues, Population Dynamics and Risk Assessment, Wild Population Management, and Captive Population Management. Following a set of brief presentations on the status of the Wyoming toad in the wild and in captivity, the remainder of the workshop was devoted to working group sessions.

Each working group was asked to:

- Examine the list of problems and issues affecting Wyoming toad survival as they fell out under each working group topic, and expand upon the list if needed.
- Consolidate when needed and prioritize the list of problems and issues.

- Beginning with the highest-priority issues, develop broader strategies and, ultimately, detailed actions designed to address each of the identified problems
- Prioritize the strategies to give a complete picture of the recommendations developed by the group.

Working groups presented the results of their discussions in daily plenary sessions to ensure that everyone had an opportunity to contribute to the work of the other groups and to facilitate the review of the full body of work being produced. Recommendations stemming from the workshop were accepted by all participants, thereby representing a shared agreement of the direction needed after the conclusion of the workshop.

Working Group Summaries

Disease Issues

The problem presented to the working group concerned disease problems, both in captivity and the wild, that may represent significant threats to the survival of the Wyoming toad. Of particular concern is chytridiomycosis caused by the amphibian chytrid fungus *Batrachochytrium dendrobatidis*. Chytridiomycosis has been associated with significant amphibian population declines on several continents and has recently been identified in both captive and wild Wyoming toads. Furthermore, is likely that previously described infections with *Basidiobolus ranarum* in this species represent cases of chytridiomycosis. Overall, chytridiomycosis has the potential to negatively impact both the captive management of the toad as well as any subsequent reintroduction program. Other potential disease concerns were identified as problems that limit captive production and survivability of toads intended for use in the reintroduction program. These concerns – which include “short tongue syndrome” (a condition where animals miss their target when attempting to capture food items), an “adult edema syndrome”, high tadpole mortality and high adult mortality prior to 3 years of age – are all of unclear or undetermined etiology and require investigation.

The group divided their subject under three headings - disease in captivity, disease in the wild and, where the one impacts on the other, the translocation of disease. The group’s priority recommendations for action spanned all three areas.

First they identified the singular lack of available guidelines towards the management of infectious diseases in the captive population and in the translocation of animals. To this end, immediate creation of protocols for treatment of chytridiomycosis and for disease control in institutions and in translocation was recommended. Such protocols will be compiled and distributed to the participating SSP institutions and the Recovery Team.

Next, of equal, urgent priority came an investigation into mortality of the Wyoming toad in captivity and in the wild. Particularly, a need was identified for coordinated documentation and evaluation of disease problems between institutions holding Wyoming toads. The recent appointment of SSP Veterinary and Pathology Advisors represent a major step towards addressing this need. The ability to sacrifice surplus affected animals to help determine the cause of some identified disease problems (such as short tongue syndrome or edema in tadpoles) would be very helpful.

Finally, there were concerns about the role of disease, particularly chytridiomycosis, in the low survivability of animals released as part of the recovery effort. To address these concerns, a recommendation to immediately put in place the daily monitoring of released toads to detect and determine the cause of any mortality events was made. Long term studies to evaluate reservoirs of *Batrachochytrium dendrobatidis* in the environment and on sympatric amphibian hosts were proposed.

Population Dynamics and Risk Assessment

The population dynamics and risk assessment group used *VORTEX* to create a population dynamics model of the Wyoming toad. The model was based on data collected 1990-1992. These data are the best available and produced a model that reasonably simulated the observed behavior of the Wyoming toad population at Mortenson Lake, Wyoming.

Using that model, the group developed a demographic sensitivity analysis that identified the relative importance of adult female reproductive success (defined as production of metamorphs) and metamorphic survival as primary determinants of population growth dynamics. They also developed a pair of models that showed the devastating effect of the chytrid fungus. These models are based on the best available data. However, the best available data are incomplete, of questionable accuracy and precision, which emphasizes the need for systematic collection of demographic data.

The group identified 14 issues and problems associated with demographics and genetics. These were condensed into 3 goals aimed at improving the chances of recovery of the Wyoming toad: Revision of the recovery plan using defensible and reasonable biological criteria; determination of the level of genetic management required for effective species recovery; and development of an optimal reintroduction strategy.

To accomplish these goals, detailed action steps were identified. These action steps were ranked in order of importance based on the criterion of improving the chances of recovery for the species. The action steps, in rank order are: 1) Detailed demographic study of Wyoming toad at Mortenson Lake; 2) (tied) intensive PVA analysis; and reintroduction scenario development and testing; 4) demographic study of *Bufo hemiophrys* (range-wide); DNA study of captive individuals to establish genetic relationships in captive population and 6) DNA taxonomic study of *B. hemiophrys* versus *B. baxteri* to clarify taxonomic status.

The consensus of the group was that existing data are clearly inadequate to conduct realistic population modeling. Methods used previously in data collection on Wyoming toads have emphasized minimal handling of individual toads. It is not possible to collect required demographic data using these methods. Although the desire to minimize stress to individual toads is understandable, minimal handling has not protected this species. If population modeling is to contribute to recovering the toad, more aggressive data collection is imperative.

Wild Population Management

The Wild Population group brainstormed and identified 45 problems related to Wyoming toad recovery. They then grouped those into seven categories that were prioritized using a paired ranking system. There were several issues raised that were tabled either because they were premature or they needed to be dealt with in other groups. The seven categories in order of priority are monitoring/research problems, identification of release sites, development of habitat management practices, dealing with outreach/people issues/landowner concerns, lack of resources, collating and sharing information, and finding new populations of toads. Action items within each of these categories were identified along with major partners, responsible parties, obstacle, outcomes, etc. for each action item. We then ranked the various action items using paired rankings. The top priority action items are in priority order: Hire a full-time permanent coordinator (72), develop process for choosing new release site (70), determine ecological criteria for selecting release sites (65), conduct an ongoing survey of historic toad habitat (52), train people to recognize toads (52), compiling all known informatio on habitat use and evaluate what critical information is missing, with particular emphasis on hibernation (49), and identifying funding sources through contacts developed via other activities (48). After the first seven priorities there was natural break in ranking, so all seven were included. Items 4 and 5 were tied in points, items 6 and 7 were very close in points. Because several these items relate to the same need, we combined some of them. Our final categories to present to the whole group were:

1. Hire a full-time permanent coordinator,
2. Identify new release sites, to select new release sites and to determining ecological criteria to guide selection of sites,
3. Continue surveys of historic toad habitat and training landowners and the community to identify toads,
4. Compile existing information on habitat use and determine what critical information is missing, with an emphasis on hibernation,
5. Identify funding sources through contacts developed via other activities,
6. Developing public/ stakeholder involvement, including selecting and producing informational materials for use in outreach, and finding common ground with and between stakeholders and act together to promote these.

Some general issues discussed but not dealt with specifically were problems created by the past hand-off approach to handling toads, to the need for more rapid decision-making by the team, and the need to integrate and coordinate among groups regarding concerns about disease.

There are needs to correlate between groups on research efforts. For example, the captive breeding group is planning a research of hibernation temperatures, etc. We would like to expand this research as needed to increase the numbers of toad, so that information about habitat use during hibernation and other information about habitat use can be simultaneously gathered.

Captive Population Management

Captive husbandry and reproduction of the Wyoming toad is of paramount importance to the recovery efforts of the species. With the wild population in extreme peril, it is the responsibility of institutions housing the remaining captive population to explore all options in order to not only significantly increase the overall numbers of Wyoming toads, but also to attempt to understand the unique and challenging physiological and environmental demands of this species.

Much of the toad's natural history is unknown and this lack of information leads to gaps in knowledge of captive husbandry. A more complete understanding of diet, hibernation, and reproductive cues would allow the captive program to rapidly improve their husbandry and captive reproduction procedures. Current wild toad management practices have made acquiring these needed data impossible. The "hands off" attitude has been a major impediment to advancing both the wild and captive programs.

The toad is at a critical juncture in its struggle to survive. In order to resolve this crisis, actions must be taken rapidly and the resulting information shared quickly between the participating services and facilities. The fate of the toad does not rest solely on any one organization but rather a united cooperative front.

Concerns for the captive population were discussed and prioritized using paired-ranking. Improving captive reproduction rose quickly to the top as the most critical topic facing the captive program. In descending order the top five priorities for the captive program are:

1. Increase the long-term survival rate of yearlings to 80%.
2. Improve larval rearing success from 25% to 95%.
3. Increase the number of viable eggs by increasing the hatch rate from 27% to 95%.
4. Develop protocols for treating toads infected with chytrid fungus.
5. Work with veterinarian advisors to develop protocols to reduce the risk of disease transmission.

The first three goals focus on specific developmental stages where an increase in the survival will have a profound impact on the captive population. The last two goals acknowledge the potentially disastrous consequences of the spread of chytrid fungus through the captive population. Although seemingly unrelated, reproductive success and disease control are both integral to the long term survival of the captive population.

Working Group Recommendations

Each working group prioritized their recommendations, and presented their top five items during the final workshop plenary session. After some brief discussions led to a consolidation of this set of twenty recommendations down to sixteen, the entire group of workshop participants then prioritized this reduced set using the paired-ranking method. Listed below are the top 10 action recommendations as ranked by the larger group or workshop participants (total vote count given in parentheses):

- Development of captive/wild infectious disease management protocols (246)
- Gather disease information and begin research to reduce the rate of mortality in the captive population (226)
- Increase the long-term survival rate of captive yearlings from 50% to 80% (223)
- Improve captive larval rearing success from 25% to 95% (210)
- Assemble existing and collect new, accurate demographic and ecological data from the Wyoming toad in the wild (209)
- Increase the number of viable (captive) eggs by increasing the egg hatch rate from 27% to 95% (192)

- Develop the funding sources necessary to hire a full-time, permanent Recovery Coordinator (185)
- Using existing data, determine the appropriate ecological criteria for identifying new release sites for the establishment of wild populations, and develop a detailed process for choosing new sites (177)
- Determine mortality-causing disease factors at proposed release sites (173)
- Conduct molecular genetic analyses (DNA fingerprinting and mtDNA) to determine the overall degree of relatedness among those individuals thought to constitute the captive population's founder base, to assess the potential for the identification of new genes within the "B Line" of captive Wyoming toads, and to establish the taxonomic relationship between *Bufo baxteri* and *B. hemiophrys* (112)

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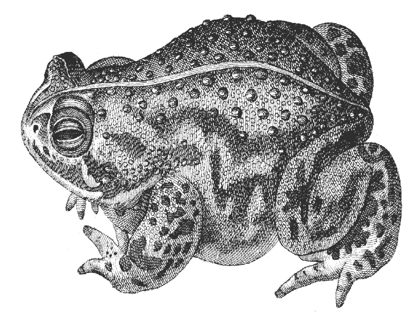


SECTION II
DISEASE ISSUES

Wyoming Toad (*Bufo baxteri*)
Population and Habitat Viability Assessment (PHVA)
Disease Issues Working Group Report

Working Group Participants:
Stan Anderson*, US Geological Survey / University of Wyoming
Virginia Bien*, Private Rancher
Simon Hicks, Conservation Breeding Specialist Group
Mary Jennings*, US Fish & Wildlife Service
Terry Kreeger*, Wyoming Game & Fish Department
Greg Lipps*, Toledo Zoo
Don Miller*, Wyoming Game & Fish Department
Margaret Page*, Private Rancher
Allan Pessier, University of Illinois - Loyola
Deedee Roberts, Saratoga National Fish Hatchery
Ed Stege, Saratoga National Fish Hatchery
Patti Worthing*, US Fish & Wildlife Service
*Part-time participants

Identified Disease Problems and Issues

- Captive standpoint - Several significant disease problems have been identified in the captive population including bacterial infections (“red leg”), fungal infections (including chytridiomycosis), short tongue syndrome and edema syndrome, among others. Other problems with the captive population may have some disease basis, but the causes and extent are unknown. For example, 13% of larvae are making it to metamorphosis; sometimes tadpole edema is seen, but is this a disease issue? Animals over 3 have the best breeding success, but there is also high mortality before animals reach this age. Is this due to identifiable and treatable or preventable disease? When disease is identified, many treatments are based upon limited experience (one treatment having been carried out at a single facility). Perhaps the new Species Survival Plan veterinary advisor (Kevin Wright) can help in this regard. Currently treatment for just about everything is to treat with Baytril.
- Pre-release disease screenings. What do we need to do? The AZA Amphibian Taxon Advisory Group has formed some guidelines. Are these applicable to the Wyoming toad?
- There is a lack of recent compiled and analyzed disease data. Necropsies have been inconsistently performed on dead toads. It is hard to make recommendations for disease control without complete data and information from throughout the captive breeding program. Maybe we need to revisit how necropsies are done? We need to formulate necropsy and disease treatment protocols.
- As far as captive population, most animals don’t make it over three. The biggest group is the two year olds. Three and over is best breeding success. Disease issue? In the wild the same thing could be seen. What’s happening with survival to breeding age? Both in captivity and in the wild. There is a difference between metabolic age and chronologic age. In captivity you don’t get good breeding until males are three years of age. In the wild, breeding begins at age 3 for females, 2 for males.

- Should we be breeding disease resistant animals? Chytridiomycosis is probably not lethal to all animals that encounter the fungus. Could selected resistant animals form the basis for captive breeding efforts?
- There are numerous unknowns about the biology of the amphibian chytrid that hinder development of management strategies. How are chytrid fungi being dispersed (people, wind, commercial pet trade)? What is maintaining it through the winter (? substrates, ? reservoir species such as tiger salamanders and chorus frogs)? What is needed to get this answered? How lethal is it? Is freezing a mechanism being used by some frogs to deal with infection?
- Funding for disease studies. Several individuals and institutions are carrying out studies on the general biology of chytrid fungal infections. Efforts to address questions on infection in the Wyoming toad should/could be coordinated with other investigators worldwide. Resources for the Wyoming toad could be directed towards practical studies that would affect management. As an example, Dr. David Green of USGS has a funded study to look at tiger salamanders as a possible reservoir species. Other studies to look at fish or environmental reservoirs as well as disease impacts on wild populations may need to be designed and funded.
- Is chytridiomycosis a problem at the Mortenson Lake release site? Small numbers of toads from the Mortenson Lake site have been examined and found to have chytrid fungal infections. The extent of the problem is unknown, however, based on chytrid fungal outbreaks in other species, the observation of even a small number of affected animals is highly significant. In order to answer the question of the role of disease (particularly, chytridiomycosis) in mortality of wild toads, the model used by Colorado Division of Wildlife and USGS in monitoring of boreal toads could be applied. It may not be just a disease issue (? predation, other mortality factors). Could we have a review of the data that has been compiled? Confirmation of the suspicion that some of the early cases of *Basidiobolus ranarum* infections in Wyoming toads may have been chytrid fungal infections may help in this regard.
- Questions about releases of toads to Mortenson Lake. By releasing large numbers of animals from the captive breeding program are we just perpetuating chytrid fungal disease problems at the site ("fuel to the fire")? If you were to set the site alone for years, would it clear? Will PCR testing for the amphibian chytrid (under development) help to identify disease free animals for release as well potential disease-free release sites (by analysis of substrates)? In the short term, could you introduce animals in controlled enclosures at Mortenson Lake and monitor them for disease development? Development of translocation protocols should be considered to minimize risk of disease transmission. For newly identified release sites, will need ability to screen animals for disease prior to release (as above) because chytridiomycosis is also a problem in parts of the captive population.
- What model species are available to better understand aspects of chytridiomycosis in Wyoming toads? Surrogate species may be a problem. For instance, many current studies on treatment of chytridiomycosis have been conducted in poison dart frogs and there are differences between toad and dendrobatid skin. How do we extrapolate data on chytridiomycosis in other species to Wyoming toads? Studies planned in other species include different drug treatment protocols and temperature effects on clinical course, among others. Coordination of research efforts with those working on other species (particularly the boreal toad) will be needed.

- Future options? What is the likelihood that efforts to combat chytridiomycosis and its effects on successful reintroduction will be successful? Should we give up (or when do we give up)? For the short term, the priority may be to get captive health issues addressed first and then deal with reintroduction. Maintenance of captive populations and control of disease in these animals may be necessary as an emergency measure. Better inter-agency communication on disease issues may be necessary.
- There are two separate issues - captive vs. wild. Releasing/reintroduction could be another. There are different approaches for each.

Prioritized Problems and Issues

Issue	Vote Tally	Rank
Wild		
High mortality among toads < 3 years	36	1
Population impact	27	2
Host/Vector/Reservoir	26	3
Is chytrid primary killer?	21	4
Documentation protocols	20	5
Tissue preservation	14	6
Who's working on it	12	7
Life history of organism	11	8
Implications of number dead found	7	9
Give up	3	10
Captive		
Treatment	38	1
What is short tongue syndrome	35	2
Prevention protocols	33	3
Documentation protocols	31	4
High Mortality less than 3 yrs	31	4
Edema	27	6
Survival of larvae low	25	7
Tissue preservation	20	8
Who's working on it	10	9
Selection of surrogate	9	10
Give up	2	11
Reintro/Translocation		
Protocols for translocation	22	1
Disease dispersal	15	2
Implications of translocations	15	2
Pre-release screening protocols	13	4
Can we beat chytrid with numbers?	9	5
Disease resistance	1	6

Action Steps (Prioritized)

Management Goals

Short term (1 year):

- Maintain survivability in captive population

Long term (5 years):

- Reintroduction of uninfected animals to uninfected sites

1. Development of Captive/Wild Infectious Disease Management Protocols

Infectious diseases (e.g. chytridiomycosis) have been identified as a significant cause of morbidity and mortality in captive and wild Wyoming toads. At this time, there is a lack of guidelines for reducing the transmission of infectious disease during movement and translocation of animals. Such movement of animals would include within facilities, between facilities, during reintroduction, and between release sites and each movement requires specific guidelines. Specific protocols for prevention of infectious disease transmission are needed for captive programs and for reintroduction programs.

Captive and reintroduction disease protocols will require screening of animals for chytridiomycosis and other infectious diseases prior to release, and may require sacrifice of sentinel animals for disease surveillance. As more sensitive diagnostic tests, such as polymerase chain reaction (PCR) for the amphibian chytrid *Batrachochytrium dendrobatidis* becomes available, this methodology should be incorporated.

Chytridiomycosis is a disease threat that, in some circumstances, can result in high captive mortality and requires a specific treatment plan to minimize impact on the captive population in the face of an outbreak. The question has been raised if treatment of chytridiomycosis could, in some cases, lead to carrier-state infections. Optimization methods for treatment protocols are needed to eliminate infection.

Concerns exist about the current release program because animals with chytridiomycosis have been identified both from facilities that provide a source for release as well as at the Mortenson Lake release site. Furthermore, animals have been transferred between Mortenson Lake and Lake George release sites without disease screening. Release of infected captive animals, as well as release of animals to sites with potential chytrid reservoirs raise the possibility that release sites may be or have become unsuitable because of increased potential for disease associated die-offs. These concerns make discontinuation of releases a consideration at this time. On the other hand, discontinuation of releases would create an undesirable captive surplus and release of these animals would allow monitored observations that could provide information on chytridiomycosis at Mortenson Lake.

The following are desired protocols:

Institutional Protocol

Action: Develop protocol to minimize the potential disease transmission within the institutions participating in the American Zoo and Aquarium Association's Species Survival Plan (SSP)

- *Responsible Parties*: SSP Veterinary and Pathology advisors
- *Timeline*: Less than 1-year
- *Outcome*: All captive facilities will develop and follow procedures that minimize transmission of infectious diseases
- *Collaborators*: SSP facilities, SSP advisors
- *Costs*: Donated, however, costs for implementation of disease screening protocols will require sources of funds
- *Consequences*: Reduce the spread of disease in captive populations
- *Obstacles*: Cooperation by all facilities, expense involved in applying the recommendations

Translocation Protocol

Action: Develop an infectious disease related protocol for all translocations (Captive to Captive / Captive to Release Site / Release Site to Captive / Release Site to Release Site)

- *Responsible Parties*: SSP Veterinary and Pathology Advisors
- *Timeline*: 6 months (August)
- *Output*: SSP Institutions and Recovery Team will have formal procedures that minimize transmission or introduction of infectious diseases.
- *Collaborators*: SSP Veterinary Advisors, SSP Institutions, Recovery Team
- *Costs*: Costs donated for formulation of protocols; costs for implementation of disease screening protocols will require sources of funds
- *Consequences*: Such actions may limit the impacts of infectious diseases
- *Obstacles*: Potentially interfering with desired paired breedings and release of captive reared animals, by slowing or preventing the movement of animals

Chytrid Management Protocols

Action: Minimize deaths due to chytridiomycosis through the development of an aggressive treatment protocol (currently in progress, with completion expected in six months)

- *Responsible Parties*: SSP Veterinary Advisor and Pathology Advisor
- *Outcome*: All captive breeding facilities will have a protocol in place to effectively treat clinically significant chytridiomycosis.
- *Collaborators*: Facilities and SSP Veterinary Advisors
- *Costs*: Donated by SSP Veterinary and Pathology Advisors
- *Consequence*: Reduced deaths due to chytridiomycosis
- *Obstacles*: No obstacles anticipated

Action: Eliminate the fungal disease in captivity by optimizing treatment protocols to seek elimination of carrier states.

- *Responsible Parties*: SSP Veterinary Advisor and Pathology Advisor
- *Timeline*: Completion by 2006
- *Outcome*: Potential sub-clinical chytridiomycosis controlled in captive populations
- *Collaborators*: Captive facilities and SSP advisors
- *Costs*: $50,000
- *Obstacles*: Potential lack of funding support; lack of suitable personnel to perform studies

Action: Investigate eggs as a source of animals free of infection with the amphibian chytrid

- *Responsible Parties*: SSP Veterinary Advisor and Pathology Advisor
- *Timeline*: Completion by 2006
- *Outcome*: Chytridiomycosis controlled in captive populations
- *Collaborators*: Captive facilities and SSP advisors
- *Costs*: Unknown at this time
- *Obstacles*: None anticipated

2. Understanding Captive Diseases

Participating SSP institutions have identified several potential disease problems which may limit or adversely affect survivability of captive animals. These include chytridiomycosis, the poorly understood "short-tongue syndrome" (STS – a condition where animals miss their target when attempting to capture food items), an adult edema syndrome (which may be associated with chronic kidney disease), high tadpole mortality, as well as high adult mortality prior to three years of age. The significance and the cause of many of these potential disease problems is unknown, because a mechanism for the consolidation and analysis of morbidity and mortality data had not been established until recently, with the appointment of SSP Veterinary and Pathology Advisors.

Action: Gather information on the occurrence of disease problems in SSP participating institutions, and subsequently pursue research of these diseases in order to reduce captive mortality (i.e. "Short-tongue syndrome", edema syndrome, chytridiomycosis, tadpole and adult mortality, etc.). Additionally, necropsy protocols will be developed and SSP institutions encouraged to submit dead animals for pathologic examination. In some cases, elective euthanasia of surplus animals with some disease conditions (such as short tongue syndrome, or tadpole edema) will be required for effective investigations.

- *Responsible Parties*: SSP Veterinary and Pathology advisors
- *Timeline*: Ongoing
- *Outcome*: Identify incidence and causal factors of short tongue syndrome, edema syndrome, tadpole mortality, and chytridiomycosis in captive populations
- *Collaborators*: SSP, SSP Veterinary and Pathology Advisors
- *Costs*: $5,000 to $25,000
- *Consequences*: Better understanding and reduction of disease in captive populations
- *Obstacles*: Money, personnel time, limits on number of animals

3. Determine Mortality-Causing Factors at Release Sites

Survivability of released animals is low. Based on the recovery of animals with chytridiomycosis at the Mortenson Lake release site, it is suspected that chytridiomycosis may contribute to mortality, however, other factors cannot be excluded. These factors may include other diseases, predation, and decreased intrinsic survivability. Additional information on causes of death at release sites is necessary. Initially this information may be gathered by increased surveillance of sites to better detect mortality events, and to collect samples for diagnostic evaluation. In an effort to determine mortality causing factors, prospective studies will be necessary to obtain more useful information. In the absence of more sophisticated tools for detection of *Batrachochytrium dendrobatidis* in the environment, one suggested long-term study may include placing enclosed sentinel animals at potentially chytrid contaminated release sites (e.g. Mortenson Lake). Similarly, surveys of sympatric amphibians should be conducted at release sites to detect carriers of *Batrachochytrium dendrobatidis*. These actions would aid in an attempt to determine if environmental reservoirs are present that may contribute to disease outbreaks and mortality.

Action: Determine wild mortality factors.

Immediate - hire a technician for intensive (preferably daily) monitoring for mortality events.

Longer term - identify mechanisms to accomplish longer-term studies, which might include support for a PhD candidate.

- *Responsible Parties*: Greg Langer
- *Timeline*: Monitoring is ASAP, other studies start 2002
- *Outcome*: Identifying mortality factors for Mortenson Lake
- *Collaborators*: University of Wyoming; United States Fish and Wildlife Service (USFWS); United States Geological Survey – Biological Resources Division (USGS – BRD)
- *Costs*: $60,000 to $100,000
- *Consequences*: Public relations; useful information for determining what is happening in the wild
- *Obstacles*: Funding

Action: Collect tiger salamanders and chorus frogs from Mortenson Lake National Wildlife Refuge to analyze them for infection of the fungus *Batrachochytrium dendrobatidis*.

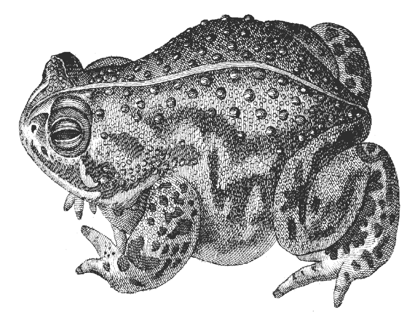
- *Responsible Par*ties: Greg Langer
- *Timeline*: 2-years
- *Outcome*: Indicate potential amphibian reservoir hosts for *Batrachochytrium dendrobatidis* at Mortenson Lake NWR
- *Collaborators*: USGS BRD, USFWS
- *Costs*: $10,000 (Refuge personnel and Dr. David Green)
- *Consequences*: Wider understanding of the ecology of chytrid fungus
- *Obstacles*: Collection of a sufficient number of animals for analysis

POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)

for the

WYOMING TOAD
(*Bufo baxteri*)

12 – 15 February 2001
Laramie, Wyoming



SECTION III
POPULATION DYNAMICS AND RISK ASSESSMENT

Wyoming Toad (*Bufo baxteri*)
Population and Habitat Viability Assessment (PHVA)
Population Dynamics and Risk Assessment Working Group Report

Working Group Participants:
P. Stephen Corn, US Geological Survey
Mary E. Jennings, US Fish & Wildlife Service
R. Andrew Odum, Toledo Zoo
Phil Miller, Conservation Breeding Specialist Group
Erin L. Muths, US Geological Survey
Richard D. Scherer, Colorado State University

Brainstorming of Issues and Problems

1. How can the Recovery Plan be revised with more reasonable and biologically defensible criteria? Do we need to recover species in all of its former range – how much is enough? We must incorporates some geographic variability in PVA.

- How many subpopulations are needed to constitute a viable metapopulation? The current Recovery Plan identifies six individual populations as the recovery goal: is this enough?
- Are the current quantitative recovery goals – 200 adults in the existing population, and 100 adults in each of five new populations – reasonable? (These numbers are currently rather arbitrary.) What about the issue of generating and maintaining a stable age distribution, and how many clutches of eggs per year will be required to maintain a population at the required level?
- We need variety of sensitivity analyses to look at a number of alternative recovery scenarios
- How do we work the chytrid fungus into the general issue? Can we model chytrid infection as some sort of stochastic effect? What is the impact of chytrid fungus on population viability? It looks like its lethal in general, but we don't really know.
- How useful are data on other species to use as surrogate information to use in modeling? For example, what about the utility of population data on Canadian toads? How similar is this species? Is it more appropriate to use data from a toad that is found at a similar latitude?
- How much demographic data do we already have from Wyoming toad populations? We need to determine the relative quality and quantity of the data.
- What about the applicability of using captive data for wild population analyses?
- There is an absence of a proper methodology for population data collection.
- How do demographic parameters respond to environmental changes, e.g. UV radiation, climate change?
- What are the impacts of predation on Wyoming toad population viability? We have some information on this issue, e.g. badgers eat adults, but how many adults can they take before population crashes? What is the relative impact of predation on juveniles v. adults?
- What are the characteristics and impacts of other diseases? Iridovirus, other pathogens, stress?

- How much genetic load can the Wyoming toad (species) tolerate? Mortenson Lake is a genetic bottleneck probably anyway, so maybe the problem is in the founder population originally.

2. How much genetic management required for effective species recovery (e.g. to prevent inbreeding depression)?

- What is the extent of genetic divergence between *Bufo hemiophrys* and *Bufo baxteri*? Are they really different species? Skull differences suggest significant divergence (Smith et al. 1998)
- How do we balance genetic and demographic issues in captive management? What about mixing of subspecies in the program?
- How far do we go in saving the species? For example, if there is too much inbreeding in the captive population and no other populations exist in wild, should we import male Canadian toad sperm to keep the maternal line in existence? In other words, do we translocate Canadian toads or genes into the existing Wyoming toad populations?
- What about the possibilities for outbreeding depression in crosses between these two taxa?

3. What is the optimal reintroduction strategy (which lifestage to release; numbers to use in each reintroduction)? How many consecutive years do we reintroduce individuals? This is a type of "eggs in one basket" question: do we expend a big effort at one place or reduced effort at many places? [See Muths et al. 2001; Cooke and Oldham 1995.]

The group then ranked these three broad issues in order of priority according to the following criterion:

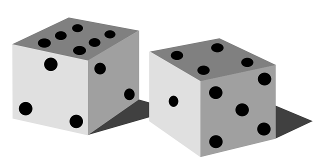
Improving chances of species survival

The paired-ranking system was employed, with the following results:

Issue	A	B	C	D	E	TOTAL
1	2	2	2	2	2	10
2	0	0	0	0	1	1
3	1	1	1	1	0	4

It was clear from this simple analysis that the overall issue of recovery goal asssessment and possible revision was a high priority for the group. With this in mind, the group began a detailed discussion around demographic data suitable as input to the *VORTEX* population viability model.

Wyoming Toad Life History and Population Biology



The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in conserving the Wyoming toad. *VORTEX*, a simulation software package written for population viability analysis, was used as a tool to study the interaction of a number of life history and population parameters treated stochastically (randomly). In addition, we were able to explore which demographic parameters may be the most sensitive to alternative management practices, and to test the effects of a suite of possible management scenarios.

VORTEX is a 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 many organisms.

VORTEX is not intended to give absolute answers, since it is projecting 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 Wyoming toad, the environmental conditions affecting a given population, and possible future changes in these conditions. In fact, it quickly became clear during this workshop that a detailed analysis of individual Wyoming toad population viability would not be possible due to the lack of suitable demographic data from the field. Consequently, the model was used to demonstrate the kinds of analyses that are possible and the ways in which it can be used to guide future research and management efforts.

For a more detailed explanation of *VORTEX* and its use in population viability analysis, refer to Miller and Lacy (1999) and Lacy (2000).

Our initial goal in this *VORTEX* modeling effort was to develop a realistic retrospective model of the Wyoming toad population inhabiting Mortenson Lake, beginning about 1990. This corresponds to the period immediately prior to the major population crash at the lake. By attempting this initial retrospective analysis, we will focus on the development of a model that we hope will reasonably accurately portray the observed growth dynamics of the actual population.

Before beginning a detailed discussion of the demographic data used as input to the population modeling process, it is important to point out an additional source of complexity that arises when simulating the population dynamics of many amphibians using an individual-based model like *VORTEX*. Because of the high levels of reproductive output among females of many species of amphibians, it is difficult and oftentimes impossible to explicitly track the fate of individual eggs or tadpoles that usually number in the thousands per successful adult female. Consequently, we must redefine "reproduction" to mean the production of individuals of a slightly more advanced life stage. In the case of the Wyoming toad, we defined "birth" as the production of metamorphs in mid-July, following the successful production of an egg mass in May and the hatching of eggs a short time later. In this fashion, we are able to reduce the total reproductive output per female by at least on order of magnitude – leading to a number of offspring that is usually manageable.

Input Parameters for Simulations

Breeding System: Monogamous. In large populations, a few males will probably breed with more than one female. With current population sizes at Mortenson Lake, this is not likely to be an issue. Given the external fertilization of eggs in this species, multiple paternity is also unlikely.

Age of First Breeding: *VORTEX* precisely defines breeding as the age at which offspring are born (in this case, metamorphose), not simply the age of sexual maturity. In addition, the program uses the mean age rather than the earliest recorded age of offspring production. Data from both wild and captive individuals indicates that females will begin breeding at three years of age, while males will breed when they are two years old.

Maximum Breeding Age: *VORTEX* assumes that animals can breed (in its simplest form, at the normal specified rate) throughout their adult life. A single individual named "Precious" lived and bred to eight years of age in captivity. While she was well cared for during her life, we thought it was possible that, under optimistic conditions, this was also a reasonable maximum age for a wild individual.

Sex Ratio of Offspring at Metamorphosis: Field data indicate no deviation from an equal sex ratio among adults, and there is no reason to hypothesize differential mortality between sexes between metamorphosis and sexual maturity.

Offspring Production: Based on observations at Mortenson Lake, about 30% of 3-year-old females are expected to produce eggs in a given year. If we assume that this rate of breeding success is characteristic of all adult females (and this may be an optimistic assumption), we therefore conclude that 30% of all adult females produce an egg mass in a given year. Data from 1988-1991 suggest that about 10% of egg masses are infertile or are destroyed before hatching. Therefore, about 27% of adult females are expected to breed (produce metamorphs) in a given year. In making this estimate, we are also assuming that the chytrid fungus currently present at Mortenson Lake does not affect breeding success – except more indirectly through increased mortality of adult females (see below).

On average, a successful adult female will produce about 3000 eggs (range = 1000 – 6000) in early June. If we exclude infertile egg masses, as these were considered in the calculation of the annual percentage of adult females producing metamorphs, we estimated that about 95% of eggs hatch successfully in mid-June. The resulting tadpoles will them metamorphose in mid to late July, with little better than a 10% rate of metamorphosis. This rate estimate is derived from observations made at Mortenson Lake in 1990, where about 10,000 eggs were laid but only 1000 metamorphs were estimated to have survived to August. Given these data, we estimate the total average reproductive output per adult female as

(3000 eggs)(0.95 hatching rate)(0.1 metamorphosis rate) = 285 metamorphs per female

with a range of 95 to 570.

Environmental variability (EV) in these demographic rates is expressed as a standard deviation (SD) around the mean estimates. In the absence of adequate time-series data, we assumed that the annual environmental variability in the percentage of adult females breeding was 10%. In other words, the percentage of adult females producing metamorphs in a given year ranges from 7% - 47% (mean ± 2SD). In a similar fashion we estimated the variability in the actual number of metamorphs produced from the range calculated above – in this case, the standard deviation was about 100.

Age-Specific Mortality: We developed the following mortality schedule based on historical field data from Mortenson Lake (note that there is no difference between males and females):

Age Class	With chytrid	Without chytrid
0 (Metamorph) – 1	43%*	43%
1 – 2	85%**	40%***
2 – 3	85%	40%
3 +	85%	40%

* Based on data from '91 YOY and '92 subadults
** Based on '90-'92 field data
*** Best guess

The intense additional mortality in the face of infection by chytrid fungus is evident from the mortality schedule. Note that we assumed that the infection does not impact metamorphs and young of the year.

During our deliberations, we discussed the possibility of simulating the development of resistance to infection by chytrid fungus. This would be accomplished most directly by specifying a decreasing function for mortality rate over time, although the detailed form of that function is not yet known. In addition, we may be able to develop or use an existing epidemiological model of chytrid fungus infection that describes the change in individual state over time. This could then be translated into a specification of age/sex-specific mortality for the population over a given time interval. Those who are working to further develop *VORTEX* are dealing specifically with this capability and hope to have a broad epidemiology module in place within the next year or so.

While specific time-series data are not available to estimate environmental variability in mortality rates, we recognize that mortality rates are prone to strong annual fluctuations. Consequently, we included a standard deviation (EV) of 20% across all rates.

Correlation in Environmental Variation of Reproduction and Survival: Favorable conditions in the spring, which will help to determine reproductive success, may be very different from those influencing survival later in the year. For example, there was a large reproductive output in the spring and fall of 1988, but very low survival of the resulting year class after the following winter.

Inbreeding Depression: *VORTEX* includes the ability to model the detrimental effects of inbreeding through reduced survival of metamorphs through their first year. Because of the recent history of a small population inhabiting Mortenson Lake, we assumed that inbreeding depression could be a concern in the future. The Mortenson Lake population is probably an inbred relict population, before work began; on the other hand, deleterious genes responsible for inbreeding depression could have already been purged from the population through the inbreeding and selection process. Unfortunately, the difficulties experienced by the captive breeding community make it very challenging to detect inbreeding depression in that population.

While we initially decided to include inbreeding depression in our models, we quickly found that the large population sizes we were modeling made this inclusion very difficult as it slowed the models down tremendously. As a result, we reluctantly removed inbreeding depression from all subsequent models.

<u>Catastrophic Events</u>: Catastrophes are singular environmental events that fall outside the bounds of normal environmental variation affecting reproduction and/or survival. For some species hurricanes, floods, disease, etc. could wipe out a large part of a population in a single year. These events are modeled in Vortex by assigning a probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect).

We identified two distinct events that could qualify as a catastrophe:

- "Alberta Clipper" – A total of 450 young of the year were observed on one occasion in the fall of 1988 (suggesting a total number of young of the year at least three times this number), but no yearlings were found in the following spring. In December 1988 – January 1989, there were 10-15 days when temperatures failed to climb above –15F. Of course we can't prove conclusively that this event killed the cohort, but it is an interesting set of observations that warrant investigation through the modeling process. We assumed that this type of event would occur once every 50 years. We then wrote a simple function to define baseline age class 0-1 mortality as 43%, but randomly jumping to 100% when a "Clipper" is deemed to have occurred.
- Spring blizzard – In some years, an early spring thaw may induce adults to come out of hibernation and begin breeding. If a late spring blizzard then follows, all egg masses could freeze and reproduction could easily be eliminated for that year. We assumed that this type of event would occur about once very 15 years.

[Note that more definitive information on the frequencies of both of these events could be obtained from, for example, long-term climatological data from the National Oceanic and Atmospheric Administration, NOAA.]

In addition we identified a severe drought that would probably not affect Mortenson, but it may affect other sites not yet identified. This particular event was not included in the models discussed in this report.

<u>Adult Male Breeding Pool</u>: This parameter defines the proportion of the total adult male population that is capable of breeding in a given year. This is not related to physiological capability, but is more a measure of social standing. Highly social species may strongly limit the proportion of males that can establish territories or find females.

There is no specific data to evaluate this parameter, but we have reason to believe that all adult males are equally capable of successfully calling and finding a mate. Hence, we identify 100% of all adult males available for breeding.

Initial Population Size: Using Mortenson Lake 1991 data (as way to take a retrospective look at the situation), we identify 415 adult toads (males and females) present (individuals greater than or equal to 1 yr old), but, these were mostly all 1-yr old toads, only 19 seen that were thought to be greater than 1 yr old. This number does not include young of the year. Nevertheless, we initialized our baseline model with a total of 420 individuals, distributed among age-sex classes according to the stable age distribution calculated from the reproduction and mortality schedules.

Habitat Carrying Capacity: The habitat carrying capacity, K, defines an upper limit to population size. When the population exceeds this level at the end of any given year, additional mortality is imposed across all age-sex classes in order to return the population to the value set for K.

We were forced to set K considerably smaller than we thought would be realistic for Mortenson Lake. This was a direct consequence of the difficulty in modeling large populations of highly fecund species using an individual-based model like *Vortex*. While we thought that the lake could support a total population numbering in the high tens of thousands, we determined through initial trials that K could not be greater than about 7000 total individuals under the more favorable mortality and reproductive values discussed above. Despite this limitation, we are very confident that this modeling environment will nevertheless allow us to study the growth dynamics of Wyoming toad populations under a variety of alternative management scenarios.

All models were simulated using 100 iterations using *Vortex* version 8.41. This is less than the usual number of iterations we would use for less highly fecund individuals, but the computational complexity of the models discussed here forced us to use a smaller number in order to investigate a larger number of different scenarios.

Results from Simulation Modeling

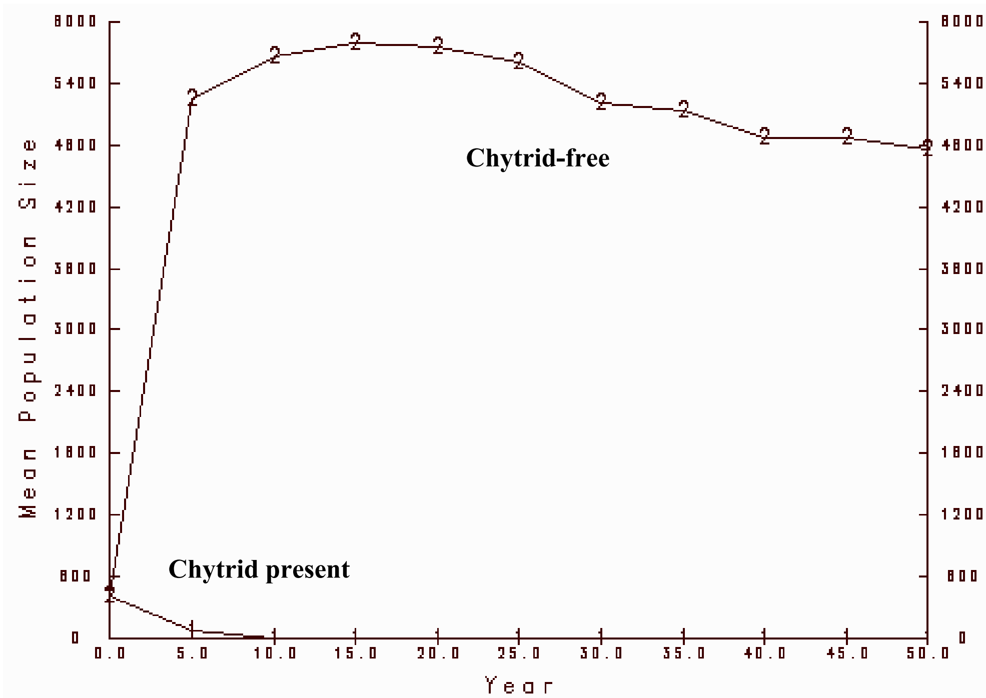
Baseline Model Results

Using the input parameters discussed above, we developed a model that simulates, with reasonable accuracy, the true toad population trajectory at Mortenson Lake beginning in 1990.

Specifically, the population growth rate r was -0.302, indicating very rapid population decline. After just five years of the simulation, 93% of the simulated toad populations declined to zero, while 99% became extinct after 10 years. This rapid decline is a reasonable simulation of the actual situation observed at Mortenson Lake beginning around 1990; consequently, we feel confident that this baseline demographic dataset does an acceptable job of describing the growth dynamics of the Wyoming toad population at Mortenson Lake. Furthermore, based on our understanding of Wyoming toad population biology, we conclude that the extremely rapid decline of the Mortenson Lake population is directly linked to the presence of the chytrid fungus in the toad population.

Immediately following the results of this baseline model, we set up an alternative model that would directly assess the impact of the fungus on population viability. This second model was identical to the first, but we replaced the 85% rate of non-metamorph mortality with the "chytrid-free" value of 40%.

Figure 1. Results from baseline simulation models of a Wyoming toad population at Mortenson Lake, initiated in 1990 using demographic data collected from 1988 to 1992. Alternative population trajectories show the impact of a simulated infection of chytrid fungus affecting individuals older than one year of age. We assume here that the infection is manifest as a greatly increased mortality among yearlings and adults. The lower curve simulates the actual Mortenson Lake population in the presence of chytrid fungus, while the upper curve is a trajectory of a population presumed to be free of the fungal infection (yearling / adult mortality decreased from 85% to 40%).



The results of this and the original baseline model are shown in Figure 1. In stark contrast to the chytrid scenario, the "chytrid-free" model shows rapid population increase to the habitat carrying capacity. The dramatically different projections with chytrid fungus present or absent point to the significant impact that the fungus can have on Wyoming toad population viability.

Based on these simple models we conclude that, based on our best estimates of Wyoming toad population biology and demography, the Mortenson Lake population is not viable in the presence of chytrid fungus.

Demographic Sensitivity Analysis

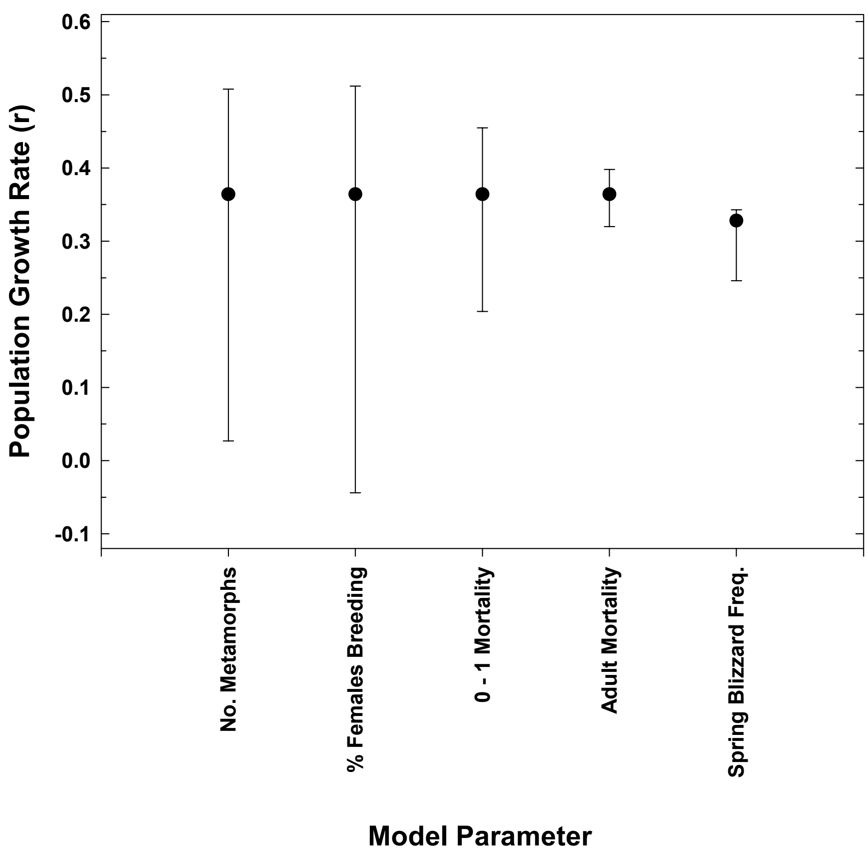
Several participants at this workshop expressed concern about the number of *Vortex* input parameters that were best guesses, and/or a desire to explore the importance of uncertainty in our knowledge of Wyoming toad biology. To deal with this issue, we set up a table with upper and lower bounds for each selected parameter used as Vortex input, based on confidence limits for parameter estimates when possible, and otherwise on group participants' expert judgement.

Parameter	Minimum	Midpoint	Maximum
# Metamorphs / female	95	280	475
Females breeeding (%)	10	27	44
Metamorph mortality (%)	45	60*	75
Adult mortality (%)	45	60	75
Blizzard frequency (%)	4.0	6.7	20

* Set artificially high to provide more instructive population growth performance

To explore the potential significance of this uncertainty, we ran a set of simulations by varying only the indicated parameter while holding all the other parameters at their intermediate value. We then compared how our uncertainty in each parameter translated into uncertainty in the average growth rate of the simulated populations. This exercise tells us both how confident we can be in our point estimates of Vortex output parameters, and which parameters are the driving forces in determining population growth dynamics and, consequently, should receive priority consideration for additional study and management.

Figure 2. Demographic sensitivity analysis for simulated Wyoming toad populations. The graph shows stochastic population growth rate for models in which a particular demographic parameter is varied from a given baseline value (indicated by the middle dot) to the presumed minimum (lower bar) and maximum (upper bar) values considered biologically plausible.



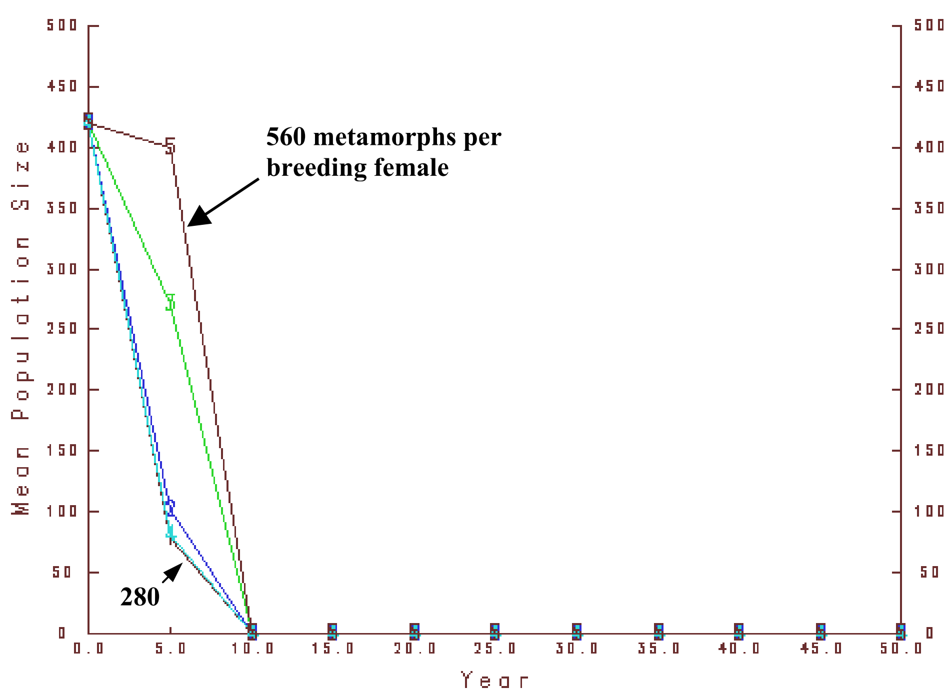
From this sensitivity analysis, we identified that Wyoming toad population growth is most sensitive to changes in female reproductive success, metamorph production, and over—winter survival of those metamorphs. Interestingly, the model is less sensitive to change in adult mortality compared to the same magnitude of change in metamorph mortality. It is clear that a more detailed sensitivity analysis – including a more comprehensive set of models with variation in more than one parameter – would shed additional light on this complex issue. Nevertheless, the analysis clearly suggests that additional research on these aspects of the toad's life history would be an extremely valuable contribution to a better understanding of the species' population biology and would lead to more effective population viability analysis modeling efforts. Moreover, relatively simple management guidelines directed at metamorph survival can emerge from this type of comparative analysis.

Metamorph Production and Chytrid-Based Mortality

Based on the preceding sensitivity analysis, it became clear that successful demographic management of Wyoming toad populations might require a focus on the early stages of the species' life cycle. In that vein, we posed the following question for analysis: Would it be possible to counter the high yearling and adult mortality through fungal infection by increasing the production of metamorphs by adult females?

To test this hypothesis, we developed a set of simulation models in which the high fungus-based mortality was retained, but the reproductive output was incrementally increased from the baseline value of 280 individuals.

Figure 3. Size trajectories for simulated Wyoming toad populations as a function of differential metamorph production in the face of high mortality of yearlings and adults resulting from infection by chytrid fungus (see text for details of infection characteristics). Metamorph production ranges from the baseline value of 280 to 560 individuals per breeding adult female.



The results of this analysis are summarized in Figure 3. Even when the annual production of metamorphs is doubled, the simulated Wyoming toad population declines rapidly to extinction in ten years. Once again, we can attribute this dramatic decline to the action of the chytrid fungus infection among adults: regardless of how many yearlings are produced, the mortality rate among adults is so high that reproduction is very limited right from the onset of the simulation. As a simplified example, consider a population composed of 50 adult females and subject to the conditions we have imposed in our model. Only 27% of those adults – about 13 animals on average – are expected to breed in the first year of the simulation, and more than 40 of those are expected to die before the next breeding season. In year 2, only 2-3 of the surviving females are expected to breed, with only two or three surviving to the third breeding season. When the various sources of stochasticity are added to the system, including catastrophes, it is clear that there will be an insufficient number of adults available to ensure the population's survival.

We are able to conclude from this analysis that, despite the importance of early life stages to the overall population dynamics of the Wyoming toad, the magnitude of the impact of chytrid fungus on adult survival dominates the entire situation. This again serves to emphasize the severe effect of this infectious agent on the remaining population of the Wyoming toad at Mortenson Lake. By extension, we suggest that successful conservation of this species will require management of a population that is completely free of chytrid fungus infection. This would likely involve the establishment of a new population of toads at a site other than Mortenson Lake, using individuals bred in captivity (at sites deemed free of fungus) as founder stock. We used *VORTEX* to test the validity of this type of strategy as discussed in more detail below.

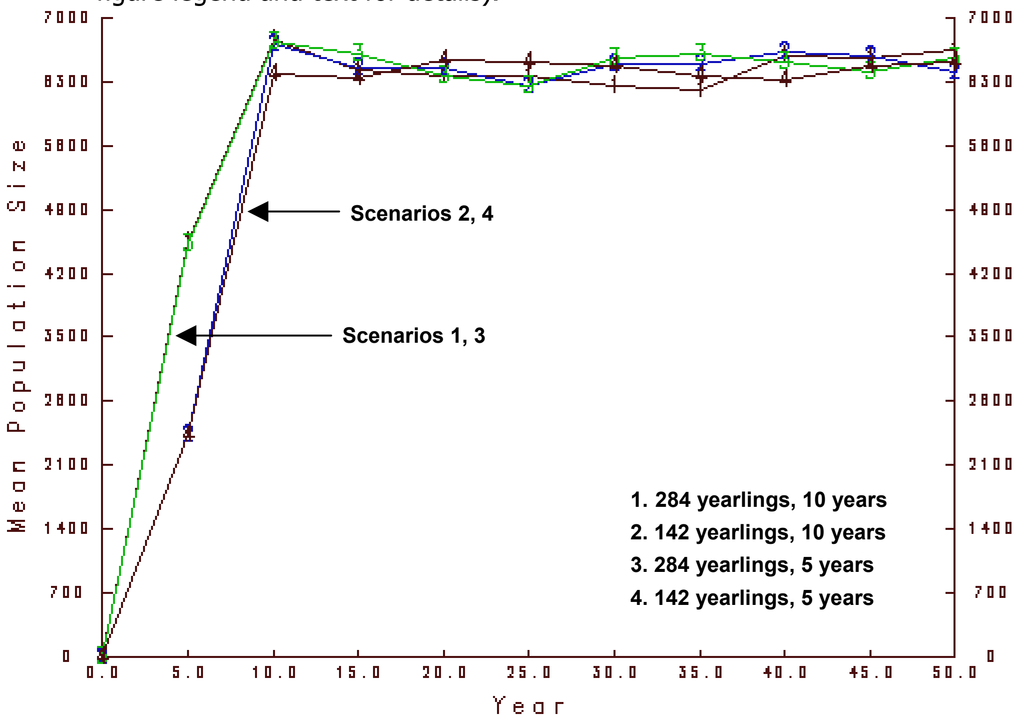
<u>New Population Establishment</u>

We developed a *VORTEX* model to investigate the feasibility of a strategy designed to establish a new population of Wyoming toads at a site separated from the current Mortenson Lake site and presumed to be free of the devastating chytrid fungus. Our model retained all of the input characteristics of the chytrid-free models discussed above; in other words, we included the low yearling/adult mortality rate of 40% instead of the higher disease-based 85% rate. However, the model differed in two important respects:

1) We began the model with an initial population size of 0, simulating the establishment of a toad population into a habitat area that did not currently have toads but was likely to have included toads in the past;
2) We added a total of 284 or 142 yearling toads (equivalent sex ratio) annually for the first 5 or 10 years of the simulation. In reality, a set of metamorphs would be released in the late summer but, because of the mechanics by which *VORTEX* simulates a supplementation (establishment) program, we added the appropriate number of yearlings assuming an initial release of 500 or 250 metamorphs and an estimated overwintering survival rate of 57%.

The results of these four scenarios are displayed in Figure 4. Each supplementation scenario results in rapid population growth towards our imposed carrying capacity. Specifically, these simulated populations grow at an annual rate of approximately 70% annually until reaching the population ceiling. Even with a more judicious use of supplemented individuals – in particular, a smaller number of yearlings supplemented annually over a shorter timeframe – the simulated populations show rapid population growth. Only one extinction event was observed across the full set of four scenarios: a single iteration in Scenario 4 declined to extinction near year 40 of the simulation. While this scenario included the most conservative supplementation scheme, the late extinction event – occurring when the population had already reached its maximum allowable size – was not a direct consequence of the type of supplementation scheme used. Consequently we can conclude that, under the conditions and assumptions acting within these simulation models, initiating a new Wyoming toad population with 300 – 500 metamorphs added annually for as little as five years may meet with a high probability of success. However, this outcome is critically dependent on the minimum requirement of maintaining the site in a chytrid fungus – free state.

Figure 4. Size trajectories for simulated releases of chytrid fungus-free Wyoming toads into a hypothetical new site also free of the fungus. The models are initiated with a habitat devoid of toads, but a specified number of yearling toads are supplemented annually for a given time period (see figure legend and text for details).



Wyoming Toad Population Demographic Data Needs

This general issue has been discussed for over a decade and never been studied sufficiently. Therefore, we wanted to take this opportunity to systematically evaluate the types of data needed for a successful analysis of toad population dynamics, particularly in the context of the demographic sensitivity analysis conducted at this workshop. In addition, we wanted to comment on the feasibility of collecting these data directly from Wyoming toad populations or from closely-related species.

Demographic data type	Use existing or collect new data from Wyoming toad	Surrogate species
Percent females breeding	X*	X
Clutch size		X
Hatching success and variation	X	X
Tadpole survival	? invasive?	X
Metamorph to 1 yr+ survival	X*	X
Adult survival	X*	X
Population size	X*	X

* Use capture – recapture data

Which surrogate species would be the most appropriate to use for this purpose? For example, should it be one whose latitudinal distribution overlaps that for *B. baxteri*? Some general candidate species include:

- *B. boreas* – no populations available, higher elevation, very different demography
- *B. woodhousii* – availability? Different habitat, demography
- *B.americanus* – East of Mississippi, habitat diffs?
- *B. fowleri* – Lake Erie, Long's Peninsula, David M. Green
- Sibling species – *B. hemiophrys*
  North Dakota / Canada
  Does earlier work (e.g., theses) already exist?

<u>Justification for demographic work</u>

The ability to construct realistic population demographic models depends on the availability of accurate demographic data, ideally from Wyoming toad populations in the field. Additionally, the predictive value of these stochastic models is strongly dependent on estimates of the degree of annual variability in these parameters.

In the past, the process of demographic data collection has been hindered by a general reluctance to allow even minimal data collection on wild Wyoming toads (some exceptions to this include the photographic capture – recapture work in 1990 – 1992, and Parker's 1999 telemetry study). Employing a surrogate species in this context may provide some valuable data for population model development and testing, but we feel that data from Wyoming toads is largely irreplaceable. Moreover, population data on Wyoming toads are essential for assessing the success of introductions and to determine the causes of failures of introductions.

In addition to the demographic data needs just described, there are a series of very important aspects of population genetic management that require their own types of data. Relevant questions here include:

- What is the degree of relatedness among the six putative animals making up the captive founder population? Can we continue to assume that these individuals are unrelated?
- What is the estimated genetic integrity of the so-called "Type B" toads? Is there any evidence we can come up with to suggest that these individuals may have mated with unknown wild toads?

- Does the genetic benefit derived from breeding unrelated individuals outweigh the inbreeding effects if a mistake is made and the two individuals are really closely related? This relates to the familiar Type I vs. Type II error discussed in statistics.
- Is *Bufo baxteri* considered to be a valid species when applying the tools of molecular analysis?

There is a large amount of genetic material in various freezers that could be used to address these important issues. Most of the material can be found at the Sybille breeding facility and the Wyoming Veterinary Laboratory, but a systematic protocol for cataloging all material at all facilities is warranted.

A Brief Discussion of Proposed Management Alternatives

Throughout our working group discussions, we proposed and ultimately converged upon three primary options for in-situ conservation management of Wyoming toads. These alternatives arose largely from knowledge gained from our demographic modeling exercise. Information gained from the modeling process is extremely useful in determining where to "go from here" or where to focus resources. Its strength is in identifying gaps in available data and projecting a pattern where specific components can be investigated and clarified. It is an adaptive management tool that will change as more data are gathered. By improving the modeling (by the input of more reliable data), we can improve introduction methods and modify other management efforts. However, with this in mind, we recognize the importance of the need to balance the many cautionary aspects of this type of incomplete quantitative tool with the usefulness of the preliminary model.

While this group does not intend to list these options as a preamble to more formal management recommendations, we hope that our ideas will spur others to consider these or similar options in greater detail.

- Continue to supplement the existing Mortenson Lake population in order to artificially maintain the population in the presence of chytrid fungus until a "cure" is found for the infection. Such a scheme would probably have to last more than five years in order to be effective. Because of the extremely high adult mortality rate assumed to exist in the presence of chytrid infection, this strategy will only serve to inflate the population with yearlings and would do little to stem the rapid decline of the adult age classes. Consequently, this strategy does not have much long-term appeal.
- Given the extensive chytrid fungus infection, consider the Mortenson Lake a lost cause and begin to search for a new disease-free site to use as a new release site. In order for this to be effective, toads to be used as founder stock must also be free of the fungus. While this may be a valuable option from a biological standpoint, there are other considerations that have made it a difficult management choice. To this point, no other alternative sites have been evaluated; Lakes Hutton, George and Mortenson are the only local lakes on public land, so they would naturally be given higher priority for future consideration.

- If it is determined that the chytrid fungus life cycle does not include a resting phase such as a cyst, it may be possible to allow the Mortenson Lake to “lie fallow” for several years in order for the infection to run its course and all host toads have died. Following this phase, it may then be possible to re-introduce disease-free toads to the now-clean site. Thousands of young toads are produced in captive facilities each year, so we have a large reservoir of individuals that could be used for this purpose. There may be real problems with the potential for other species in the system, such as the tiger salamander *Ambystoma tigrinum*, to act as a host in the absence of Wyoming toads. Because of this uncertainty, the feasibility of this strategy may be limited.

While Mortenson Lake, in its current state, is not a reasonable candidate for supporting a viable Wyoming toad population, it may serve a very useful role as a means to track released toads, if no other release site options exist. The Disease Issues working group also supports this proposal; they see this as a good use of sentinel animals to gain experience in tracking the suitability of a release site, and to gain experience in accurately diagnosing chytridiomycosis.

Goals and Actions

(Note: Total paired-ranking score and overall working group rank is given for each action in parentheses)

1. **Goal**: How should the Wyoming Toad Recovery Plan be revised with more defensible and reasonable biological criteria?
   <u>Action</u>: Collect accurate demographic and ecological data from toads in the wild through a local demographic study. Collect information while monitoring existing toads and new releases. Data to be collected include: (Score = 20; Rank = 1)
   - Number of egg masses
   - Number of males calling
   - Capture – recapture (throughout summer).
   - Three consecutive days, repeated 3-4 times in the summer, (robust model) will give interval survival and population estimates for individual episodes. Protocols for such a study can be found in Heyer et al. 1994; Corn et al. 1997.
   - Use of habitat by different age classes of toads (telemetry using temperature sensitive transmitters)
   - Hibernation sites, selection by different age classes (telemetry using temperature sensitive transmitters)
     - *Responsible Parties*: United States Fish and Wildlife Service and Mary Jennings will coordinate the effort
     - *Timeline*: Begin spring 2001, continue every year
     - *Outcome*: Accurate demographic data for use in new risk modeling efforts; information on success of releases of toads
     - *Collaborators*: University of Wyoming, United States Geological Survey (USGS), Colorado State University, Wyoming Game & Fish, American Zoo and Aquarium Association (AZA)

- *Costs*: This would require a full time person (biotech) (mid-May – mid September). Approximately $10,000 for gear and vehicle. GS 5 technician about $1000 for 2 weeks, approximately $8,000 for 16 weeks.
- *Consequences*: Better estimates of population parameter estimates for use in modeling; refinement of targets in recovery plan; collection of data to monitor success of introductions. Consequences of INACTION: inability to construct realistic models, inability to respond appropriately to problems with reintroduction, **inability to make management decisions based on data**
- *Obstacles*: The major obstacle is a reluctance on the part of the "recovery team" to allow comprehensive research e.g. handling and capture – recapture, funding.

Action: Conduct a demographic study of *Bufo hemiophrys* in another location (e.g. North Dakota or Canada). Data to be collected include: (Score = 10; Rank = 4)

- number of egg masses;
- number of males calling;
- clutch size, hatching success;
- tadpole mortality;
- capture – recapture (throughout summer).
- 3 consecutive days multiple times (3-4) in summer (robust model) will give interval survival and pop estimate for individual episodes. Protocols in Heyer et al. 1994; Corn et al. 1997.
- Use of habitat by different age classes of toads (telemetry using temperature sensitive transmitters)
- Hibernation sites, selection by different age classes (telemetry using temperature sensitive transmitters)
  - *Responsible Parties*: USFWS
  - *Timeline*: 2002 – 2004, 2005
  - *Outcome*: Demographic information about a closely related, healthy population
  - *Collaborators*: USGS, local University (Minnesota, North Dakota)
  - *Costs*: Contract with University researchers to collect data (1 person for 2-3 field seasons); approximately $24,000.
  - *Consequences*: Information available to develop more informative Wyoming toad population models and, therefore, set more reasonable recovery goals. Information from surrogate species will address gaps in data that we can't get from the Wyoming toad, e.g. clutch size.
  - *Obstacles*: The major obstacles are funding, finding suitable prospective collaborator, and limitations of sibling species data.

Action: Conduct intensive PVA (more in depth than accomplished at this meeting) – a continuing process, refined as more data comes in (see 1, 2 above) (Rank = 12; Score = 2)

- *Responsible Parties*: Rick Scherer
- *Timeline*: Winter 2001 - ongoing
- *Outcome*: More realistic models of Wyoming toad population dynamics; comparison of boreal toad and Wyoming toad demographic information; higher degree of confidence in data acquired for Wyoming toad by comparisons; same disease functions

- *Collaborators*: USGS, Colorado State University, Conservation Breeding Specialist Group, AZA, USFWS
- *Costs*: Master's degree student (currently funded)
- *Consequences*: See specific product
- *Obstacles*: Work load on Rick; otherwise none predicted

Survey protocols and details for goal #1

A. Capture – recapture protocol
   - Four, three-day surveys e.g. June 1, July 1 and Sept. 1. This is necessary because Wyoming Toads are diurnal. Using PIT tags (passive integrated transponder) cost: PIT tags are $5 each and a reader is approx. $800.00, 3-4 people, approx. 10 hrs.
   - Area to be searched must be determined and quantified. Area must remain the same size for duration of study.
   - Apply robust model design (closed model to estimate abundance from each group of samples; open model to estimate survival between sampling episodes)
   - 3 day sessions give N (= population size estimate)
   - Will also get survival and recruitment estimate
   - Will get over winter survival estimate after the first year
   - Confidence in estimate will depend on recaptures and how many toads are captured
   - Capture probabilities depend on number of animals at site
   - Standard field survey method using systematic searches (e.g. visual encounter survey sensu Heyer et al 1997 or transect methods):
   - At capture, measure mass, determine sex, evaluate for disease (visual assessment) and pit tag if not already tagged.

B. Use of habitat
   - Not a demographic question per se but should be a task in the overall description of field observations
   - Radiotelemetry study: data on use of habitat, hibernation: temperatures, locations, mortality

C. Critical issue: Survival to year 1 animals, the spring following birth. How can we quantify the number of metamorphs?
   - Toe clip entire cohort. This involves a lot of effort on the ground, and is intensive in order to obtain the required data

2. **Goal**: Development of an optimal reintroduction strategy
   Action: Test scenarios for reintroduction developed using results from demographic modeling. This process will use the *VORTEX* population modeling environment to generate hypotheses and design experiments to test different scenarios to discover the most efficacious methods for reintroduction at existing and alternate sites. (Score = 12; Rank = 2)
   The scenario generated from the initial modeling run (data from early 1990's, generated at PHVA meeting Feb 2001) will be tested. NOTE: need to consider genetics in all reintroduction efforts. The goal is to put out as much diversity as possible, e.g. not all sibs

in the headstarting and release. However, given the current difficulties in captive propagation, this might not be possible.

- *Responsible Parties*: Recovery Team
- *Timeline*: Immediately – forever?
- *Outcome*: An improved reintroduction strategy
- *Collaborators*: USGS, Colorado State University, CBSG Phil Miller, AZA, FWS
- *Costs*: Person(s) to monitor and care for headstarted toads (tadpoles in wading pools) (same person(s) as designated in goal 1, action steps 1 and 2)
- *Consequences*: Increased ability to determine optimum reintroduction strategy
- *Obstacles*: Funding, availability of site and availability of sufficient numbers of toads with appropriate genetic composition (not limiting requirement, but consider if possible) ability to handle toads

3. **Goal**: Determine degree of genetic management required for effective species recovery

<u>Action</u>: Conduct DNA analysis (DNA fingerprinting) to determine relatedness and lineages of founding stock and document the lineages of existing captive population. Determine if there are "new" genes present in toads from the "B group" (Score = 6; Rank = 5)

<u>Action</u>: Conduct mitochondrial DNA analysis of *Bufo hemiophrys* (individuals in U.S. and Canada-entire range of species) and *Bufo baxteri* (genetic analysis to determine taxonomic identity determine molecular distance between) (Anna Goebelhas mitochondrial DNA from one group in Wyoming) (Score = 0; Rank = 6)

- *Responsible Parties*: Cincinnati Zoo – Andy Kouba; Erin Muths will initiate discussions with Anna Goebel about mitochondrial DNA project to generate cost estimate for project
- *Timeline*: Current - (scoping stage) – 2002 (depends on potential technical details)
- *Outcome*: Analysis of microsatellite data and results from mitochondrial work
- *Collaborators*: University of Florida, USFWS, Anna Goebel, CSU, other geneticists?
- *Costs*: Tissue available at various locations (Cincinnati Zoo, Wyoming vet lab, others); $20,000 – ??
- *Consequences*: Determine extent of inbreeding, useful in reintroduction protocol development and in further refining of model; justification for potential supplementation from Canadian toads if closely related. Clarification of taxonomic relatedness between *B. hemiophrys* and *B. baxteri*
- *Obstacles*: Funding, confusion in carcass labeling and records

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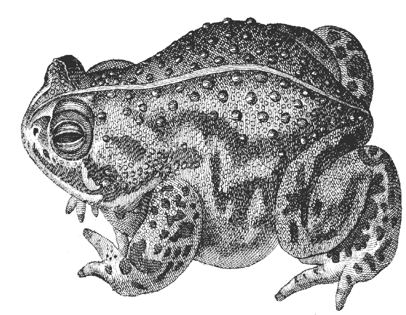
POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)

for the

WYOMING TOAD
(*Bufo baxteri*)

12 – 15 February 2001
Laramie, Wyoming



SECTION IV
WILD POPULATION MANAGEMENT

Wyoming Toad (*Bufo baxteri*)
Population and Habitat Viability Assessment (PHVA)
Wild Population Management Working Group Report

Working Group Participants:
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Ben Jennings, WY Game & Fish Department
Mary Jennings, US Fish & Wildlife Service
Greg Langer, US Fish & Wildlife Service
Don Miller, WY Game & Fish Department
Margaret Page, Private Rancher
Mike Parker, Laramie Rivers Conservation District
Larry Shanks, US Fish & Wildlife Service
Rebecca Soileau, US Army Corps of Engineers
Harrison Talbott, Big Laramie Mosquito District
Leah Talbot, Big Laramie Mosquito District
Patty Worthing, US Fish & Wildlife Service

The Wild Population Management Working Group began by identifying and prioritizing issues related to the management of wild populations of Wyoming toads. The issues and the number of priority votes each issue received are reported below. Specific goals and actions related these issue are prioritized in a second section, along with responsible parties, funding opportunities and other factors related to carrying out the action.

Prioritized Wild Population Management Issues

1. Species/Habitat Monitoring (37)

- There is a difficulty in being able to find the animals
- We have inadequate surveying and monitoring techniques
- We have a methodology problem, primarily we need GIS modeling
- We don't have standardized data management tools
- We don't agree on census methods, handling methods
- There may be too much handling of the species by too many people
- Are there other environmental/water quality issues that might be affecting the toad?
- We have not documented the successes/failures of the various release methods
- We don't know where they are hibernating around the lake, what areas are most important for hibernation
- We think that they hibernate in mammal burrows (mima mounds) but don't agree
- We don't know how chytrid persists during the winter, if other species are carriers. Fish are not supposedly not carriers
- Is there enough of the specific food sources needed for each of the life stages, or is some important component of the diet missing or reduced?
- Are researchers having an effect at Mortenson Lake?

2. Release sites (29)

- There is a lack of enough release sites
- We don't know what makes a good release site
- We need to find enough disease free release sites
- We need to determine if releases should continue at sites that have Chytrid fungus
- Have any other sites been tested for Chytrid? We have two sites now, we don't believe chytrid has shown up at Lake George
- We don't have any criteria to guide releases

3. Management Practices (28)

- Predators are impacting populations, and we don't know what the predators are.
- We don't know if the remaining sport fish impact the toad, or are preying on the toad. Does fish stocking negatively impact toads. There are no more trout being put into Mortenson Lake. To our knowledge trout are not eating the toads
- There is a lack of information about toads as it applies to management strategies, i.e. a lack of information to guide management
- Does grazing or the lack of it impact the habitat?
- There may be other land use issues that impact the species or the habitat
- Are there impacts from native ungulates, antelope and/or deer?
- Are there impacts of public access, from anglers, hikers, bicyclers, birdwatchers?
- There is a lack of management information, we don't know how we should be managing those grounds. Is there a role that fire should play?
- We don't know what the impacts of water level control are at Mortenson Lake. Water is dependent on irrigation, but lake level is dependent upon the dam
- Is irrigation positive or negative?
- What are the impacts of research activities conducted at the Lake?

4. Outreach/People/Landowners (27)

- Is malathion having an effect on toads?
- To the community, the toad has no recognized value. People may not see it as an animal because it doesn't have fur or feathers. If people understand that in general terms, something is either a plant or an animal, it will help communications. Public perception is that a cold-blooded animal isn't worthy of conservation or protection, etc.
- There is a lack of acceptance of landowners to having toads released on their lands. There is also a concern from landowners about releasing toads anywhere
- There may be a lack of education and a lot of misinformation in all aspects of the toads
- There is a lack of a positive climate and proactive interactions among the various stakeholders, including the public

5. Lack of Resources (24)

- There is not enough staff and/or money to properly monitor the site
- Having enough money/people is going to impact what can be done in all aspects
- We may not have the right expertise to work on these amphibians. We may need more herpetological expertise, we may need a specialist in outreach or fundraising
- There has been a historic lack of stable funding to focus on the various issues

6. Information (18)

- We don't have enough information about the other amphibians that exist now or did exist and share the ecosystem
- We have a lack of historical data. It may exist, but hasn't been compiled. The data that have been collected on Mortenson Lake are only from the last decade
- We don't know what we started with in the wild and where.
- There are various people doing things and they aren't sharing information well enough. There is a lack of coordination. Federal agencies are doing work, so are universities, the state, and information isn't all being shared.

7. Wild Populations (15)

- We need to find new populations.

8. Tabled Issues

- We don't know if the current recovery program is a failure and we don't know how to recognize what is a failure or success. We aren't using any tools to determine this. This is premature, will come up in problem-solving.
- There is a small number of animals and a small amount of genetic diversity, and inbreeding is a management issue. Inbreeding in toads is not the same issue as in mammals, because of the high fecundity. This is an issue for the genetics group.
- Has disease doomed us to failure? This is not our issue, should be given to disease group.

Prioritized Goals and Actions

1. Species/Habitat Monitoring

Goal: Develop and identify a set of consistent and widely accepted monitoring criteria for spring and fall surveys and population estimates.

<u>Action</u>: Compile a list of current practices, problems, and solutions with spring and fall surveys.

- *Responsible Parties*: Ben Jennings will be responsible for the compilation
- *Timeline*: This list should be completed by March
- *Outcome*: The compilation should help to define problems and actions to address these problems
- *Collaborators*: The Recovery Team (Note: Members of the Recovery Team have surveyed)
- *Costs*: Compilation will be completed by agency personnel
- *Consequences*: Development of standardized procedures and criteria for monitoring so that year-to-year comparisons can be made
- *Obstacles*: Time to complete project while carrying out other duties

<u>Action</u>: Identify scientific criteria needed for population estimates through use of the University of Wyoming, Steve Corn, and Colorado State University (Gary White)

- *Responsible Parties*: Mary Jennings (possibly Greg Langer)
- *Timeline*: Possibly completed within 6 months (July 2001)

- *Outcome*: This action should provide a protocol for monitoring to make population estimates and an initial report of needs for estimates
- *Collaborators*: The Recovery Team
- *Costs*: Briefing information, including population data, past surveys, participation, etc. will be required to provide to experts in setting criteria. The cost estimate is $1,000 to $3,000
- *Consequences*: Developing a methodology to estimate toad populations and allowing an evaluation of tradeoffs for information-gathering protocols
- *Obstacles*: There may be controversy over methods as well as difficulty fulfilling funding needs

<u>Action</u>: Follow up meetings/ workshops would convene in order to evaluate information from prior actions in order to make decisions related to the goal and to the selection of protocol.

- *Responsible Parties*: Mary Jennings
- *Timeline*: Meetings should convene in August 2001 and again 6 months later
- *Outcome*: Approval of a plan for monitoring and for estimating population size and characteristics
- *Collaborators*: Recovery Team leader
- *Costs*: $1000
- *Consequences*: Opportunity to discuss and approve a monitoring plan
- *Obstacles*: Funding to support a meeting / workshop

Goal: Formulate accurate recording mechanism for monitoring and research data. Utilize the best available technologies such as Global Positioning Systems (GPS) and Pit tagging for location information and Geographic Information System (GIS) capabilities to organize the information.

<u>Action</u>: Implement technology in surveying, monitoring and other aspects of the recovery programs prior to June 2001 survey.

- *Responsible Parties*: Greg Langer will have primary responsibility with the initiation of the program and management and maintenance of data. Mary Jennings and Ben Jennings will assist in the initiation of the program.
- *Timeline*: Meetings should convene in August 2001 and again 6 months later
- *Outcome*: The technology will provide better quality and quantity of data collected
- *Collaborators*: Collaboration will be done between U.S. Fish and Wildlife Service, U.S. Geological Survey, University of Wyoming (Jim Lovvorn), Wyoming Game and Fish, and the Wyoming Natural Diversity Database
- *Costs*: This program will likely require approximately two people to initiate the action with a cost estimate of $1,000
- *Consequences*: Resources that will be used include GPS units, GIS software (Arc Info), Data loggers, infrared (IR) guns, etc. Will need to evaluate and communicate data for uses in captive breeding and other reasons
- *Obstacles*: Short time frame and funding for needed equipment and personnel time

Goal: Evaluate and define acceptable impacts of research on the toads.

Action: The creation of a research screening advisory group to the Recovery Team which will make recommendations concerning proposed research

- *Responsible Parties*: Ideally the group will be made up of 2 to 4 people with scientific background, supported by a pool of outside and inside experts that can be called on for further support. Mary Jennings will put this action on the Recovery Team meeting agenda.
- *Timeline*: The initial steps in the formation of the group will begin at the next Recovery Team meeting
- *Outcome*: The formation of this group will create a defensible process for decision making
- *Collaborators*: This project will be a collaboration between the Recovery Team, the SSP and the Fish and Wildlife Service.
- *Costs*: $1000 - $2000
- *Consequences*: Increased research and improved coordination of the research
- *Obstacles*: Compliance with State and Federal Law may play a factor in research; source of funding to support advisory group meetings

Goal: Identify habitat usage for all life stages of the toad

Action: Compile all known information on habitat use and evaluate critical short-falls in data, with an emphasis on hibernation.

- *Responsible Parties*: Overseen by Ron Beiswenger
- *Timeline*: This project will be completed by May 2001
- *Outcome*: This will provide direction for future habitat and hibernation research
- *Collaborators*: Josh Parker, Dave Withers, University of Wyoming, and the SSP will collaborate on this project
- *Costs*: Approximately 20 hours
- *Consequences*: Improved direction for future research
- *Obstacles*: Funding to support student involvement

2. Release Sites

Goal: Determine criteria for the selecting of suitable release sites.

Action: Use of existing recent and historical data to determine ecological criteria for ideal release sites. Issues include hydrology and habitat characteristics for all life stages. (Two possible Wyoming sites discussed that will probably be available are Gelat and Meeboer Lakes, however they are open to public fishing access.)

- *Responsible Parties*: Recovery Team and Mary Jennings to raise it as an agenda item
- *Timeline*: Needs to begin now in order to be able to select two additional sites in 1 year. Need to complete in one year
- *Outcome*: This action will create an ecologically based protocol for choosing sites
- *Collaborators*: Potential collaborators are Jim Lovvorn (University of Wyoming), Josh Parker, State Engineers Office – George Baxter, Wyoming Natural Diversity Database – Doug Keinath, Stan Anderson (Wyoming Co-op), Conservation District, USGS, local landowners
- *Costs*: It will require mostly personnel time, use literature and Dr. Baxter's institutional knowledge

- *Consequences*: Establishing such criteria could create consternation among landowners that additional sites are being considered. It would be a way of focusing research and management activities
- *Obstacles*: Getting people to participate, coordinating meetings, there is no full-time coordinator

Goal: Short term need is to identify at least two additional suitable sites for releasing the toad. Long term need is to identify up to10 suitable sites for releasing toads.

<u>Action</u>: Develop process for choosing release sites

- *Responsible Parties*: Recovery Team and Mary Jennings to raise it as an agenda item
- *Timeline*: Now to February 2002
- *Outcome*: The action will result in choosing 2 to 10 new release sites
- *Collaborators*: Landowners, Recovery Team, Fish and Wildlife Service, WY Game & Fish, Conservation District, Natural Resources Conservation Service (NRCS), Bureau of Land Management (BLM), State Land Office, Mosquito Control District, County commissioners
- *Costs*: Resources needed include personnel time, FWS “mechanisms”(Safe Harbor, HCP) to protect landowners rights. Dollars for possible conservation easements for landowner
- *Consequences*: Establishment of new populations, protection of landowner and other stakeholder rights
- *Obstacles*: Concerns of landowners/other stakeholders, and time for participation

3. Management Practices

Goal: Enhance and maintain necessary aquatic and grassland habitat for all life stages of the toad.

<u>Action</u>: Write and implement a habitat management plan for current and future release sites (includes consideration of grazing, fire, water management, use by other wildlife, and access).

- *Responsible Parties*: Greg Langer
- *Timeline*: Start the plan in Feb 2002 and finishing in Feb 2003
- *Outcome*: This action would result in a management plan
- *Collaborators*: Refuge manager, Fish and Wildlife Service, Wyoming Game and Fish, Landowners, Stakeholders, Recovery Team, Toad Expert
- *Costs*: Resources would include past records, objectives of Recovery Team, ecological criteria, information from disease team and captive breeding team. Someone must use these resources to develop the plan.
- *Consequences*: Choose the best possible habitat for the Wyoming toad
- *Obstacles*: Lack of time commitment; constraints on water management; need to balance with stakeholder concerns

Goal: Identify and manage predatory species affecting survival of Wyoming toads in the wild.

Action: Determine if predatory species are a problem and identify specific species responsible, implement control in the short term, and develop a management plan in the long term.

- *Responsible Parties*: Greg Langer/Stan Anderson
- *Timeline*: Completed in two years (January 2003)
- *Outcome*: Recommendations for management (if needed) of predatory species, short term control of predatory species
- *Collaborators*: Predator control board, refuge, conservation district, landowners, non-governmental organizations (NGOs), agricultural groups, Art Anderson, Recovery Team
- *Costs*: Resources include University of Wyoming students, modeling to integrate effects of other factors (i.e. disease), money from predator control board, UW Research Associate position
- *Consequences*: Resolve whether predation is important, and increase potential for survival
- *Obstacles*: Certain species require a protocol for removal; stakeholder concerns

Goal: Identify and manage human impacts on the toads.

Action: List human activities that may impact toads. Establish priorities for which activities might need addressing immediately

- *Responsible Parties*: Recovery Team & Refuge
- *Timeline*: Begin immediately and complete inventory by the beginning of 2002. Management is ongoing.
- *Outcome*: Minimize mortality from these impacts
- *Collaborators*: Predator control board, refuge, conservation district, landowners, NGO's, agricultural groups, Art Anderson, Recovery Team
- *Costs*: Funding for a research associate or student to assemble the required data
- *Consequences*: May limit research and other human activities
- *Obstacles*: Stakeholder concerns

4. Outreach/People/Landowners

Goal: Create a positive image/relationship of the efforts related to the toad recovery.

Action: Develop an information and public outreach campaign. Media contacts should be established. Develop an organized public outreach effort to promote public awareness, understanding, appreciation and support for the Wyoming toad recovery efforts. Utilize the public school system as an important component of the public base that is receptive to education campaigns. A summary guide detailing the contacts and requirements of each educational program should be developed for distribution.

- *Responsible Parties*: Ron Beiswenger and Michelle Zitek, Don Miller, and Michell Van Vleet will have the responsibility
- *Timeline*: This will be done immediately and a program will be underway by the end of 2001
- *Outcome*: Conduct an information and public outreach campaign. This will result in better informed people and increased support of toad program

- *Collaborators*: teachers (Larry Hodgson), the Conservation District, Children's Museum, county library, Wyoming Game and Fish, University of Wyoming, news media, and American Zoo and Aquarium Association
- *Costs*: This will cost a few hundred dollars and will primarily involve people's time, plus some small publication costs. There may some funds in a Library funding source, the Wyoming Geographic Alliance, and U.S. Environmental Protection Agency education grants
- *Consequences*: We will need to find a way to show non-financial worth of the species to the public.
- *Obstacles*: Time constraints

Goal: Develop and foster positive and proactive interactions among the stakeholders.

Action: Contract with a third party to meet face to face with local landowners to develop a relationship. Clarify and publicize benefits of toad preservation, i.e. water disputes, open space preservation. Show positive common ground.

- *Responsible Parties*: Mike Parker will be responsible for finding a contact for guiding this effort in a couple months
- *Timeline*: May 2001
- *Outcome*: This will result in more positive relationships for relationships and more support for the toad program. We want to get willing and interested participants among the community.
- *Collaborators*: County Extension (Arlowe Hulett), Art Anderson, Mike Lasard are good people to contact for ideas of possible contractors. Elderhostel, and Wyoming Lyceum are possible resources to share information.
- *Costs*: The Institute for Environment and Natural Resources at the University of Wyoming is interested in programs to resolve controversial situations, so they may be a possible source of money
- *Consequences*: Interactions will increase the collective wisdom and education of everyone involved
- *Obstacles*: There is long-standing distrust and social barriers exist among the groups

5. Lack of Resources

Goal: In the short-term, we need to increase funding high priority actions to insure survival of the toad. For the long-term, we need to increase funding for other important issues.

Action: Identify possible funding sources through contacts made in other activities.

- *Responsible Parties*: Mike Parker
- *Timeline*: This will be an action that will need to be started now and will continue indefinitely
- *Outcome*: This will bring in funding from a variety of resources, potentially Institute for Environment and Natural Resources and other University of Wyoming departments, agricultural groups if they get interested in the program, and from WY Game and Fish
- *Collaborators*: Partners are all groups involved in the community and in science and amphibian interests
- *Costs*: Funding to support short- and long-term actions
- *Consequences*: Continuing support for the recovery program
- *Obstacles*: Competition for funding from other programs with similar goals

Goal: Increase staffing with appropriate/needed expertise. This will also establish continuity within resource needs.

<u>Action</u>: Find funding sources to combine to hire a full-time coordinator for the toad program.

- *Responsible Parties*: Recovery Team; involved agencies
- *Timeline*: Hire as soon as possible
- *Outcome*: This will increase communications and cooperation among groups, it will improve recovery efforts and help meet the needs of the toad as identified in this group
- *Collaborators*: Partners are Federal agencies, states, NGOs, Recovery Team, University of Wyoming Cooperative Fish and Wildlife Research Unit, agriculture groups
- *Costs*: Funding to support a coordinator position
- *Consequences*: This is essential for successful recovery of toad. It is everyone's responsibility to take this need to their agencies/corporations
- *Obstacles*: higher agency priorities, limited funds, lack of interest

6. Information/History

Goal: Have all information available in a readily accessible format for stakeholders.

<u>Action</u>: Develop a website for Wyoming toad information

- *Responsible Parties*: Recovery Team
- *Timeline*: Begin immediately; maintenance of website will be ongoing
- *Outcome*: The availability of a website to facilitate communication
- *Collaborators*: All stakeholders
- *Costs*: Funding or time allocation for a website developer and a webmaster
- *Consequences*: Improved communication among Recovery Team, stakeholders and the national endangered species management community
- *Obstacles*: Finding a way to support the required expertise

7. Wild Populations

Goal: Find new populations of toads

<u>Action</u>: Coordinate a systematic and ongoing survey of historic toad habitat for existing but undiscovered toad populations.

<u>Action</u>: Train landowners, agency, field people and citizens to identify toads in the field

<u>Action</u>: Provide a clearinghouse for reports about potential toad sightings

- *Responsible Parties*: Recovery Team; Ron Beiswenger
- *Timeline*: Begin immediately; develop and complete a plan by the end of summer 2001
- *Outcome*: A systematic effort to search for new toad populations
- *Collaborators*: Landowners, agencies, citizens
- *Costs*: Funding to support fieldwork (travel costs) and workshops (est. $3000)
- *Consequences*: Discovery of a new population of toads would potentially increase overall genetic diversity, establish a potential new site for reintroduction and population enhancement
- *Obstacles*: Landowner concerns; gaining access to private property

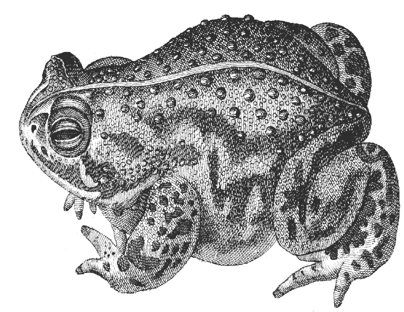
POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)

for the

WYOMING TOAD

(*Bufo baxteri*)

12 – 15 February 2001
Laramie, Wyoming



SECTION V
CAPTIVE POPULATION MANAGEMENT

Wyoming Toad (*Bufo baxteri*)
Population and Habitat Viability Assessment (PHVA)
Captive Population Management Working Group Report

Working Group Participants:
Bruce Foster, Wildlife Conservation Society
Becky Johnson, Detroit Zoological Institute
Andy Kouba, Cincinnati Zoo & Botanical Garden
Greg Lipps, Toledo Zoological Gardens
Charlie Mann, Houston Zoological Garden
Terri Roth, Cincinnati Zoo & Botanical Garden
Brint Spencer, John Ball Zoo
Michelle VanVleet, Sybille Wildlife Research Center

Preface

To improve the current captive breeding and husbandry program for the Wyoming toad, the strategic planning committee has recognized five areas of major concern, which need to be addressed. These five topics are listed below in order of priority and include; improving survival, captive reproduction and husbandry, nutrition and diet, hibernation, and appropriate environmental conditions. Within each topic is a list of objectives for improving that particular concern followed by specific actions needed to accomplish these objectives in a timely fashion. For all the actions detailed below, an individual within the strategic planning committee or their corresponding institution has agreed to coordinate the accomplishment of the listed task, as shown in parenthesis at the end of each action. In most cases, the cost of the specific action will be absorbed by the individual or institutions accomplishing each task; however, in some instances funding is requested and an estimated cost is shown at the end of these actions.

Prioritized Areas of Concern, Goals and Actions

1. **Improving Survival**
   The problem is a high level of mortality, particularly at transitional stages in the toad life-cycle (egg to larvae, larvae to metamorph, and metamorph to mature adult) and during hibernation. Factors that may be playing a role in the mortality include inbreeding depression, disease, and nutrition.

   <u>Short-term Goals (1 year)</u>

   A. Maintain a captive population of at least 500 total individuals (immature and mature).
   - Obtain an increased commitment from American Zoo and Aquarium Association facilities in supporting the Wyoming toad projects. (Brint Spencer) [rank (R)=10, score (S)=31]
   - Contact Columbus Zoo, Cheyenne Mt. Zoo, and San Antonio Zoo as possible institutions to join the Species Survival Plan (SSP). (Brint Spencer) [r=8, s=38]

- Use the amphibian taxonomic advisory group (TAG) to survey other facilities to determine if other zoos are interested in joining the SSP. (Brint Spencer) [r=12, s=24]

B. Improve disease reduction across all stages of development

- Work with the SSP's veterinarian and pathologist to develop protocols that can reduce the risk of disease transmission between institutions. Develop a Standard Operating Procedure (SOP) for all contributing AZA institutions. (veterinarian and pathologist advisor) [r=2, s=61]
- Consider different quarantine procedures for when animals are transferred. Although there is very little mortality when the toads are moved there is a concern over the transmission of diseases between facilities and/or the wild. (veterinarian and pathologist advisor) [r=7, s=40]
- Utilize protocols developed by the SSP's veterinarian and pathologist for treating toads already infected with chytrid fungus and other identified diseases. (veterinarian and pathologist advisor) [r=1, s=71]

C. Increase use of documentation and communication

- All facilities will have to comply with data requests in a timely fashion. To insure compliance, a section will be added to the U.S. Fish and Wildlife Services (USFWS) permit to hold the animals. This is already a requirement by the SSP. (Brint Spencer) [r=4, s=52]
- All facilities must have access to email in order to facilitate communication. (Brint Spencer) [r=13, s=16]

D. Improve captive husbandry.

- Compile a list of all the current husbandry practices, write, and publish a general husbandry manual that will be available to all contributing institutions. (Brint Spencer) [r=6, s=44]

<u>Long-term Goals (5 years)</u>

E. Establish a captive population that sustains 1,000 total individuals .

- Add four additional AZA accredited facilities holding Wyoming toads to our current short-term list of 11 facilities. (Brint Spencer) [r=11, s=28]

F. Eliminate disease as a primary cause of death in captive facilities.

- Refine existing treatments and protocols established in our short-term goals and decide if additional improvements can be made. (veterinarian and pathologist advisor) [r=4, s=52]
- Establish a long-term veterinary SOP to be made available to all participating institutions. (veterinarian and pathologist advisor) [r=8, s=38]

G. Publish successful Standard Operating Procedures

- Compile all Wyoming toad SOPs and set up for publication and distribute to all contributing institutions. (Brint Spencer) [r=3, s=53]

Consequences: The expected impact from accomplishing all these actions would be increases in the captive population, health, and the number of facilities protecting the population from a catastrophic disaster. Another outcome will be an improvement in communication and records.

Obstacles: Current mortality rates suggest a serious obstacle to the success of these goals. The fact that the animal is not a charismatic mega-vertebrate will make it difficult to convince other institutions to dedicate their resources to the Wyoming toad SSP. Additional obstacles to accomplishing these goals include the absence of email access which could hamper communication and low numbers of participating facilities, thereby increasing the risk to the population.

2. Captive Reproduction and Rearing

Obstacles to achieving successful captive reproduction include: low fertility rates, reproductive asynchrony of males and females, low production of eggs, and water quality issues. Compounding these issues is a lack of documentation, making the goal of natural reproduction unattainable. A lack of reproducible results in our current captive breeding programs has led to a precipitous decline in the number of captive-bred animals. Therefore, increasing the efficiency of captive breeding programs is necessary to offset our dwindling captive population. Injection of the hormone LHRH into potential breeding pairs of adult Wyoming toads to stimulate sperm and egg production is important to the successful captive reproduction of the species. Factors such as injection sites, hormone dosage, frequency of injection, and proper timing of these injections after hibernation should be carefully studied. Researching possible alternative hormones and potential detrimental health effects associated with the injections should also take place.

<u>Short-term Goals (1Year)</u>

A. Increase the current estimated success of larval rearing from 13% to 25% [r=7, s=50]

- Improve water quality by establishing standard criteria for appropriate water chemistry, i.e., nitrogenous waste and pH. (Becky Johnson)
- Evaluate the possibility of making available a reconstituted synthetic Mortenson Lake water to each contributing institution. Most institutions are reliant upon aged city water that may be sub-optimal for breeding. (Bruce Foster).
- Increase documentation of larval rearing successes and railures in regards to water quality, chemistry, food, temperature, lighting, and population density. (Greg Lipps).
- Increase examination of larval deaths and develop a protocol for preserving deceased animals suspected of Chytrid fungus infection. (veterinarian and pathologist advisor)
- Review the current tadpole diets and make recommendations on any changes that are necessary. These new or modified diets will then be made available to all participating institutions. (Brint Spencer and nutritional advisor)

B. Maintain the number of viable eggs by keeping the number of breeding pairs producing eggs at the current level of 34%. [r=8, s=40]

- Optimize the number of breeding pairs for 2001 as designated by the SSP and carefully consider populations of animals that may be infected with Chytrid fungus.
- Incorporate new information on male hormonal injections into a standard protocol. (Terri Roth).
- Investigate multiple or group pairings based on cohorts (SSP recommended). Careful genetic selection needs to be considered.
- Attempt multiple breedings in females that fail to produce eggs. (individual SSP facilities). If toads produce eggs they will not be used for multiple breedings regardless of whether the eggs were fertilized.
- Consider the use of alternative hormones for females that fail to release eggs after two breeding attempts in a given year. Decisions on this will be made by the SSP. Alternate hormone injections will be based on knowledge available for other species in the literature and research done at the Center for Research of Endangered Wildlife (CREW). [Andy Kouba].
- Solicit information and opinions from amphibian experts concerning egg fertility. (Greg Lipps)

C. Increase the number of viable eggs by increasing the average number of eggs per clutch to 1000. [r=13, s=26]

- Review adult diets and make recommendations to participating institutions. Information from our nutrition studies will facilitate these recommendations (Brint Spencer and nutritional advisor).
- Analyze the relationship of clutch size to historical captive records of pedigree, age at egg laying, weight of females, general health, hibernation data, and hormonal injections. (Greg Lipps).
- Explore and compare results of post-hibernation and/or pre-breeding feeding strategies for adult Wyoming toads that may facilitate an increase in egg clutch size and compare these results to what may occur in the wild. (Greg Lipps)
- Solicit information and opinions from amphibian experts concerning amphibian reproduction. (Greg Lipps)

D. Increase the number of viable eggs by increasing the current number of hatched eggs from 27% to 40%. [r=9, s=39]

- Review adult diets and make recommendations to participating institutions. Information from our nutrition studies will facilitate these recommendations (Brint Spencer and nutritional advisor).
- Analyze the relationship of egg hatching success to historical captive records for pedigree, age at egg laying, weight of females, general health, hibernation data, and hormonal injections (Greg Lipps).
- Explore and compare results on post-hibernation and/or pre-breeding feeding strategies for adult Wyoming toads that may facilitate an increase in egg clutch size and compare these results to what may occur in the wild. (Greg Lipps)

- Solicit information and opinions from amphibian experts concerning amphibian reproduction, particularly factors affecting hatching success (Greg Lipps)

E. Increase the average survival rate of yearlings (both genders) to 50%. There is a critical need to increase the survival rate of yearlings (only 40% of males are surviving and 30% of females). [r=4, s=63]

- Compile and analyze the captive historical data on mortality and how the yearlings are being reared (Greg Lipps and Andy Odum).

F. Effectively use hormone injections by developing dosages, frequency, and injection site protocols. Develop recommendations for alternate hormones using knowledge available (published data) and new protocols being established at CREW.

- Review information available from CREW at the Cincinnati Zoo on sperm collections done in Wyoming toads using LHRH and distribute this information to participating institutions. This information will also be included in the husbandry manual. (Terri Roth)
- Current information from all participating institutions will be reviewed in regard to their use of hormone injections. (Michelle VanVleet)

G. Obtain data on natural environmental cues that stimulates natural breeding. [r=12, s=34]

- Analyze historical environmental data at Mortenson Lake including air, water, and soil temperature, and humidity. (Bruce Foster).
- Place data loggers at Mortenson Lake from May 15 to October 15 in order to measure temperature and precipitation. This data will need to be correlated with breeding activities (calling, amplexus, egg laying etc.). This will require the presence of a technician at the site to record and monitor this activity. Cost of study for a technician for 2 months to record, compile, and analyze data, $5,000. (Bruce Foster and Michelle VanVleet).

<u>Long-term Goals (5 Year)</u>

A. Improve larval rearing success from 25% to 95%. [r=3, s=64]

- Analyze all captive rearing records and develop an SOP for long-term larval management. (Greg Lipps and SSP)

B. Increase the number of viable eggs by increasing the number of breeding pairs producing eggs from 34% to 75%. [r=5, s=57]

- Review all the information that was collected in the short-term goals in Part B and develop SOPs that will then be implemented by all participating institutions. In addition, nutrition, hibernation, and environmental data obtained from Part B short-term studies, will be factored in. (Brint Spencer, SSP chair).
- Incorporate new sperm and egg collection techniques that are developed by research institutions like CREW. (Terri Roth and Andy Kouba).
- Investigate use of alternative hormones and the current use of LHRH for the Wyoming toad using the Canadian toad (*Bufo hemiophrys*) as a model species. (CREW –

estimated cost of project may be $15,000). Commitment to this project will need to be confirmed by CREW and their animal management committee.

C. Increase the number of viable eggs by increasing the number of eggs per clutch from 1000 to 3000. [r=6, s=56]

- Review all the information that was collected in the short-term goals in Part C and develop SOPs that will then be implemented by all participating institutions. In addition, nutrition, hibernation, and environmental data obtained from Part B and C short-term studies will be factored in. (Diane).
- Incorporate new sperm and egg collection techniques that are developed by research institutions like CREW. (Terri Roth and Andy Kouba)
- Investigate use of alternate hormones and the current use of LHRH for the Wyoming toad using the Canadian toad (*Bufo hemiophrys*) as a surrogate species. (CREW – estimated cost of project may be $15,000. This is not a separate cost from the study described in the previous section. Commitment to this project will need to be confirmed by CREW and their animal management committee.

D. Increase the number of viable eggs by increasing the hatching rate from 27-40% to 95-100% hatched. [r=2, s=68]

- Review all the information that was collected in the short-term goals in Part D and develop SOPs that will then be implemented by all participating institutions. In addition, nutrition, hibernation, and environmental data obtained from Part B and C short-term studies, will be factored in. (Diane)
- Incorporate new sperm and egg collection techniques that are developed by research institutions like CREW. (Terri Roth and Andy Kouba)
- Investigate use of alternate hormones and the current use of LHRH for the Wyoming toad using the Canadian toad (*Bufo hemiophrys*) as a model species. (CREW – estimated cost of project may be $15,000. Again, this is not a separate from the study described above. Commitment to this project will need to be confirmed by CREW and their animal management committee.

E. Increase the long-term survival rate of yearlings from 50% to 80%. [r=1, s=85]

- Continue to analyze successes in our short-term goals to modify or improve our current protocols in order to increase our success rate (Diane).
- This increased success rate will require publishing a SOP and making this document available to all participating AZA facilities. (Brint Spencer)

F. Develop complete SOPs for hormone use. [r=10, s=38]

- Compile and analyze short-term goals and create an SOP. (Terri Roth)

G. Eliminate hormones required for captive breeding in order to promote natural breeding. [r=14, s=23]

- Compare environmental data collected during short-term studies and compare to the captive data to determine if hormone use can be eliminated by providing natural environmental cues. (Diane)
- Purchase and install a weather station at Mortenson Lake to monitor long-term environmental data. Estimated cost is $5,000. (Bruce Foster).

Consequences: The expected outcome of the listed actions will be to increase the captive population size by improving hormone injections, water recipes, egg/sperm harvesting, and environmental cues. This ultimate goal would be the complete elimination of hormones, relying on only environmental cues to stimulate natural breeding. Furthermore, a synthetic water for Sybille would reduce the spread of chytrid fungal infections (this facility currently obtains water from the wild).

Obstacles: One specific conflict to accomplishing the listed actions would be non-compliance for data requests. Other obstacles would include the time required to develop hormonal protocols, the risk to the animals treated with hormones, and low numbers of animals for research.

3. Nutrition / Diet

With the assistance of the nutrition advisor, identify and analyze the wild adult and tadpole diets. This information will be compared to the captive diets fed and recommendations for improvements made.

Short-term Goals (1 Year)

A. Understand natural diets by determining available natural prey.

- Analyze fecal samples of wild Wyoming toads held by University of Wyoming. These samples will be sent to The Toledo Zoo for analysis by an expert entomologist. (Greg Lipps) [r=4, s=20]
- Field collect potential food items and compare to fecal samples that will be analyzed in number 1. In addition these food items (insects) will be evaluated for nutritional value by a nutritionist at an estimated cost of $5000. (nutritional advisor to the SSP) [r=3, s=22]
- Determine if any preserved stomach contents of wild-collected Wyoming toads exist. (Michelle VanVleet) [r=7, s=8]
- Refine techniques for stomach washes in other toad species (Bufo sp.) held in captivity that can then be applied to the Wyoming toad. (Karen Graham) [r=5, s=15]
- Obtain permit to examine stomach contents of wild Wyoming toads if the process appears to be safe and reliable in other toad species. (Brint Spencer and USFWS) [r=6, s=11]

B. Obtain a commitment from a nutritionist for analysis of the toads diet.

- The SSP will confirm the commitment from a nutritionist to work closely with the SSP coordinator to develop an appropriate healthy diet. (Brint Spencer) [r=2, s=33]

<u>Long-term Goals (5 Year)</u>

A. Develop an artificial feeding regimen that mimics the wild diet.

- Compile and analyze the data obtained from the short-term goals and along with the nutritionist develop an optimum captive diet for the Wyoming toad. (Brint Spencer and nutritional advisor) [r=1, s=39]

Consequences: The outcome of these actions will be an increase in reproductive success, an increase in longevity, general health, and resistance to disease.

Obstacles: Specific conflicts to obtaining our goals may be the cost of lab work, the commitment from a nutritionist on the project and how fast nutritional data can be analyzed. Other obstacles may be obtaining permits for field work, acquiring outside expertise (such as an entomologist), collecting enough material for nutritional experiments, and unknown nutritional food requirements for the toad.

4. Understanding Hibernation Requirements

Several factors regarding Wyoming toads and their hibernation in captivity need to be addressed. The topics of concern are: preparation for hibernation, the duration of hibernation, temperature, humidity and moisture content during hibernation, the substrate of the enclosure used during hibernation, the cooling rate at which toads enter and leave hibernation, and whether or not both sexes require hibernation for a successful breeding.

<u>Short-term Goals (1Year)</u>

A. Determine if hibernation is required by examining captive historical patterns

- Historical data from participating institutions will be compiled and analyzed to determine the relationship between hibernation and successes and failures in captive reproduction (Greg Lipps) [r=3, s=16]

<u>Short-term Goals (2 Year)</u>

A. To develop optimal hibernation protocols by examining captive historical patterns and determining wild hibernation conditions. The development of this particular objective may depend upon the conclusions drawn from section 4A.

- Compile and analyze historical captive data from participating AZA institutions, and make recommendations to the SSP coordinator. (Greg Lipps) [r=1, s=20]
- Design a field study in which several toads (n=2-5) are outfitted with temperature-sensitive radio-telemetry devices in order to monitor hibernation temperatures and location. Location may also provide additional data on the depth toads select for hibernation. Estimated cost = $3,000-5,000 for equipment and technician salary for the short duration of the study. The technician’s work will also include other studies mentioned within this text. Considerations will be made for the hiring of a full-time field researcher to be coordinated with other strategic planning committees. (Becky Johnson and Michelle VanVleet) [r=4, s=9]

Long-term Goals (5 year)

A. Conclude definitely if hibernation is necessary

- Analysis of data from the short-term study will establish whether hibernation is necessary or determine if further comparative investigation is required. This information is necessary for Part D. (Becky Johnson) [r=4, s=9]

B. Develop a consistently successful SOP for hibernation protocols

- Begin to implement a range of successful hibernating conditions or protocols and modify as necessary over the next 2-3 years. (Brint Spencer) [r=2, s=17]

Consequences: The expected impact of achieving our listed goals will be a decrease in the mortality of the Wyoming toad and an increase in captive reproductive success.

Obstacles: Specific conflicts that may hinder us from accomplishing our goals will be acquiring permits and funding for field studies along with recruiting personnel for the field studies.

5. Environmental Requirements

There are a number of environmental parameters that need to be established to increase the survival of Wyoming toads in captivity. These include: substrate, light requirements, water quality and exchange, moisture/humidity, cover, cage type, cleaning procedures, and population density.

Short-term Goals (1 Year)

A.Optimize environmental conditions by determining captive and wild historical patterns.

- Compile and analyze captive data. (Greg Lipps) [r=1, s=17]
- Ensure data is submitted to SSP coordinator. (Brint Spencer) [r=4, s=7]
- Compile and analyze wild data. (Bruce Foster) [r=3, s=8]

Long-term Goals (5 Year)

B. Optimize environmental conditions by developing an SOP.

- Begin to implement a range of successful husbandry conditions based on environmental data compiled from the short-term studies. (Brint Spencer) [r=2, s=10]

Consequences: Compiling information from the above studies should decrease mortality and increase the reproductive rate of the Wyoming toad.

Obstacles: Obstacles to achieving these goals include failure of participating facilities to submit required historical data and resistance to changing their current, non-standardized environmental conditions.

Final Action Rankings

1. Increase long-term survival rate of yearlings from 50% to 80% (score = 72).
2. Improve larval rearing success from 25% to 95% (score = 72).
3. Increase number of viable eggs by increasing hatch rate from 27% to 95% (score = 65).
4. Develop protocols for treating toads infected with chytrid (score = 57).
5. Work with vets to develop protocols to reduce disease transmission (score = 56).
6. Compile and analyze captive data to determine an optimal diet (score = 54).
7. Begin to implement a range of successful husbandry conditions (score = 53).
8. Compile and analyze captive environmental data (score = 49).
9. Confirm the commitment of a nutritionist (score = 41).
10. Begin to implement a range of successful hibernation techniques (score = 39).
11. Compile and analyze captive hibernation data; short term (score = 39).
12. Compile and analyze captive hibernation data; long term (score = 39).
13. Compile all Wyoming Toad SOPs for publication (score =30).
14. Compile and analyze wild environmental data (score = 29).
15. Field collect food items to identify species and for nutritional analysis (score = 28).

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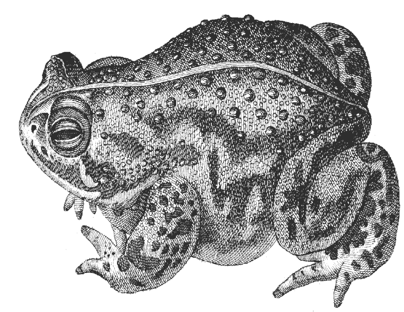

SECTION VI
LIST OF WORKSHOP PARTICIPANTS

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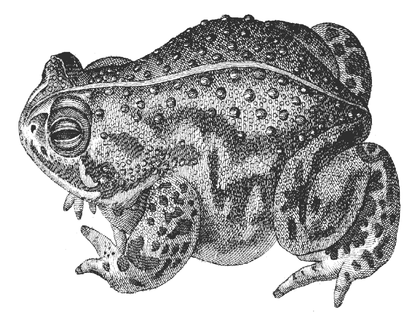
POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)

for the

WYOMING TOAD

(*Bufo baxteri*)

12 – 15 February 2001
Laramie, Wyoming



SECTION VII
APPENDICES

Appendix I
Individual Responses to Introductory Workshop Questions

What do you hope this workshop will accomplish?

- I hope this workshop can bring forth suggestions that may answer the questions and many problems that plague the toad
- I hope for a revised recovery plan that takes into account and attempts to address the complex issues (disease, suitable habitat for reintroduction) facing this toad
- To create a new recovery plan and conservation action plan that has a "high" probability of success for *Bufo baxteri*
- A clear consensus about what to do next
- Recognize the balance required among ecological and natural concerns with economic and human requirements-agricultural use vs. subdivision use vs. fallow use
- Not to spend large amounts of money trying to perpetuate the balance of nature in conjunction with changing economics of the area (people growth, land use, etc.)
- Species survival must consider the economic aspects i.e. cost/benefit vs. lab experimentation. We can't maintain numbers for numbers sake, but must consider the impact of the numbers loss
- I would like to see cooperation between the various agencies represented in this workshop in attacking the problems plaguing the Wyoming Toad. I would also like to see new protocols in both captive husbandry and wildlife management that might provide a more successful recovery program for the species
- To exchange knowledge from various parties and gain understanding and some consensus on what direction needs to be taken for toad recovery
- Guidance regarding how to achieve recovery of the toad, and some new ideas
- Determine if we can still recover the Wyoming Toad, if we should still put efforts to try to recover it and how to focus our limited resources and on what topics/issues
- To gain an understanding of what are the major problems the Wyoming Toad is facing and ideas how to address them
- I hope the workshop will provide guidance and commitments for broad scale collaborative research and management
- To create a list of tasks required to attain the goal of recovery
- The production of a cohesive plan of action including long term goals, the identification of short-term goals and funding sources
- To see whether there are any applications of conservation biology that can be of immediate practical use in management of the Wyoming Toad
- Provide management direction that facilitates the full recovery of the endangered Wyoming Toad
- I hope we can establish directives for recovery of the toad
- To gather information and bring together experts to hopefully develop a strategy to recover this species
- Why can't we let nature take its course? To let us keep using chemicals to control mosquitoes
- Knowledge and interest of persons needed for project
- Be brought up to date on status of toad survival recovery efforts
- Develop a working strategy to conserve the Wyoming Toad, and balance the needs of all involved parties

- I'm hoping this workshop will be able to break down political and personal barriers and get people to focus on the recovery of the toad. I'm also hoping this workshop will rejuvenate recovery efforts
- A clear set of methods or objectives that will lead to the survival of the toad
- A cooperative agreement on protocol and strategies for the best breeding and reintroduction methods for the Wyoming toad
- I am in hopes this workshop will help greatly to improve the captive propagation of the species because this species is so close to extinction
- Identify and clarify issues and needs for recovery of the Wyoming Toad
- I am interested in finding out how I can assist the recovery of the Wyoming Toad as a reproductive physiologist at a zoo
- I would like to see the Wyoming Toad PHVA meeting compile a list of the likes and concerns involved with Wyoming toad management and come to a consensus on what improvements are necessary and how these changes can be accomplished
- I would like to see this group identify and prioritize some of the problems facing the toad's recovery. Further suggestions of solutions may be useful as well

What, in your judgement, is the primary problem affecting Wyoming toad survival and recovery?

- There are so few of them and so little genetic diversity it's hard to bring them back from their low numbers
- Their sensitivity to everything
- I am certainly biased because my exposure to the toad has been through diagnostic pathology submissions. On an immediate basis, disease (particularly chytridiomycosis) seems a serious threat both to captive propagation efforts and in re-introduced animals
- Lack of understanding about the complex issues regarding the decline and management of the toad
- The lack of a concern by the human community for the non-human community
- The changing balance of nature can't sustain the survival of all species. We have more wildlife and forests now than in 1900
- I think the population dipped to too low a level before the severity of the problem became apparent. We have too few toads in which to work with
- I don't think there's a primary problem. I think it is several issues that are additive: habitat loss, genetic diversity loss, environment quality, and disease
- Suppressed immune system, disease, limited numbers, and genetic problems
- Disease, limited numbers, limited habitat and/or altered habitat, and limited funds
- The unknown factors that seem to be limiting the success of the toad recovery effort
- A lack of a clear understanding of the reasons for the decline of the toad
- Individual and societal priorities (e.g. philosophical, economic, aesthetic.)
- Disease possibly chytrid fungus and/or other related or non-related diseases and stresses.
- Disease and the lack of a way to combat it
- Known and unknown diseases
- Diseases and unknowns
- Disease
- This unknown fungus, Red Leg, and human handling (human handling is a problem not only to the Wyoming Toad but also to all amphibians)
- More info needed as number of toads etc., when first noticed, interference of toad populace.
- They no longer can survive in the wild
- Lack of knowledge regarding biology and natural history combined with marginal habitat
- There are many obstacles but the biggest problem is lack of specific knowledge about the toad

- Lack of a clear set of objectives, and methods for measuring our accomplishments and failures towards these objectives
- Chytrid fungus
- We have little or no reproduction of this species in the wild and the captive propagation is not too successful either.
- Probably disease and undefined insults on the habitat
- The chytrid fungus recently identified and Mortenson Lake seems to be the biggest blow to the program in several years
- In my judgement the primary problem affecting toad survival and recovery is the inefficiency and die-off found in captive breeding programs throughout different zoological institutions
- The primary problem facing the toad is the lack of information on a variety of aspects in recovery of the toad

What do you bring to the workshop to assist conservation or recovery of the Wyoming toad?

- Help in the captive breeding program for three years
- Experience with amphibian disease and particularly chytridiomycosis
- I bring expertise in captive management, small population management, and general herpetology to these meetings
- A working knowledge of the PHVA process
- Pragmatism of real life land use:
    - Ranchers are natural conservationists who must take care of all aspects of the land for economic survival
    - Concern about everyone trying to do the best job independently, which in a total environment creates conflicts such that the entire process fails
    - Help those making the decisions who have no economic or human stake recognize the impact of their decisions of those who are impacted so that their decisions are sound
- I bring my knowledge of captive husbandry and reproduction of the species including participation in the Houston Toad recovery program, which is why our institution was invited to participate in the Wyoming Toad program
- Some fieldwork experiences determining environmental conditions at Mortenson NWR
- The conservation mandate of the EA, and maybe a little knowledge of Conservation Biology
- An ear to help focus FWS efforts, to seek funding sources, to inform/convince FWS about what can/can't be done for recovery, and help form future direction of FWS recovery efforts for the toad
- Management of and on the ground observation of some history of Mortenson Lake NWR
- I bring to the workshop experience with field research related to toads and a strong desire to contribute to toad recovery
- Time for participation; desire to listen, some knowledge
- Six years experience with boreal toads in Colorado including monitoring of a declining population and chytrid fungus infection
- I have field experience with the toad before captive breeding was begun, including population estimates and growth data
- Captive breeding experience and heart
- Land manager of Mortenson Lake NWR, and the ability to control and manage land activities
- A willingness to be involved
- To work with toad administration to control mosquitoes by arial spraying

- Knowledge of use of Malathion for insect control and not endangerment to toad
- Land owner concerns
- Commitment to conservation of endangered species
- Captive breeding experience, some field experience, and a lot of energy and enthusiasm
- I bring knowledge on the husbandry and captive breeding of the toad. Personally, I bring enthusiasm and optimism
- Knowledge in toad husbandry
- History and money
- Some knowledge of hydrology and fluvial systems, some knowledge of workshop processes, interest in endangered species
- Scientific expertise in the area of reproductive physiology and a lab committed to an amphibian research program
- I think I bring to this meeting possible future directions for captive breeding and management practices utilizing assisted breeding technologies
- As a recent addition to the program I bring an outsiders perspective thus the ability to discover new questions

Appendix II
An Introduction Simulation Modeling and Population Viability Analysis

Introduction

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).

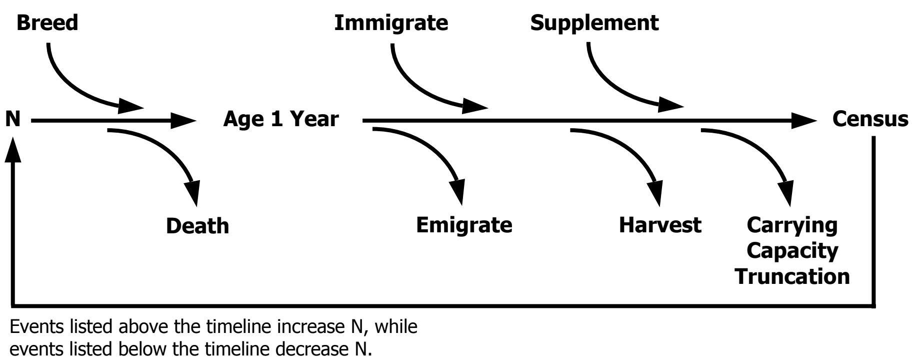
A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and many of the factors interact in complex ways. For example, increased fragmentation of habitat can 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.

VORTEX Simulation Model Timeline



The *VORTEX* Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) 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 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. Uncertainty can occur because limited field data have yielded estimates with potentially large sampling error. Uncertainty can occur because independent studies have generated discordant estimates. Uncertainty can occur because 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. Uncertainty can occur because 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 pronghorn population. 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:

Deterministic r -- 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.

Stochastic r -- 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.

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POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA)

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12 – 15 February 2001
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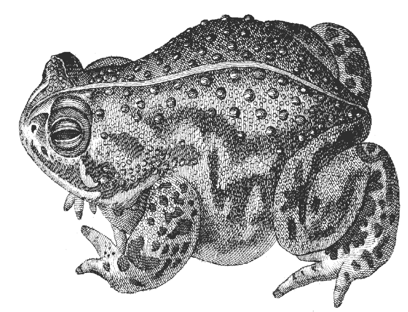

SECTION VIII
IUCN POLICY STATEMENTS

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

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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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

A) Introduction of an alien species should only be considered if clear and well defined benefits to man or natural communities can be foreseen.

B) 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

C) 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

D) 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

E) 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

F) 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.
