The Rio Grande Silvery Minnow (*Hybognathus amarus*)

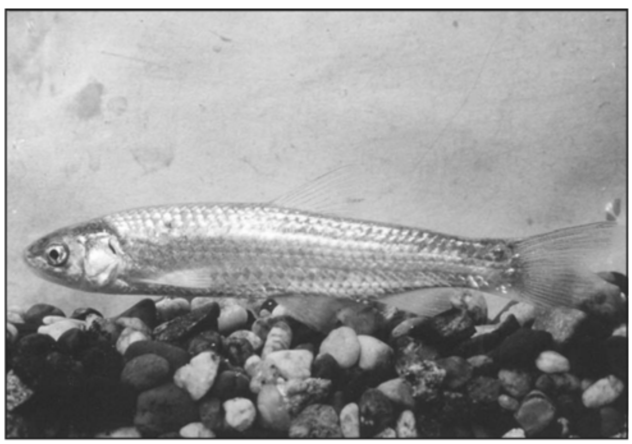
Population and Habitat Viability Assessment WORKSHOP REPORT

August 2008

Population and Habitat Viability Assessment for the Rio Grande Silvery Minnow

4 – 7 December, 2007
Albuquerque, New Mexico

WORKSHOP REPORT



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31 August 2008

Population and Habitat Viability Assessment
Rio Grande Silvery Minnow

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Section I
Executive Summary

Rio Grande Silvery Minnow (*Hybognathus amarus*) Population and Habitat Viability Assessment (PHVA) Workshop Report Executive Summary

The Rio Grande silvery minnow (*Hybognathus amarus*) historically occupied approximately 3,862 river km (2,400 mi) in New Mexico and Texas. It was found in the Rio Grande from Española, New Mexico, down through Texas to the Gulf of Mexico (Bestgen and Platania 1991). It was also found in the Pecos River, a major tributary of the Rio Grande, from Santa Rosa, New Mexico, downstream to its confluence with the Rio Grande in Texas.

Currently, the Rio Grande silvery minnow (silvery minnow) is believed to occur in only one reach of the Rio Grande in New Mexico, a 280 km (174 mi) stretch of river that runs from Cochiti Dam to the headwaters of Elephant Butte Reservoir. Its current habitat is limited to about 7 percent of its former range. The species was listed as federally endangered in 1994 (59 FR 36988, 36995).

Increasing demands for available water have altered the normal hydrologic and ecological processes in the Rio Grande. Ongoing drought in this area of the United States has exacerbated these problems still further. As a result, the long-term persistence of endangered species such as the silvery minnow will likely be compromised to a greater degree. To this point in time, however, a comprehensive quantitative analysis of the risk posed by these activities to silvery minnow population persistence has not been completed. Only by implementing such an analysis can specific, robust recommendations be made concerning management of the species and its habitat.

To assist in the completion of this task, the Conservation Breeding Specialist Group (CBSG) of IUCN-The World Conservation Union's Species Survival Commission was invited by The Middle Rio Grande Endangered Species Collaborative Program to design and conduct a workshop process that will produce a population viability analysis (PVA) and a set of conservation strategies for the silvery minnow. The product of this effort, known as a Population and Habitat Viability Assessment or PHVA, will be a detailed action plan for future management of the silvery minnow within New Mexico and throughout its range. This interactive, participatory workshop is designed to broaden stakeholder involvement and enhance information sharing across scientific, social, and economic groups/interests.

For nearly three months before the PHVA workshop, CBSG conducted a PVA in collaboration with a variety of local and regional experts in silvery minnow and Rio Grande river ecology and hydrology. This analysis consists of a computer simulation that incorporates our knowledge of the biology and ecology of the species – rates of reproduction and survival, population structure, habitat requirements, etc. – and projects the relative performance of silvery minnow populations under alternative scenarios of management or lack thereof. Using these alternative projections of population performance, typically described as relative rates of population growth or decline, species managers and interested stakeholders can determine the most effective practices to minimize the risk of extinction of the species.

The PHVA workshop was organized and hosted by the Collaborative Program in early December 2007. Participants in the workshop represented a wide variety of stakeholder domains, including academic, agency and tribal biologists, wildlife managers, water management experts, legislative representatives, and other interested parties. The general goals of the workshop were to assist stakeholders to: 1) use a demographic simulation model (PVA) to guide and evaluate species management and research activities; 2) formulate priorities for a practical management program for long-term survival of the species in an urbanized environment; and 3) promote effective collaborations between stakeholder domains that foster conservation of Rio Grande silvery minnow habitat while accommodating responsible economic development in the region.

The Workshop Process

The PHVA workshop began on 4 December 2007, with approximately thirty experts gathered together at the Bureau of Indian Affair's newest office complex in downtown Albuquerque. After a brief set of opening remarks by Dr. Brian Millsap, Acting Assistant Regional Director for the US Fish and Wildlife Service (a signatory to the Collaborative Program), each participant was then asked to introduce themselves and to share with the group their personal goal for the workshop, and to give the group their opinion of the greatest challenge to sustainable management of the silvery minnow in the urbanizing Middle Rio Grande and surrounding areas. Common themes expressed during this session revolved around effective water management in the river, and the need for more productive communication and collaboration among the many entities comprising the Collaborative Program. A short presentation was then given by Dr. Jennifer Parody, the Endangered Species Act Coordinator for the US Fish and Wildlife Service, on the history of the Collaborative Program and how the PHVA workshop was seen in the broader context of silvery minnow management in New Mexico. Dr. Philip Miller, the workshop facilitator from CBSG, introduced the PHVA workshop philosophy and the role of population modeling in the decision-making process; this led into a more detailed presentation on the structure and results of the PVA, conducted before this workshop as a way to inform the biological aspects of minnow viability in the context of water management in the Middle Rio Grande.

Through consideration of information presented on this first day of the workshop, three working group topics were identified that would form the basis of the meeting's subsequent activities:

- Shorter-Term Species Management (alleviating jeopardy)
- Longer-Term Species Management (facilitating recovery)
- Communication and Collaboration

All workshop participants were invited to choose which group they wanted to join. Through this process of self-selection, workshop participants were provided with the opportunity to contribute their information and perspective in the most effective way.

In the afternoon of the workshop's first day, the working groups began moving through a set of structured tasks set forth by the workshop facilitator. First, each group was asked to amplify those relevant issues / challenge statements identified earlier, to identify new challenges of importance to their specific topic, and to prioritize them according to an agreed criterion. The groups were then brought together as a larger group, and each working group shared their information and was able to provide commentary and perspective with their peers. This process of working group sessions, followed by plenary reports and discussion, continued throughout the workshop. Once issues were identified and prioritized, the next working group task centered on assembling the relevant information for each topic in order of priority issue, with an emphasis placed on separating known facts from assumptions, identifying the important justifications around each assumption, and (perhaps most importantly) flagging areas where potentially important information is missing. Through this process, the subsequent identification of management and / or research priorities was greatly enhanced.

Once information assembly was complete, each working group was asked to brainstorm, refine and prioritize goals specifically designed to address the issues identified previously. Each group brought their top five priority goals to a plenary session on the morning of workshop Day 3, and the entire group was then asked to provide an overall sense of priority for these goals based on the importance of achieving these goals for successful management of the silvery minnow. Since these goals are directly tied to the issues identified in the early stages of the workshop, the workshop design facilitates the resolution of the needs of the diverse stakeholder domains that are present.

With goals identified, each working group then began the task of identifying specific actions that would achieve those goals. These actions are intended to include important details such as the individual responsible for moving the action forward, a timeline for completion of the action, important collaborators, and specific obstacles to be overcome if the action is to be completed. With this level of detail, those agencies responsible for managing and recovering the species have a valuable set of comprehensive recommendations that can be used to guide future actions.

The workshop was not without its contentious moments, centered around issues of trust and accountability among institutions comprising the Collaborative Program as well as the nature of the information used to draw conclusions about silvery minnow population trends in the recent past. The PHVA workshop process is specifically designed to help stakeholders address these issues and to move towards a shared understanding of them with respect to the species conservation challenges put forth at the workshop. Through the structured methods of discussion and analysis discussed here, all participants can make tangible progress in articulating their views and, more importantly, making themselves heard more effectively in the larger community arena. We feel that, with respect to the difficult issues brought out during this workshop, such progress has been made.

Workshop Results

Population Viability Analysis

The PVA analyses were conducted using the *RAMAS METAPOP* software package. The modeling effort was specifically designed to (*i*) determine those aspects of Rio Grande silvery minnow demography that are primary factors in driving population growth; (*ii*) evaluate potential threats (severe drying, habitat loss, reduced water quality, etc.) for their severity in the context of species extinction risk; and (*iii*) provide a preliminary investigation of the efficacy of alternative species management options for the species, including metapopulation management, augmentation, and salvage.

The simulations indicate that reproductive output of those individuals just shy of one year old entering their first spawning season – hereafter referred to as Age 0 fish – is a primary factor that determines the extent of population growth from year to year. This reproductive rate, as defined in our analysis, includes both egg production and larval / juvenile survival rate to the next year’s spawn.

Additionally, the PVA suggests that severe drying (defined here as at least about 2/3 of the Middle Rio Grande becoming dewatered in a given year, leading to roughly equivalent levels of minnow mortality) can have significant effects on the long-term growth dynamics of minnow populations. The frequency of such an event is likely to be a more important factor in determining overall impacts than the severity of any single event. Similarly, events that dramatically reduce water quality in a given reach can also have significant effects on local populations, with frequency of occurrence likely to be the primary factor in determining overall long-term impact of the event.

The highly variable nature of silvery minnow demographic rates over time makes local populations (i.e., reaches) prone to extinction – even under expectations of long-term demographic stability. This risk increases markedly with decreasing long-term population size. Dispersal of minnows between reaches could be viewed as a mechanism for increasing population viability. However, because of the one-way nature of dispersal in the fragmented Middle Rio Grande, downstream dispersal can have a positive impact only on the lower reaches of the river. In other words, this benefit to downstream reaches may come at a cost to the upstream “source” reaches that cannot be replenished by natural dispersal in the opposite direction.

Augmentation as a population management strategy can lead to marked improvements in long-term minnow population dynamics. The extent of this improvement, however, is critically dependent on the survival rate of those introduced individuals to the next year's spawning season.

Discussions during the PHVA workshop led to the derivation of a number of additional scenarios to be evaluated in continued application of the PVA methodologies following the conclusion of this workshop. Most of these scenarios involve predicting the demographic consequences of specific alternative water management strategies along the Upper and Middle Rio Grande River. The results of these analyses, to be conducted during the first half of 2008, will be reported elsewhere.

Goals for Management

Shown below is a prioritized list of the top goals identified by each working group, presented in a plenary session on Day 3 of the workshop and then evaluated independently by the entire body of participants. The prioritization was based on each participant's perception of the importance of achieving these goals for successful management of the silvery minnow in the Middle Rio Grande.

1. Provide an adequate and secure long-term water supply in the Middle Rio Grande to allow the silvery minnow to complete its life cycle.
2. Use a combination of available water and operational flexibility to meet the short-term management needs of the species.
3. Define the parameters of trust and accountability among Middle Rio Grande Endangered Species Collaborative Program members and determine the parameters by which that definition is violated.
4. Maintain and improve silvery minnow habitat in order to maximize rates of recruitment and survival.
5. Agree to and distribute common vision and mission statements for the Collaborative Program that can then be articulated by ALL participants.
6. Continue to move long-term management of silvery minnow to an ecosystem-wide approach.
7. Develop a Technical Program Assessment (TPA) process that synthesizes data, provides for interdisciplinary discourse resulting in future action recommendations and measures progress; internal and external components to be considered.
8. Synthesize information on ecosystem, human population, habitat, water, land use, and climate change to develop projections of future trends in order to implement adaptive management strategies.
9. Manage silvery minnow populations in their native habitat in order to minimize the risk of extinction
10. Improve habitat connectivity within and between reaches in the Middle Rio Grande.
11. Maximize legal and institutional flexibility to more effectively manage the species for short-term sustainability.
12. Create institutional buy-in and Collaborative Program follow-through to manage for short-term species sustainability.
13. Develop opportunities and incentives for municipal water users to contribute conserved water back to the Middle Rio Grande.
14. Develop more multi-organization projects that require collaboration to complete successfully (vs. single organization projects).
15. Increase Collaborative Program resources (such as money, dedicated staff) that are focused on accomplishing the Program's outreach goals.

The very existence of a working group dedicated to issues of communication and collaboration, along with the recognition of trust and accountability as important elements of success in a complex species management program, provide a testament to this workshop process achieving its goal of interdisciplinary dialog and problem-solving for collaborative biodiversity management.

The action steps constructed by each working group, tied to the goals specified within their own deliberations (and, where appropriate, for those goals classified as high priority overall in plenary), are to be found in each of the individual working group reports within this full PHVA Report. Throughout the action development phase of this workshop, the facilitator emphasized the importance of identifying specific details for each action including who will be responsible for implementing the action (or directing its ultimate completion), realistic timelines, and collaborations necessary for its successful implementation.

By combining the use of rigorous scientific analysis of biological data with thoughtful and structured discussion of the needs of diverse stakeholder domains, the Rio Grande silvery minnow PHVA workshop was a valuable tool for natural resource management priority-setting in the Middle Rio Grande. Those involved in its organization and implementation hope that it will serve as a model for responsible endangered species conservation planning elsewhere in the region.

Rio Grande Silvery Minnow
Population and Habitat Viability Assessment

Section II
Preliminary Population Viability Analysis for the Rio Grande Silvery Minnow

Preliminary Population Viability Analysis for the Rio Grande Silvery Minnow (*Hybognathus amarus*)

Report prepared by:
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IUCN / SSC Conservation Breeding Specialist Group

In collaboration with

Members of the
Rio Grande Silvery Minnow Biology Working Group,
Middle Rio Grande Endangered Species Collaborative Program

Preliminary Population Viability Analysis for the Rio Grande Silvery Minnow(*Hybognathus amarus*)

Philip Miller, Conservation Breeding Specialist Group
and
Rio Grande Silvery Minnow Biology Working Group,
Middle Rio Grande Endangered Species Collaborative Program

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Philip Miller, Conservation Breeding Specialist Group
and
Rio Grande Silvery Minnow Biology Working Group,
Middle Rio Grande Endangered Species Collaborative Program

Introduction

The Rio Grande silvery minnow (*Hybognathus amarus*) historically occupied approximately 3,862 river km (2,400 mi) in New Mexico and Texas. It was found in the Rio Grande from Española, New Mexico, down through Texas to the Gulf of Mexico (Bestgen and Platania 1991). It was also found in the Pecos River, a major tributary of the Rio Grande, from Santa Rosa, New Mexico, downstream to its confluence with the Rio Grande in Texas. Currently, the Rio Grande silvery minnow is believed to occur in only one reach of the Rio Grande in New Mexico, a 280 km (174 mi) stretch of river that runs from Cochiti Dam to the headwaters of Elephant Butte Reservoir. Its current habitat is limited to about 7 percent of its former range. The species was listed as federally endangered in 1994 (59 FR 36988, 36995).

Human settlement in this region, followed by increasing demands for available water, has altered the normal hydrologic and ecological processes in the Rio Grande. Ongoing drought in this area of the United States has exacerbated these problems still further. As a result, the long-term persistence of endangered species such as the Rio Grande silvery minnow will likely be compromised to a greater degree.

Population viability analysis, or PVA, can be an extremely useful tool for investigating current and future risk of Rio Grande silvery minnow population decline or extinction. The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in managing silvery minnow populations in its wild habitat. *RAMAS METAPOP*, a simulation software package written for population viability analysis, was used here as a vehicle to study the interaction of a number of silvery minnow life history and population parameters, to explore which demographic parameters may be the most sensitive to alternative management practices, and to begin testing the effects of selected management scenarios. This package has undergone rigorous testing since its introduction more than a decade ago, and is highly-regarded as a realistic and competent platform for conducting credible analyses of wildlife population processes.

The *RAMAS* package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. *RAMAS* 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 recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms.

PVA methodologies are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed et al. 2002; Ellner et al. 2002; Lotts et al. 2004). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. Interpretation of this type of output depends strongly upon our knowledge of Rio Grande silvery minnow in its habitat, the environmental conditions affecting the species, and possible future changes in these conditions.

The *RAMAS* system for conducting population viability analysis is a flexible and accessible tool that can be adapted to a wide variety of species types and life histories as the situation warrants. This makes it a trusted method for assisting in the definition of practical wildlife management methodologies. For a more detailed explanation of the program and its use in population viability analysis, refer to Akçakaya (2005).

Specifically, we were interested in using this preliminary analysis to address the following questions:

- Can we build a series of simulation models with sufficient detail and precision that describe the dynamics of Rio Grande silvery minnow with reasonable accuracy?
- What are the primary demographic factors that drive growth of silvery minnow populations?
- What are the predicted impacts of severe drying on silvery minnow populations?
- What are the predicted impacts of a water quality event on silvery minnow populations?
- How vulnerable to extinction are small, fragmented silvery minnow populations under current management conditions? How small must a population become to increase its risk of extinction to an unacceptable level under conditions of minimally acceptable population growth?
- What is the impact of dispersal on the viability of source and recipient reaches?
- How effective can augmentation of silvery minnow individuals be as a long-term population management strategy?
- How effective can salvage of silvery minnow individuals be as a long term population management strategy?
- Which water management strategies work best towards the goal of increased viability of silvery minnow populations?

Baseline Input Parameters for Stochastic Population Viability Simulations

The biological information used to develop demographic input for these PVA models comes from a variety of published and unpublished sources. Of greatest relevance to this process is the series of meetings involving members of the Rio Grande Silvery Minnow Biology Working Group and associated invited guests. This group was composed of representatives from a number of diverse agencies and other interested parties, including:

- US Fish & Wildlife Service
- US Army Corps of Engineers
- Interstate Stream Commission
- New Mexico Department of Game & Fish
- The Offices of Senators Jeff Bingaman and Pete Domenici
- City of Albuquerque
- American Southwest Icthyological Researchers
- US Bureau of Reclamation
- US Bureau of Indian Affairs
- Santa Ana Pueblo SWCA
- Environmental Consultants
- University of New Mexico

Through five days of discussions spread across three meetings, and dozens of electronic messages distributed in the intervening periods, this group provided and evaluated data and information in an open and productive process. As a result, while some differences of opinion remain concerning the interpretation of selected elements of the data, and while significant gaps in our definitive knowledge of the species' biology remain, the information discussed below represents an effective consensus regarding our collective understanding to date of Rio Grande silvery minnow demography and population ecology.

Structure of Demographic Information Used in PVA

The analysis discussed here employs an age-structured matrix model of silvery minnow demography, with input data on age-specific fecundity and survival rates based on an assumed pre-breeding census methodology. The matrix that describes these demographic rates, known as a Leslie Matrix, is algebraically combined with a description of this year's population to project the size of that population in the next year. Specifically, if we assume that a species lives until just beyond two years of age, we can describe one year's change in population size algebraically by:

$$\begin{bmatrix} N_0(t+1) \\ N_1(t+1) \end{bmatrix} = \begin{bmatrix} F_0 & F_1 \\ S_1 & 0 \end{bmatrix} \begin{bmatrix} N_0(t) \\ N_1(t) \end{bmatrix}$$

where $N_0(t+1)$ and $N_0(t)$ are the numbers of individuals in age class 0 (here, 0 – 12 months) at time (t+1) and (t), respectively; F_0 is the fecundity of age 0 individuals (defined here as the average number of offspring that are produced by individuals in age class 0 and are censused at the next time step); and S_1 is the survival rate of individuals in age class 1 (i.e., the proportion of individuals that survive from 12 months to 24 months of age). Note that the Leslie matrix value in the lower-right corner is automatically set to 0 because, in this case, we assume that individuals do not live to see their third birthday. Therefore, survival rates beyond 24 months of age are 0.0.

The process of developing input data for the PVA revolves largely around the estimation of the fecundity and survival rates that define the Leslie matrix. Moreover, it is important to remember that we are assuming that these age-specific demographic rates are not static in time, but instead fluctuate randomly from one year to the next in response to changes in the environment within which the minnow lives. Consequently, in addition to estimating mean rates of birth and survival we must also try to assess the degree to which these rates fluctuate through time.

We opted to construct a matrix model for the Rio Grande silvery minnow that includes only females. This is a rather common approach in the matrix-based analysis of wildlife populations in which there are few if any measurable differences in demographic behavior between males and females. With this formulation, we are interested only in the number of female offspring produced by a given adult female, and only in the survival rates of female fish in each age class. This approach simplifies the overall computational structure and also reduces the number of required variables and, more importantly, their measurement uncertainty.

Finally, we assume here that only two age classes are required to realistically describe the demographics of the silvery minnow. Specifically, we define <u>Age 0</u> fish as those that are produced immediately after the preceding census and live to the next census when they are counted as just under 12 months old. Additionally, we define <u>Age 1</u> fish as those that are 12 months old in the current census and survive to be counted again in the next census as just under 24 months old. We further assume that both Age 0 and Age 1 fish produce offspring, with the Age 1 fish dying soon after their second annual spawn and, therefore, failing to reach the next census as 36 months old. There was a proposal put forth by some PVA workshop participants that some number of minnows live to be as old as four or five years of age. In our initial analysis of this proposal, and given our survival estimates for younger fish (see below), we concluded that the total number who would reach this age are so few as to be of very limited demographic value. Initial matrix analyses with the inclusion of these older age classes (which are not presented here but can be obtained from the lead author of this report) confirms this expectation. Based on this logic, and in the interest of maintaining a manageable level of simplicity in the model (particularly in the context of the paucity of demographic data available for older fish that may be present in the river), we retained the initial structure of two age classes for all further analyses.

Age-specific fecundity rates

Based on how fecundity is defined in our matrix approach – namely, the average number of offspring that survive to the next census period that are produced by an individual female of a given age class – our definition of this parameter is slightly more complicated than what might be apparent at first glance. In particular, we must account for those individuals that are "born" to a given female during the reproductive event that occurs just **after** the current pre-breeding census – this is referred to as *maternity* – as well as the survival of those newborns until the next census, just under one year from the present. In other words, our definition of age-specific fecundity is

$$F_0 = m_0 S_0$$
$$F_1 = m_1 S_0$$

where m_0 and m_1 are the maternity values (specifically, the number of female eggs) for Age 0 and Age 1 fish, respectively, and S_0 is the survival rate of those newborns to one year of age (i.e., the next census). We assume here that the survival of newborns to one year of age is independent of their mother's age. In the calculations that follow, we assume that very close to 100% of all reproductively capable females do in fact spawn.

Data from experiments conducted by C. Altenbach and S. Platania (American Southwest Icthyological Researchers) in May – June 1994 were used to estimate maternities. In these experiments, gravid females were collected and treated with hormones and then introduced to males. The number of spawning events and the total number of eggs was counted, with up to 30 females used in each trial. The length of each adult female was measured and, using established length – age relationships, each fish was assigned to one of the two age classes. The total number of eggs from each female is tabulated below.

Age Class (x)	Mean # eggs (SD)	Females produced (m_x)
0	1316 (582)	658
1	2961 (826)	1480.5

Note the larger maternity for larger (older) females, as is expected. Since we assume no skewed sex ratios among clutch of eggs, we can simply halve the total number of eggs in order to estimate the number of female newborns produced per adult female.

J. Remshardt (US Fish & Wildlife Service) attempted to estimate survival of Age 0 fish to 12 months of age. Specifically, data were collected from Angostura Reach on a monthly basis from June 2004 to the following May 2005. His observations led to an estimated survival rate of newborns across this period of 0.00832 or 0.8%. However, this accounts for only a part of the full 12-month period; the first app. 45 days of life from spawning to the beginning of Remshardt's observation period are not included in this numerical estimate. Unfortunately, the small size of the individuals in this very early period and the difficulties associated with studying them in detail makes it very difficult to make a confident estimate of this parameter. Discussions among Biology Working Group members led to the acceptance of a 10% mean survival rate for this early period. Taken together, we therefore estimate the total survival rate for silvery minnows through their first year as 0.00083. The fecundity values then become (658)(0.00083) = 0.547 for Age 0 fish, and (1480.5)(0.00083) = 1.229 for Age 1 fish.

Survival from Age 0 to Age 1 classes

To calculate matrix parameter S_1, we relied primarily on field data collected by J. Remshardt in a mark-recapture study of stocked fish conducted in 2004 – 2005. A monthly survival estimate of 0.662 was calculated through the period of study, which was not a full year in the field. From this observation, and assuming a constant rate of monthly survival throughout the year, we estimate the survival of individuals (females) age 12 months to age 24 months as

$$S_1 = (0.662)^{12} = 0.007.$$

In addition to this estimate, we discussed the technique employed by M. Hatch (SWCA Environmental Consultants) using observations of salvaged fish. Hatch estimated the age class distribution of fish collected in salvage operations and, using these frequency data, was able to calculate an expected survival rate that would most likely give rise to the observed distribution of individuals in the two different age classes. This estimate was equal to 0.09. While both methodologies are reasonable approaches to estimating survival rates, the meeting participants reached consensus that, due in large part to the likely complexities of relying on salvaged fish (that may be significantly different in their overall characteristics compared to the larger pool of individuals within a given age class) for this type of analysis, the mark-recapture data derived using a more representative sample of the entire age class would likely provide a more reliable estimate of Age 1 survival rate. It may very well be reasonable to expect the value derived by Hatch to be more of an upper bound on survival.

Sources of variability in demographic rates

Annual environmental variation (EV) in demographic rates is modeled in *RAMAS* by specifying a standard deviation (SD) that is applied each year to the base rates in order to simulate fluctuations due to extrinsic factors (both natural and anthropogenic) in the environment within and near the Middle Rio Grande. Specifically, we used a lognormal distribution of demographic rates over the period of the simulation, using the specific extent of environmental variation as the standard deviation of the distribution. The lognormal distribution is often a more accurate reflection of random variability in demographic rates, and often reduces truncation bias when describing rates bounded by 0 and 1.0.

Unfortunately, the methods to arrive at mean estimates of Rio Grande silvery minnow fecundity and survival described in the preceding section are effectively only "snapshots" of data within a short time period – often over a single year (spawning season). In the general case, while there may be relatively more data on, for example, the *spatial* nature of variance in demographic rates, there is no way to estimate the *temporal* variation in these same rates from just one year of data. Instead of trying to accurately assign a particular level of environmental variability to fecundity and survival rates in the absence of appropriate data, we took a more exploratory approach to this facet of silvery minnow population biology. More precisely, we used a sensitivity analysis methodology to investigate the impact of systematic changes in EV on overall model performance. To accomplish this, a range of plausible values for EV in both fecundity and survival rates were calculated by computing coefficients of variation (CV, defined as standard deviation divided by mean value) for each rate that varied from 10% to 50%. For example, if we assume CV = 10% our two estimates of EV in fecundity (given mean values for Age 0 and Age 1 fish of 0.547 and 1.229, respectively) would be 0.0547 and 0.1229 for Age 0 and Age 1 fish, respectively. The same degree of variability would be calculated for the survival parameter S_1. Furthermore, we assume in all our models that EV for fecundity and survival will be correlated within a year; in this way, the model draws only a single random normal deviate for a population and applies that same deviate to each demographic rate.

In addition to environmental variability, our simulations include demographic stochasticity. This factor describes the uncertainty within a given year that arises when applying birth and death rates to a population that must be described in whole numbers (e.g., you cannot have 1.2 offspring per female, but only 1 or 2 offspring). This source of uncertainty is most important when populations become quite small, when such uncertainty can have major impacts on rates of fecundity or survival. To simulate demographic stochasticity in *RAMAS*, the number of survivors for the *i*th age class is drawn from a binomial distribution with parameters S_i (survival rate) and $N_i(t)$ (as sample size). The number of young produced by the *i*th age class is then drawn from a Poisson distribution with mean $F_i(t)N_i(t)$.

Initial population size

In order to construct a meaningful PVA model, we must derive even a crude estimate of population size so that we can evaluate the impact of predicted growth dynamics that emerge from our Leslie matrix analysis. We must therefore assess the relevant information available to us and decide on a productive course of action.

The best data we have at our disposal to begin estimating the Rio Grande silvery minnow population size is the data on catch per unit effort, or CPUE, that has been collected since the early 1990s by S. Platania and R. Dudley. There are some concerns with using data like these for the purpose of estimating total population size – both within the silvery minnow management group and in the broader population biology community (see, for example, Maunder et al. 2006). We can acknowledge these concerns and use this preliminary analysis to stimulate further discussion towards a more robust evaluation of the size of the silvery minnow populations and an estimate of the recent trend in numbers.

We started by using the October 2006 mean estimate for silvery minnow CPUE in the Middle Rio Grande, namely 1.4 individuals / 100m^2. In order to transform these data to an estimate of population size for each reach of the river, we had to make the following assumptions:

1. The sex ratio among those individuals captured as part of the CPUE effort is 50:50.
2. The habitat for silvery minnows is uniformly distributed throughout the length and breadth of each reach. In effect, we are assuming for this initial estimate that the morphology of the Middle Rio Grande is akin to a channel with constant width and depth from north to south.
3. Silvery minnows are evenly distributed throughout this channel-like habitat.
4. At this stage of model development, the model does not specifically include water-management induced changes in channel area resulting from changes in flows.

With the exception of (1.) above, each of these assumptions are over-simplifications of the true system and, therefore, introduce errors into a truly accurate description of the river system and its management. It is important to remember, however, that at this stage of the larger analysis we are interested in deriving models that provide us with comparative (relative) measures of population performance under different assumptions, as defined by alternative model input datasets. The assumptions listed above provide a robust framework for such comparative analyses.

With these assumptions in place, we simply estimate reach-specific population size by multiplying the CPUE (effectively, a density) by the measured length and average width of each reach, remembering to divide by 100 given the units used to measure CPUE. Finally, we must reduce this size estimate by 50% as we are modeling only females. The results of this analysis are presented in the table below.

Reach	Length (m)	Average Width (m)	N_{Total}	$N_{♀♀}$
Angostura	65,000	182	165,600	82,800
Isleta	85,500	161	192,700	96,350
San Acacia	92,000	182	234,400	117,200

Additional efforts will be directed towards improving our understanding of habitat heterogeneity within each reach, and deriving functional relationships between hydrologic parameters influenced by water management and silvery minnow demography. Through these expanded efforts, we will be able to come up with a more accurate estimate of total population size and a more realistic framework to explore alternative water management scenarios.

Density dependence and habitat carrying capacity

The regulation of one or more demographic rates by density is a nearly universal phenomenon among wildlife populations. Birth and/or survival rates can be reduced when density increases to a point where competition for space or resources becomes critical; at the other extreme, very low population densities can lead to a reduction in breeding rates simply because individuals of the opposite sex have difficulties in finding each other to mate (known as the Allee effect). Therefore, a proper PVA must include at least some form of density-dependent regulation of vital rates (see Morris and Doak (2002) and references therein for more information on this topic).

At the present time, no studies exist that explicitly investigate density dependence in silvery minnow vital rates. We must therefore rely on information from other species and expert opinion to derive some form of relationship. In the interest of simplicity here in our initial model, we assume that Allee effects are not present, and we will also assume that processes operating at high densities are most easily explained by a ceiling model of density dependence. Under the ceiling type of density dependence, the population grows exponentially until it reaches the ceiling, also known as the carrying capacity K (e.g., until all available habitat is occupied), and then remains at that level. For large population sizes, the population size at t+1 is a constant function of the population size at t. A population that reaches the ceiling remains at that level until a population decline (e.g., a random fluctuation or an emigration) takes it below the ceiling.

After numerous discussions among Working Group members on this issue, spanning multiple meetings, a consensus was reached on a process for simulating carrying capacity throughout the Middle Rio Grande with an acceptable degree of accuracy. Over the past 15 years of observation, the maximum density calculated from CPUE data is approximately 40 fish / $100m^2$. It is possible that this density may be even higher in a single year, although the likelihood of achieving such high densities is relatively small. More reasonably, we might expect the long-term maximum to be on the order to 30 fish / $100m^2$, with some degree of variability around this value to simulate changes in local environmental conditions such as water availability (annual levels of river drying not labeled as "severe": see below), predator or competitor densities, etc. Using this logic, we set the average maximum density at 30 fish / $100m^2$ with annual variability expressed in terms of a standard deviation in this density equal to 10 fish / $100m^2$. Using this range of densities, and applying them to the reach-specific morphology data given above, we arrive at the following estimates for reach-specific carrying capacity:

Angostura: 1,775,000 ± 394,000
Isleta: 2,065,000 ± 459,000
San Acacia: 2,512,000 ± 558,000

The variability around reach-specific carrying capacity is described by a normal distribution with mean K and the standard deviation specified above.

Simulating External Impacts on Silvery Minnow Population Demography

Severe drying event

As stated above, "normal" levels of variability in annual estimates of habitat carrying capacity are in part attributed to comparatively lower levels of annual drying throughout the Middle Rio Grande. Periodically, however, there will be much more severe levels of drying due to natural environmental processes such as low rainfall, possibly combined with water management strategies in the same year that lead to very low levels of water availability. To capture this additional element of variation, the Working Group identified severe drying as an event that could be labeled as a "catastrophe": an event with comparatively low probability of occurrence but with the potential for significant demographic impact in any given year. Because we want to be able to look at the long-term dynamics of each reach separately, in addition to analyzing the composite Middle Rio Grande, we discussed development of reach-specific multiplicative factors that describe the impacts of such an event on silvery minnow fecundity and/or survival.

We have defined a severe drying event to be one with characteristics similar to that which occurred in 2003, where a total of 70 miles of river between Isleta Dam and Elephant Butte Reservoir (64% of the 110 total miles) dried. In the absence of specific data on this issue, we simply assume that every mile of river that dries results in a 1% decline in silvery minnow abundance throughout the reach of interest. [Note that this assumption will be explored further in subsequent refinement of the model.] Therefore, we assigned a 64% decline in silvery minnow abundance in the Isleta and San Acacia reaches during the severe drying event. For the Angostura reach, we assume that drying would occur but at a lower severity as the river would remain connected more readily through its reduced width. We do not have specific data to apply to a precise estimate of the amount of drying. Expert opinion based on experience and qualitative observation resulted in an estimated 20% decline in abundance in the Angostura reach during a severe drying event. Finally, we assumed that such an event would be expected to occur approximately once every ten years. We have observed the 2003-type event once in a six-year period, but are unwilling to consider this to be representative of a long-term estimate of probability of occurrence. A long-term expected probability of 10% for each reach was considered to be more realistic. The severe event was expected to be classified as regional, i.e., each reach would experience the severe event in the same year.

Water quality event

This event was defined as, most likely, a release of a toxic chemical that would lead to significant loss of fish immediately after the release of the chemical into the river. We focused our attention on the release of chlorine from the industrial areas around Albuquerque, as some data are available on the frequency and impact of such an event and it seems to be representative of the type of event intended to be investigated using this process. With this in mind, and because of the highly localized nature of these events, we assume that the impacts of a water quality event will be restricted to the Angostura reach.

Analysis by Working Group members of recent significant chlorine releases into the Rio Grande near Albuquerque (unpublished data available from USFWS personnel) indicate a rough average periodicity of about five years between releases. Using this information, we assumed an average probability of occurrence of 20% in a given year. With regards to the severity of such an event, Working Group members consider an event of this type would lead to local extermination (i.e., 100% mortality) of fish within close proximity of the event. However, members also assumed that the impact would dissipate quickly away from the point source of the event. Taken together, we assume that an event akin to a chemical spill would lead to a 33% reduction in abundance across the entire length of the Angostura reach.

The Middle Rio Grande as a metapopulation: Dispersal rates between reaches
Although the three reaches of the Middle Rio Grande are separated by diversion dams, there will inevitably be some small level of movement of individuals from one reach to another. More specifically, because of the morphology and dynamics of the river itself, we expect all movement of relevance to this PVA to be downstream and to occur largely between neighboring reaches.

In a 2002 study of silvery minnow movement conducted by S. Platania, nearly 12,000 VIE tagged fish were released into the San Acacia reach in early January. He was later able to collect a total of 66 fish in the period February – May and found that a small number of these fish traveled as far as 25km, while the majority of them stayed with 1 – 5km of the release site. While this study suffered from a few unavoidable complexities, including a major drought in 2001 – 2002 that made conditions in the river more problematic for the purposes of the study, that led to extremely low recapture rates of marked fish, the information obtained sheds some light on the issue of dispersal capability in Rio Grande silvery minnow.

We assume that there is some level of downstream dispersal, although the Platania study above is not adequately designed to accurately determine rates of dispersal among nearby reaches. Given this data deficit, we devised a basic range of plausible (and perhaps upper-end) dispersal rates that ranged from 0.5% to 1.5% between neighboring reaches. These percentages refer to the average proportion of the population that is expected to disperse from one reach to the neighboring downstream reach in a given year. In addition, we assumed that dispersal between the Angostura and San Acacia reaches was only 33% that of the rate between neighboring reaches. For example, if the rate between neighboring reaches is set at 1.0%, then the rate between Angostura reach and San Acacia reach is 0.33%. We did not include any source of environmental variability in annual dispersal rates.

Iterations and years of projection

All stochastic population projections (scenarios) were simulated 1000 times. Each projection extends to 50 years, with demographic information obtained at annual intervals. All simulations were conducted using *RAMAS METAPOP* version 5.02 (2007).

Results from Simulation Modeling Analysis

A summary of baseline model results: Implications for subsequent model parameterization

Based on the above discussion of input data used in constructing our first PVA models for the silvery minnow, we can construct the following basic Leslie age-specific transition matrix for the Rio Grande silvery minnow:

$$\begin{bmatrix} 0.547 & 1.229 \\ 0.007 & 0.000 \end{bmatrix}$$

The above matrix is used when we assume a lower bound on S_1, the survival of fish from 12 to 24 months. When we assume the upper bound survival for this parameter, our matrix changes to:

$$\begin{bmatrix} 0.547 & 1.229 \\ 0.090 & 0.000 \end{bmatrix}$$

We can conduct a deterministic analysis of this matrix – assuming no random variability in demographic rates or density dependence – in order to calculate the annual rate of growth of the population, often designated as λ. The estimate of growth rate of a population is a useful metric to assess the consequence of the various matrix elements and their interactions (although, because of the deterministic nature of the analysis, λ is an inadequate and often misleading metric when applied to the assessing of risk of population decline or extinction in the presence of demographic variability in the long term).

Using this analysis, the population growth rate λ is estimated to be 0.561 when the lower S_1 value is used. This means that, on average, the population is expected to decline deterministically by more than 40% annually. This is, of course, a rapid rate of population decline and is entirely unsustainable. When the larger value of S_1 is used, the growth rate increases to $\lambda = 0.703$ – but the overall trend remains highly negative with a nearly 30% rate of population decline expected annually.

While it is important to remember that these growth rate estimates must be interpreted with great caution from the standpoint of determining a meaningful risk estimate, it is also worth noting that the inclusion of stochastic elements into the model, such as environmental variability and density dependence through carrying capacity, will only serve to decrease mean λ in the long term. With this in mind, it is instructive to reflect on the meaning of these initial results in the context of what one predicts from larger-scale observations of trends in population size on the Middle Rio Grande. In other words, do these growth rate estimates seem to accurately reflect what we think is happening on the river itself? If not, then we must revisit either our gross observations of long-term population trends, or our estimates of baseline demographic rates calculated from field data. Nevertheless, it is perhaps most critical to remember that, despite the exact numerical results one can obtain from any single modeling scenario, the true value of PVA methods lies in its ability to facilitate comparative analysis of alternative scenarios in order to make more informed decisions about how to manage wildlife populations in the face of oftentimes considerable uncertainty.

With this preliminary analysis as a backdrop, we attempted to make some statement on the trend in silvery minnow population size throughout the period of time (1993 – 2007) in which data on catch per unit effort, or CPUE, were collected. Our goal was to use this analysis to put our initial demographic analysis in context, and to provide some rationale for how to best proceed with the construction of additional PVA models that could be used to guide future species management more effectively.

A preliminary analysis of historic Rio Grande silvery minnow population trends

In the course of preparing this PVA, members of the Biology Working Group and other experts agreed that it would be valuable to make an attempt at using the population monitoring data collected since 1993 to infer a trend in the total size of the minnow population in the Rio Grande, and to use this trend analysis to derive a crude estimate of the population growth rate, λ. Such an estimate could provide a more accurate starting point for the PVA in the context of understanding what types of management strategies should be employed to minimize the risk of additional population decline, and the intensity with which those strategies should be pursued (given the assumption that a specific biologically-based management strategy is designed to increase λ).

It should be recognized, however, that the use of these population monitoring data, often presented in the form of catch per unit effort or CPUE, for the purposes of estimating population size is controversial (e.g., see Maunder 2006). While there may be difficulties involved in the interpretation of CPUE data, the intention here is to present a starting point for discussion of the means by which these data can be interpreted more effectively and, therefore, can be made more valuable for conservation management planning.

CPUE data were obtained from silvery minnow population monitoring reports prepared by Steven Platania and Robert Dudley. Graphical depiction of annual October CPUE data from 1993 to 2007 were used to derive numerical estimates of minnow density (number of fish / 100m^2) across the areas sampled.

Table 1. Census estimates for silvery minnow in the Middle Rio Grande based on catch-per-unit-effort (CPUE) reports. Raw CPUE data transformed to total census estimate through multiplying by total Middle Rio Grande reach length = 242.6 km and average river width = 150m.

Year	CPUE (fish / 100m2)	Census estimate
1993	14.452	5,259,083
1994	15.285	5,562,212
1995	26.078	9,489,784
1996	1.400	509,460
1997	13.916	5,064,032
1998		
1999	6.289	2,288,567
2000	0.208	75,691
2001	0.814	296,215
2002	0.080	29,112
2003	0.025	9,098
2004	0.858	312,226
2005	36.990	13,460,661
2006	1.378	501,454
2007	10.847	3,947,223

In order to transform these density data to crude estimates of total population size, annual CPUE values were multiplied by the total stretch of the Middle Rio Grande reach, defined as the sum of the distances defining the Angostura, Isleta, and San Acacia reaches (65.0 km + 85.5 km + 92.1 km = 242.6 km), as well as by a (very) crude estimate of the average width of the Middle Rio Grande, defined here as 150m.

It is important to remember here that precise estimates for the length and width of the Middle Rio Grande are not important from the standpoint of evaluating the relative change in total census number from one year to the next – as long as the same transformation is used for each datapoint in the time period of interest. This allows for some greater flexibility in the use of CPUE data for estimating population growth parameters. The raw and transformed data are presented in Table 1 above.

These data were then plotted, and non-linear regression was used to fit an exponential growth curve of the form

$$N_t = N_0 \lambda^t$$

where N_t = population size estimate at time t, N_0 = population size estimate at time $t = 0$, λ = annual rate of population growth, and t is time in years. In our regression, N_t is the dependent variable and t is the independent variable. Values for $\lambda > 1.0$ indicate a population that is increasing in size, while $\lambda < 1.0$ indicates a population that is decreasing in size.

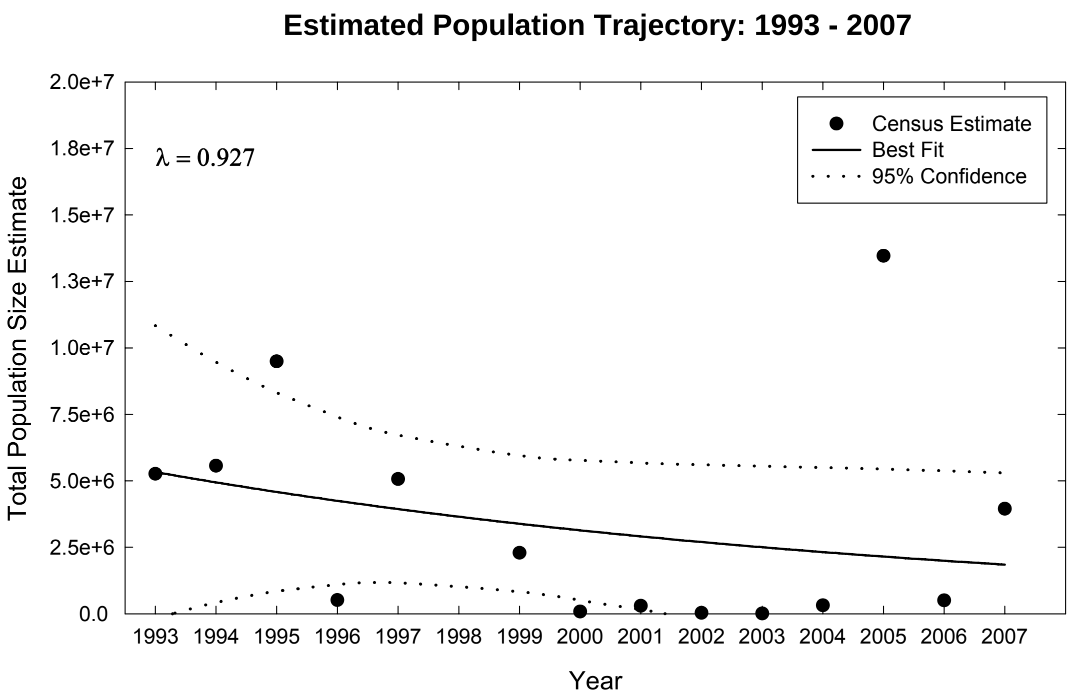


Figure 1. October abundance estimates for Rio Grande silvery minnow obtained from CPUE data. Statistical analysis of data suggest a long-term rate of population decline of approximately 7% annually (shown by best-fit curve), but high levels of variability in the data do not allow us to reject the alternative hypothesis of λ = 1.0 over the time period of data collection. See text for details of data transformation and analysis.

Statistical analysis of the full dataset suggests a long-term population decline of silvery minnow in the Rio Grande over the period of observation (Figure 1). Through the 14 years that make up this analysis, the growth rate λ is estimated to be 0.927. This equates to, on average, a 7% decline in population census each year through the period of study. Of course, there is considerable variability in this rate of growth from year to year. The high level of variance in the data, due most likely to both sampling variance inherent to the data collection procedures as well as environmental variability influencing minnow demographics from year to year, leads to rather wide confidence intervals in the statistical analysis of the CPUE data and, by extension, the total population size estimate. In fact, the 95% confidence intervals for this analysis include $\lambda = 1.0$; in other words, we are unable to reject the conclusion that the data show annual variability around a long-term mean growth rate of 1.0.

Based on our statistical analysis of abundance, and because of the inherent complexities surrounding the interpretation of CPUE data, and the relatively short period of observation of silvery minnow population fluctuation, we decided to adopt a baseline condition of stochastic $\lambda = 1.0$ for subsequent PVA models designed to investigate the impact of specific environmental conditions acting on the river currently, or the impact of alternative management strategies directed at minnow populations or habitat. This approach would facilitate the analysis of comparative or relative risk in deference to trying to estimate an absolute risk of minnow population extinction in the presence of considerable uncertainty around our knowledge of the current situation facing the species in its habitat. The means by which we derived this baseline condition are described in the next section.

Demographic sensitivity analysis

During the development of the baseline input dataset, it quickly became apparent that a number of silvery minnow demographic parameters were being estimated with varying levels of uncertainty. This type of measurement uncertainty, which is distinctly different from the annual variability in demographic rates due to extrinsic environmental stochasticity and other factors, impairs our ability to generate precise predictions of population dynamics with any degree of confidence. Nevertheless, an analysis of the sensitivity of our models to this measurement uncertainty can be an invaluable aid in identifying priorities for detailed research and/or management projects targeting specific elements of the species' population biology and ecology.

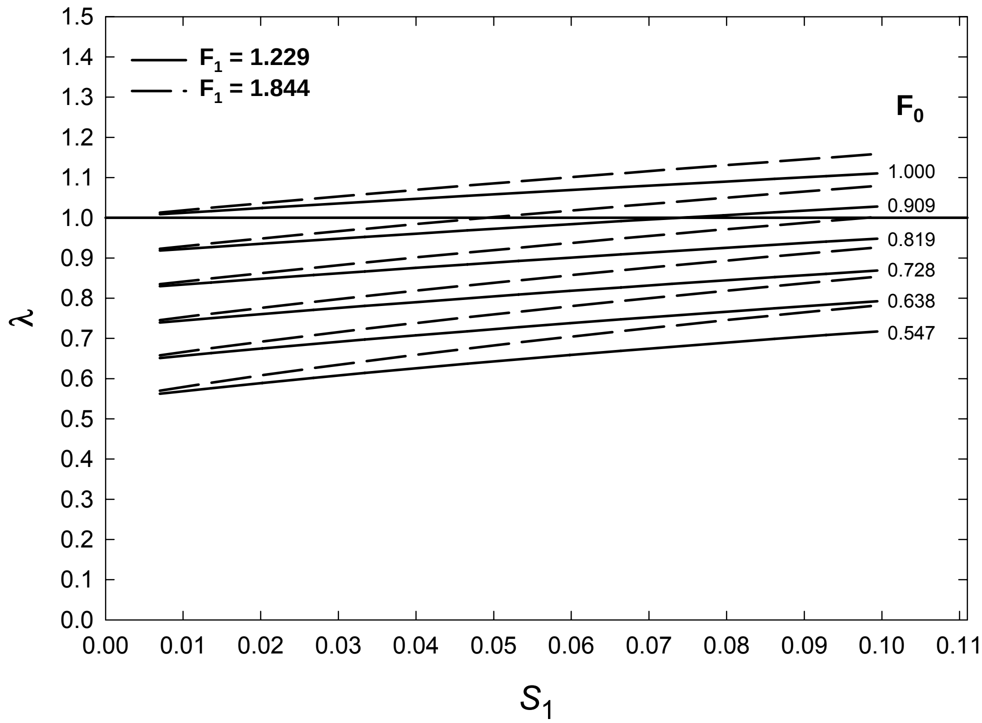
We focused our attention on each of the three nonzero elements of the basic Leslie matrix. Specifically, the fecundity of Age 0 fish (F_0) was varied from 0.547 to 1.000; fecundity of Age 1 fish (F_1) was varied from the baseline value of 1.229 to 1.844, equivalent to 150% of the original value; and the survival of Age 0 to Age 1 (S_1) was varied from the low estimate of 0.007 derived by Remshardt to a high estimate of nearly 0.010, close to the maximum estimate derived by Hatch's analysis of salvaged fish. Each parameter was analyzed individually, with the other two parameters held constant at their original baseline value.

The results of this analysis are presented in Figure 2. We can make the following observations from the data presented in this Figure:

1. When F_0 is set at 0.547 and F_1 at 1.229, varying S_1 across the full range of parameter values yields a 28% increase in λ, from $\lambda = 0.562$ at $S_1 = 0.007$ to $\lambda = 0.717$ at $S_1 = 0.0994$. This magnitude of change is consistent across all values of the other two matrix elements.
2. When S_1 is set at 0.007 and F_1 at 1.229, varying F_0 across the full range of parameter values yields a 79% increase in λ, from $\lambda = 0.562$ at $F_0 = 0.547$ to $\lambda = 1.009$ at $F_0 = 1.000$. This magnitude of change is also consistent across all values of the other two matrix elements.

3. Increasing F_1 from 1.229 to 1.884 shows a slight increase in λ, with a maximum extent of change seen at the largest estimates of S_1 (approximately a 4 – 9% increase in λ at S_1 = 0.994 across the range of F_0).

Figure 2. Population growth rate λ under a range of fecundity and survival values used in silvery minnow demographic sensitivity analysis. Survival of Age 1 fish (S_1) spans a range of about 14x, while fecundities of Age 0 and Age 1 fish (F_0 and F_1) spans ranges of about 1.8x and 1.5x, respectively. Largest change in λ occurs across range of values used for F_0. See text for further details of model construction and interpretation.



The graphical results portrayed in Figure 2 can be summarized more precisely in a formal analysis of the *elasticity* of the matrix we constructed for Rio Grande silvery minnow. Elasticity is defined as the proportional sensitivities of the finite rate of increase λ to small changes in individual matrix elements. They are measures of the contribution that each matrix element makes toward the calculation of λ for the Leslie matrix used by this particular population. With this definition, it is clear that matrix elements with larger elasticity values are primary drivers of population growth of the species of interest. It is important to remember that the elasticity values derived from the matrix do not take into account more complex elements of the demographic model, such as stochastic variance in mean demographic rates, density dependence in these rates, catastrophic variation, or the initial age distribution. As such, they are to be considered only approximate.

The elasticity matrix for our silvery minnow baseline model is

$$\begin{bmatrix} 0.947 & 0.027 \\ 0.027 & 0.000 \end{bmatrix}$$

As expected, the elasticity for F_0 is considerably larger than either of the remaining nonzero elements, effectively corroborating our graphical analysis. Remember that these elasticity values are approximate, i.e., the precise values are themselves a function of the underlying Leslie matrix values. Nevertheless, the relative magnitude of the elasticity values remains consistent, as does the overall message to be gleaned from this exercise.

Impact of environmental variability on population dynamics

We began our analysis of this aspect of silvery minnow population dynamics by creating a revised Leslie matrix that would result in a deterministic growth rate of very close to 1.000. This would then be our starting point for all subsequent analyses. The matrix giving this result is shown below.

$$\begin{bmatrix} 0.909 & 1.229 \\ 0.0796 & 0.000 \end{bmatrix}$$

With this matrix as our starting point, we imposed standard deviations on each of the nonzero elements, with coefficients of variation ranging from 10% – 50% of the mean values.

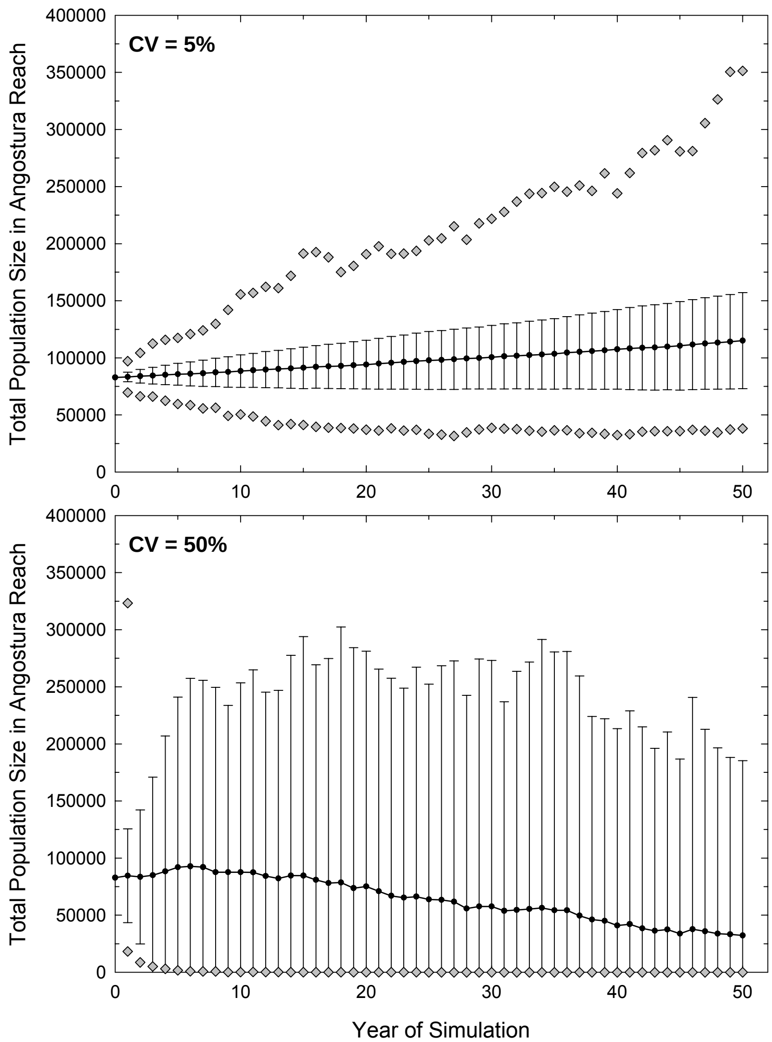
The results for analyses focused on the Angostura reach are presented in Table 2 and Figure 3. While only one reach is shown here for the sake of simplicity and brevity, the general trend and conclusion is the same for both the Isleta and San Acacia reaches; in fact, since Angostura is the smallest reach, and therefore subject to the greatest sensitivity to annual variability in demography, one can interpret these results as representing the maximum effect along the entire Middle Rio Grande. As the amount of environmentally-induced variability in demographic rates increases, the long-term expected growth rate also declines and, more importantly from the standpoint of risk assessment, the probability of extinction within this reach also increases.

Table 2. Impact of increasing levels of environmental variability in mean silvery minnow demographic rates, EV (expressed as coefficient of variation on fecundity and survival rates), in a simulated population inhabiting the Angostura reach. Population growth rate given by λ; $P(E)_{50}$ is the terminal extinction risk after 50 years within a given simulation. See text for additional information on model construction and interpretation.

EV (% of mean value)	λ	$P(E)_{50}$
0.0	1.006	0.000
10.0	1.006	0.000
20.0	1.003	0.000
30.0	1.001	0.000
40.0	0.992	0.013
50.0	0.981	0.065

Figure 3 graphically demonstrates the relationship between the extent of environmental variation and the long-term growth dynamics of a population subjected to these kinds of fluctuations. As EV rises, not only do we see a greater level of variability around the mean expected population size at any time during the simulation (as is to be expected), but we also see a reduction in the mean long-term population growth rate. In fact, in the highest levels of variability used as input to the model, the long-term λ flips from a value describing long-term growth (λ > 1.0) to a value describing long-term decline (λ < 1.0). This is a fundamental tenet of stochastic demography in small populations that has been discussed since the earliest days of the study of PVA (e.g., Goodman, 1987).

Figure 3. Simulated population projections for Rio Grande silvery minnow occupying the Angostura reach, under conditions of low (top panel) and high (bottom panel) levels of environmental variability (EV) in demographic rates. EV is expressed as the coefficient of variation, or the standard deviation divided by the mean value of a given demographic rate. Error bars give ±1 SD in population size, and gray diamonds indicate the minimum or maximum value of population size for each year of the simulation. See accompanying text for additional information on model construction and interpretation.



Another interesting way to look at the results of these models from a risk assessment perspective involves the construction of *terminal quasi-extinction curves*. These curves give the probability that the population of interest will fall below the range of threshold abundances at the end of the simulation. A curve of this type is shown in Figure 4 for the Albuquerque reach in the presence of low levels of environmental variation (CV = 0.05; see top panel of Figure 3). A simple analysis of long-term λ and mean final population size suggest that the population will increase in size over the duration of the simulation. However, the imposition of stochastic variability in demographic rates imparts a risk that the population will not increase in size over time and may in fact decrease. The communication of this risk is important when making decisions about alternative management procedures designed to reduce risk.

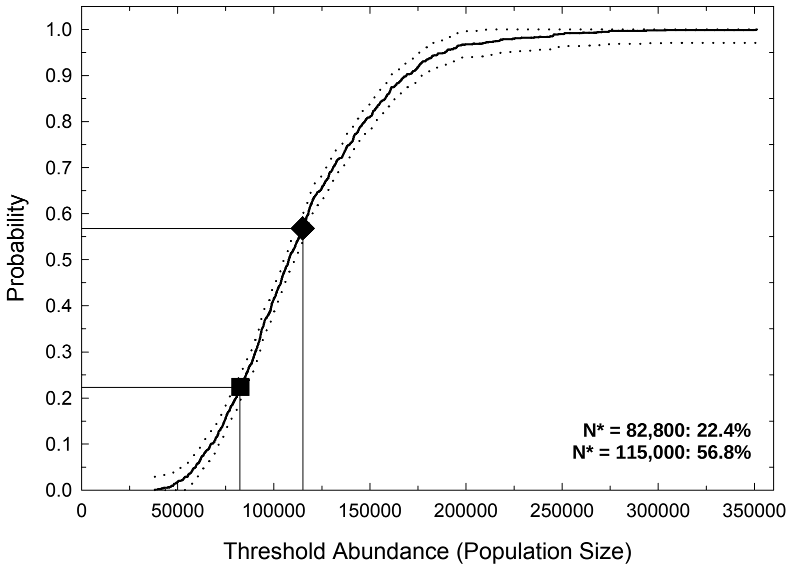


Figure 4. Terminal quasi-extinction curve (±95% confidence intervals) for simulated silvery minnow population in Angostura reach. Stochastic simulation included low levels of environmental variability (coefficient of variation CV = 0.05). The curve gives the probability that the population of interest will fall below the range of threshold abundances at the end of the simulation. Diamond symbol indicates mean final population size from simulation, while square indicates initial population size in the simulation. Corresponding quasi-extinction estimates are provided in the legend. See text for additional details of model construction and interpretation.

As seen in Figure 4, specifying the mean final population size from a stochastic simulation does not often tell the whole story. Specifically, the quasi-extinction curve shows us that there is almost a 57% chance that the final size of the simulated minnow population in Angostura reach under the specific conditions of the model will actually be below the listed mean. In other words, the distribution of final population sizes is not symmetric (or normally distributed). Furthermore we can see that, although the mean final size after 50 years is approximately 110,000 individuals, with a long-term average $\lambda = 1.006$, there is actually a 20% chance that the population will end up **smaller** than the original starting size of 82,800 fish. This type of analysis points out the often complex impact that random variability in species demography can have on population viability.

Although the depiction of quasi-extinction curves such as the one in Figure 4 is instructive, in the interest of clarity and simplicity we have chosen to restrict the display of model results to more direct metrics such as long-term growth rate, mean final population size, and risk of population extinction (defined here as the complete elimination of individuals from the simulated population). The reader that is interested in more detailed studies of quasi-extinction is encouraged to contact the primary author of this report.

Severe event analysis I: Impact of severe drying

In these models, we used the same Leslie matrix values as in the previous section in order to produce a deterministic growth rate $\lambda = 1.006$ in the absence of stochastic variability in annual demographic rates. We then added a level of environmental variability (EV) in these rates equivalent to 25% of the mean rates of fecundity and survivorship (coefficient of variation, CV, of 0.25). This extent of EV was chosen to represent the reasonable middle ground between the extremes that were chosen for our study of the influence of demographic variability on population stability (see Table 4 and Figure 5).

As defined in our stochastic models, a severe event that dries nearly 75% of the river in a given year can have a dramatic effect on the long-term viability of silvery minnows inhabiting the Rio Grande river (Table 4, Figure 5). In all three reaches, the inclusion of the severe event led to a major shift away from long-term population stability in the absence of the event to a marked decline in population size and stability ($\lambda < 1.0$) when the severe drying is included. This shift is less pronounced in the upstream Angostura reach, where the drying event is considered to be less severe.

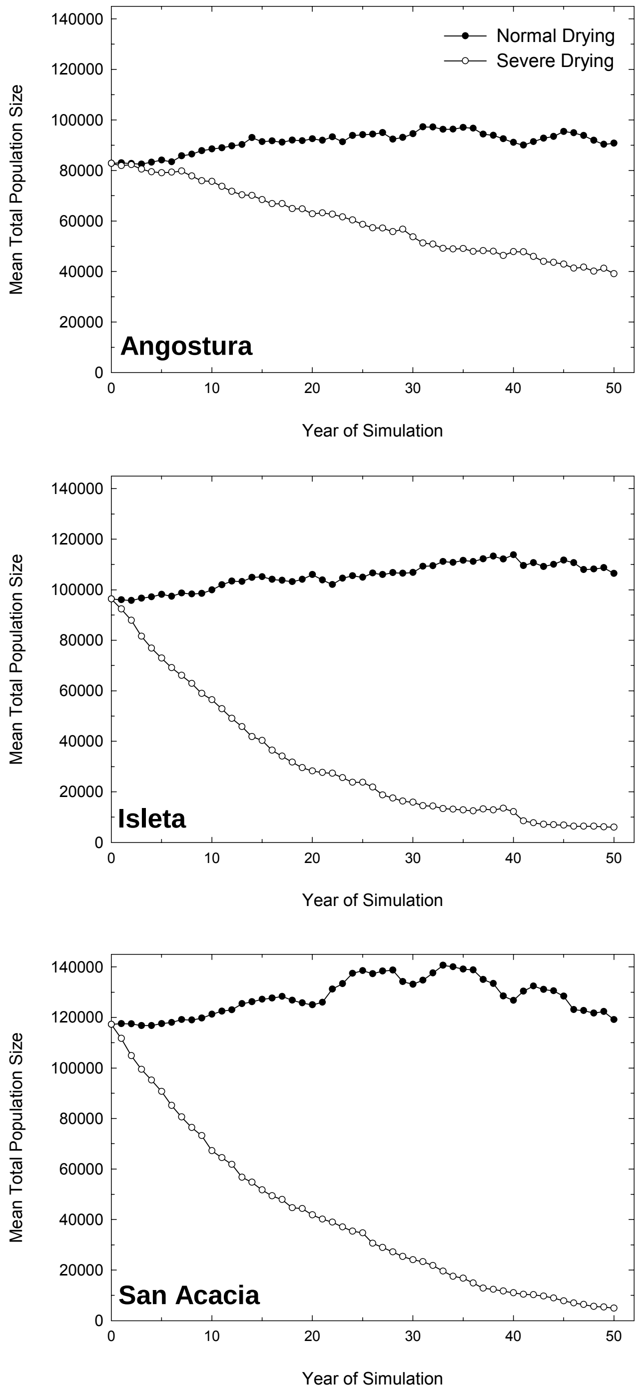


Figure 5. Fifty-year projections for simulated populations of silvery minnows occupying the three reaches of the Middle Rio Grande. Models that include a severe drying event are shown by white symbols, while those models that exclude such an event are shown by black symbols. Deterministic growth rate expected to be $\lambda = 1.006$. Environmental variability in demographic rates set at 25% of the mean rates (CV = 0.25). See accompanying text for additional information on model construction and interpretation.

Table 4. Population growth rate (λ) and terminal extinction risk ($P(E)_{50}$) estimates for simulated populations of silvery minnow occupying each of the three reaches of the Middle Rio Grande river. "Normal" scenario conditions do not include a severe drying event, while "Dry" scenarios include the severe event at the specified frequency and severity. See accompanying text for model construction and interpretation.

	Growth Rate (λ)		$P(E)_{50}$	
Reach	Normal	Dry	Normal	Dry
Angostura	1.001	0.985	0.000	0.000
Isleta	1.002	0.946	0.000	0.089
San Acacia	1.000	0.939	0.000	0.076

Severe event analysis II: Impact of water quality event

We focused our efforts on the Angostura reach for this analysis. As in our other analyses, we used the same Leslie matrix values as in previous stochastic models in order to produce a deterministic growth rate $\lambda = 1.006$ in the absence of stochastic variability in annual demographic rates. We then added a level of environmental variability (EV) in these rates equivalent to 25% of the mean rates of fecundity and survivorship (coefficient of variation, CV, of 0.25).

The impact of the water quality event as defined in this PVA is shown, in the context of the additional severe drying event also present in the Angostura reach, in Table 5 and Figure 6.

Table 5. Population growth rate (λ) and terminal extinction risk ($P(E)_{50}$) estimates for simulated populations of silvery minnow occupying the Angostura reach of the Middle Rio Grande river. "Normal" scenario conditions do not include a severe drying event, "Dry" scenarios include the severe drying event, and "Spill" scenarios include the severe water quality even. See accompanying text for model construction and interpretation.

Model Conditions	Growth Rate (λ)	$P(E)_{50}$
Normal	1.001	0.000
Dry	0.985	0.000
Spill	0.935	0.014
Dry / Spill	0.925	0.035

While both severe events lead to a marked reduction in both the growth rate and persistence probability of the affected populations, these results demonstrate the relatively greater impact of the water quality event as we have defined it here. The drying event reduces λ by approximately 1.5%, while the water quality event leads to a 6.5% reduction in the same metric. This result is to be expected given that the water quality event has a higher probability of occurrence in a given year compared to the severe drying event – in fact, the probability that a water quality event will occur in this reach is double that for a drying event. Moreover, we are assuming that a water quality event leads to a 33% reduction in minnow abundance in the Angostura reach, while a severe drying event reduces abundance in this reach by just 20%. Taken together, the conclusion of this analysis confirms the greater impact of the water quality event.

It is important to remember that the characterization of such events as severe drying and, particularly, serious reductions in overall water quality is extremely difficult to accomplish with high levels of accuracy. The description and use of the water quality event discussed here has generated considerable discussion on the realism of the event as currently portrayed. Additional work will be required to fully analyze the available historic data on such an event in order to provide a more realistic description of this process.

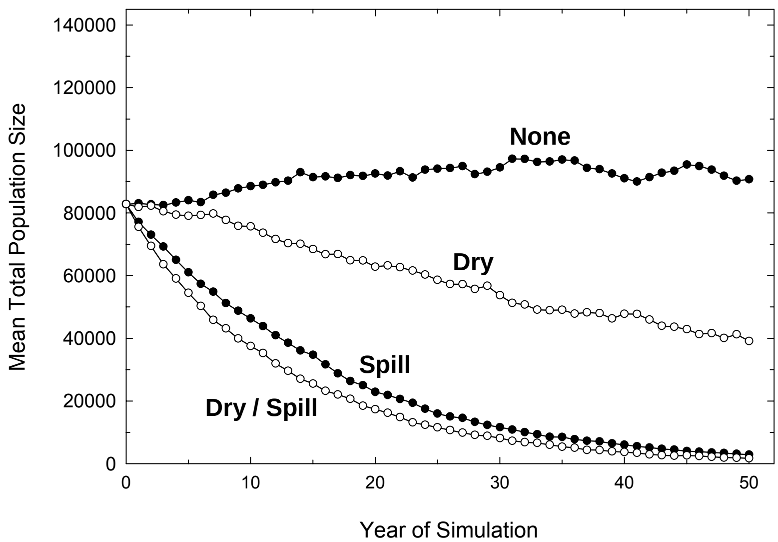


Figure 6. Fifty-year projections for simulated populations of silvery minnows occupying the Angostura reach of the Middle Rio Grande. Impacts of severe events are shown individually as well as in combination. Deterministic growth rate expected to be λ = 1.006. Environmental variability in demographic rates set at 25% of the mean rates (CV = 0.25). See accompanying text for additional information on model construction and interpretation

Population size risk analysis

As in our other analyses, we used the same Leslie matrix values as in previous stochastic models in order to produce a deterministic growth rate λ = 1.006 in the absence of stochastic variability in annual demographic rates. We then added a level of environmental variability (EV) in these rates equivalent to 25% of the mean rates of fecundity and survivorship (coefficient of variation, CV, of 0.25). With this as a baseline, we created a series of models with initial reach-specific population sizes ranging from 10% to 150% of the size extrapolated from the October 2006 CPUE estimates (see Data Input section on the various assumptions used to derive this extrapolation). We also included severe drying and water quality events on a reach-specific basis in selected scenarios.

We can make the following observations from the results of these models (Tables 6 and 7; Figures 7 and 8):

1. In the absence of severe drying or water quality events, each simulated population displays long-term growth rates (λ) very close to 1.0, indicating long-term population stability (Figure 6). Moreover, population extinction risk is extremely low, being most common (as expected) when the initial size of the simulated population is quite low.

   However, as we have seen before in our analysis of population quasi-extinction probability, the apparent stability of these populations is not as robust as it seems to be at first glance. Despite the frequent observation of long-term growth rates at or just above λ = 1.0, the probability that the final population size is **less** than the initial size in our selected model shown in Figure 7 is actually about 75%. This is true even if the population is rather large (right panel, Figure 7). This phenomenon occurs because the average population sizes used to calculate λ often result from a distribution of abundances across model iterations that is skewed towards very large sizes. This makes the average abundance value larger than one would expect to see in the long term; statistically speaking, this average can become rather larger than the median abundance value. Therefore, as before, it is important to temper one's interpretation of an apparently stable growth rate derived from a stochastic population projection.

Table 6. Population growth rate (λ) and terminal extinction risk ($P(E)_{50}$) estimates for simulated populations of silvery minnow occupying the three reaches of the Middle Rio Grande river. Initial population size for each reach is expressed as a percentage of the estimated abundance derived from CPUE estimates calculated for October 2006. In these models, severe events are absent. See accompanying text for model construction and interpretation.

	Angostura		Isleta		San Acacia	
N_0 (% 10/2006)	λ	$P(E)_{50}$	λ	$P(E)_{50}$	λ	$P(E)_{50}$
10	1.003	0.003	1.011	0.001	1.004	0.001
20	1.004	0.000	1.003	0.000	1.005	0.000
30	1.008	0.000	1.005	0.000	1.005	0.000
40	1.006	0.000	1.006	0.001	1.006	0.001
50	1.006	0.000	1.007	0.000	1.003	0.000
60	1.000	0.000	1.004	0.000	1.003	0.000
70	1.008	0.001	1.005	0.000	1.000	0.000
80	1.004	0.000	1.001	0.000	1.000	0.000
90	1.002	0.000	1.002	0.000	1.001	0.000
100	1.002	0.000	1.000	0.000	1.002	0.000
110	1.004	0.000	1.003	0.000	1.000	0.000
120	1.001	0.000	1.002	0.000	0.999	0.001
130	1.001	0.000	1.003	0.000	1.001	0.000
140	0.999	0.000	1.000	0.001	1.001	0.002
150	1.001	0.000	1.000	0.000	1.000	0.002

Figure 7. Terminal quasi-extinction curves for simulated silvery minnow populations occupying the San Acacia reach in the absence of severe events. Initial population sizes are 10% (left) and 150% (right) of the abundance estimate derived from the October 2006 CPUE estimate. Asterisks give location on curve of initial abundance in model. In both simulations, the probability of the final population abundance being less than the initial abundance is approximately 75%. See accompanying text for additional information on model construction and interpretation.

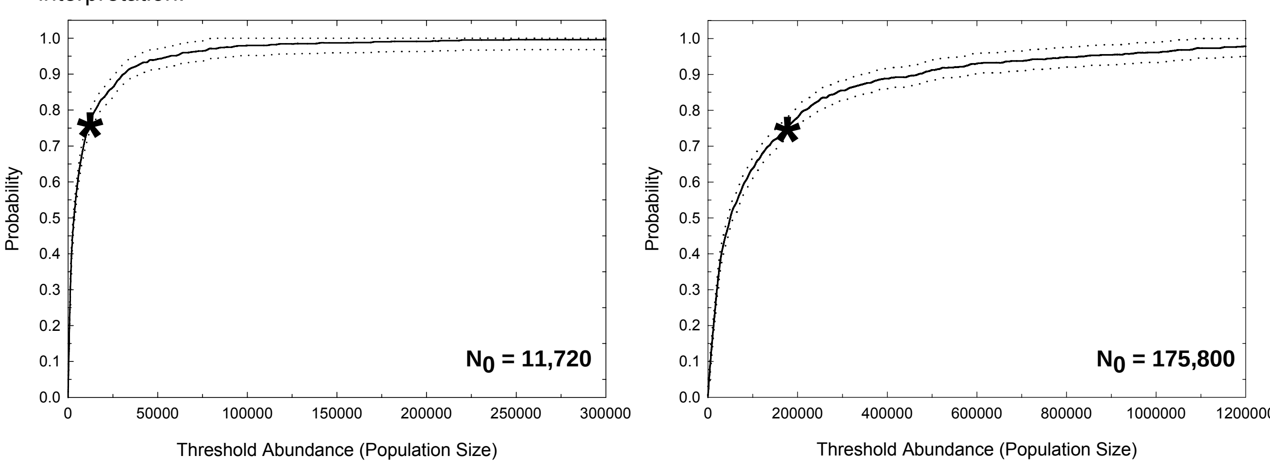
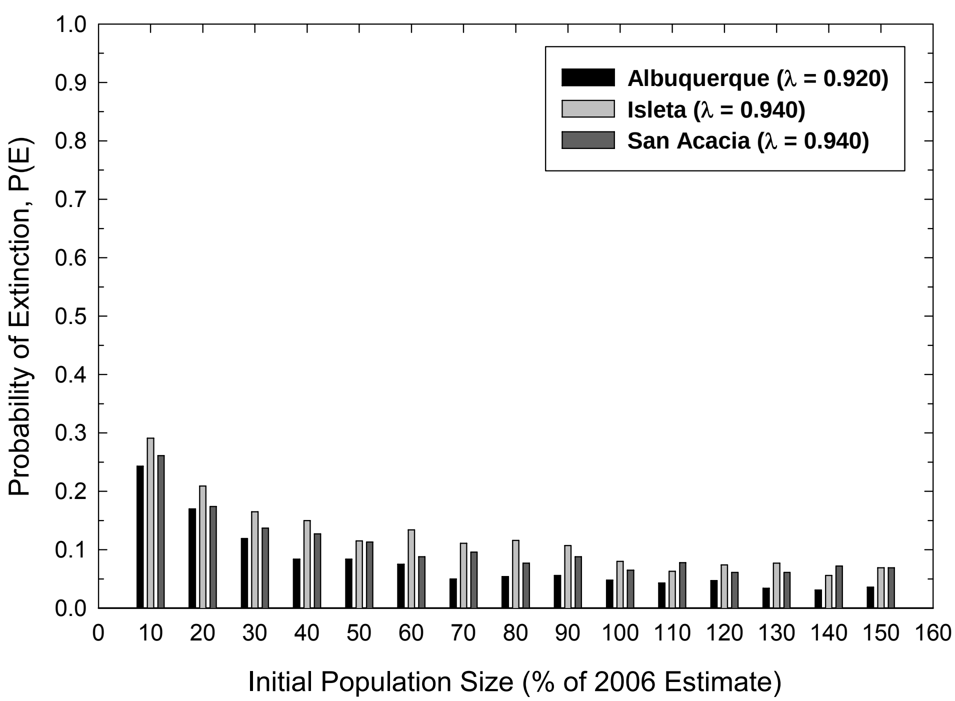


Table 7. Population growth rate (λ) and terminal extinction risk ($P(E)_{50}$) estimates for simulated populations of silvery minnow occupying the three reaches of the Middle Rio Grande river. Initial population size for each reach is expressed as a percentage of the estimated abundance derived from CPUE estimates calculated for October 2006. In these models, severe events are present on a reach-specific basis. See accompanying text for model construction and interpretation.

	Angostura		Isleta		San Acacia	
N_0 (% 10/2006)	λ	$P(E)_{50}$	λ	$P(E)_{50}$	λ	$P(E)_{50}$
10	0.919	0.243	0.936	0.291	0.938	0.261
20	0.923	0.170	0.949	0.209	0.939	0.174
30	0.919	0.119	0.942	0.165	0.942	0.137
40	0.918	0.084	0.944	0.150	0.930	0.127
50	0.914	0.084	0.938	0.115	0.940	0.113
60	0.918	0.075	0.949	0.134	0.939	0.088
70	0.917	0.050	0.938	0.111	0.950	0.096
80	0.922	0.054	0.940	0.116	0.939	0.077
90	0.921	0.056	0.943	0.107	0.941	0.088
100	0.919	0.048	0.938	0.080	0.939	0.065
110	0.919	0.043	0.940	0.063	0.937	0.078
120	0.923	0.047	0.941	0.074	0.938	0.061
130	0.923	0.034	0.942	0.077	0.949	0.061
140	0.919	0.031	0.945	0.056	0.931	0.072
150	0.921	0.036	0.949	0.069	0.935	0.069

Figure 8. Population extinction probabilities for simulated silvery minnow populations occupying the three reaches of the Middle Rio Grande in the presence of severe events. Initial population size for the models ranges from 10% to 150% of the initial size derived from the October 2006 CPUE estimate. See accompanying text for additional information on model construction and interpretation.



2. Given the same underlying baseline demographic parameters, and after the inclusion of reach-specific severe events, smaller populations across all three reaches experience a higher probability of extinction in our models than their larger counterparts. This is a graphic demonstration of the "extinction vortex" phenomenon (Gilpin and Soulé 1986) where small population size leads to demographic instability, which leads to further population reduction and even more instability.

3. Across all population sizes, the Angostura reach shows lower extinction risk compared to those reaches downstream. This no doubt results from the reduced impact of the severe drying event in the Angostura reach. It is important to note this result, even as the estimated long-term population growth rates for Angostura are consistently lower than those for Isleta or San Acacia. It seems plausible that, even though the downstream reaches are not impacted by the water quality event that leads to lower growth rates for Angostura, the greater severity of the drying event puts them at a greater risk for extinction in concert with other sources of stochastic demographic variability.

4. There appears to be a type of threshold effect in the risk of reach-specific extinction at the largest population sizes (at least, across the range studied here). The inclusion of severe events is probably the most likely explanation for this observation. While smaller populations are naturally more susceptible to the consequences of these events, these results suggest that larger populations are not immune to this source of instability, especially if events occur in relatively rapid sequence.

Metapopulation risk analysis

As in our other analyses, we used the same Leslie matrix values as in previous stochastic models in order to produce a deterministic growth rate $\lambda = 1.006$ in the absence of stochastic variability in annual demographic rates. We then added a level of environmental variability (EV) in these rates equivalent to 25% of the mean rates of fecundity and survivorship (coefficient of variation, CV, of 0.25). Finally, we linked adjacent reaches with a level of dispersal (D = 0.005, 0.010, 0.015) defined as the proportion of individuals from the upstream population expected to move downstream to the adjacent read in a given year. We also assume that some lower level of dispersal occurs between Angostura and San Acacia, equivalent to (0.33)D each year.

When individual reaches are allowed to interact with other demographically in the form of downstream dispersal of minnows over time, some interesting metapopulation dynamics become evident. These results are summarized in Table 8. Note that, as D increases, the growth rate of Angostura and Isleta declines while that of the downstream San Acacia reach increases. Conversely, the extinction risk in Angostura increases while Isleta and San Acacia experience a decline in extinction risk.

In simple form, this is a classic example of "source-sink" metapopulation dynamics, where some subpopulations serve as the source of individuals for movement to other patches of habitat that are unable to provide individuals to the same extent in return. In this case, the upstream Angostura reach is the source of all downstream movement, at a rate that is not offset by intrinsic demographic processes. As a result, the population declines further in size and suffers from a marked increase in extinction risk. The middle Isleta reach also experiences this net decline in abundance as the larger population there leads to a net outflow of individuals to the San Acacia reach. However, despite this reduced growth rate there is sufficient demographic augmentation to significantly reduce the risk of extinction in the Isleta reach. Demographically, the San Acacia reach enjoys the greatest benefit since it serves solely as a recipient of individuals without having to supply individuals to upstream reaches. This leads to both an increase in λ and a decrease in extinction risk.

Further exploration of this system will be required in order to develop more accurate models of silvery minnow population dynamics in the Middle Rio Grande. This will be the subject of additional PVA work subsequent to the publication of this report.

Table 7. Population growth rate (λ) and terminal extinction risk ($P(E)_{50}$) estimates for simulated populations of silvery minnow occupying the three reaches of the Middle Rio Grande river. The reaches in these models are connected by a degree of dispersal, D, defined as the proportion of individuals of both age classes expected to move downstream to the adjacent reach. Dispersal between Angostura and San Acacia is assumed to be only (0.33)D. See accompanying text for model construction and interpretation.

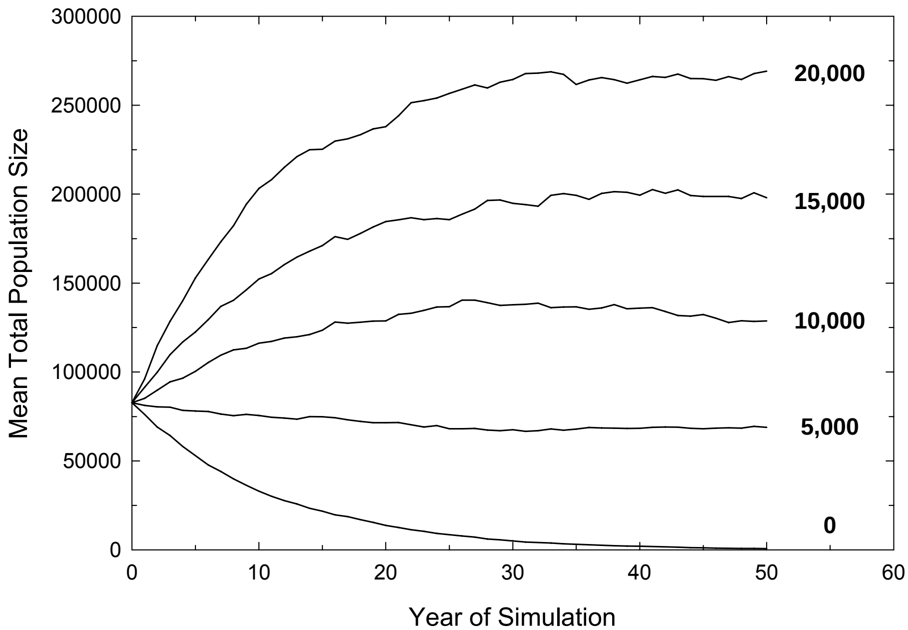
	Angostura		Isleta		San Acacia	
D	λ	$P(E)_{50}$	λ	$P(E)_{50}$	λ	$P(E)_{50}$
0.000	0.917	0.044	0.947	0.102	0.930	0.067
0.005	0.914	0.065	0.938	0.024	0.949	0.021
0.010	0.903	0.077	0.937	0.030	0.949	0.013
0.015	0.897	0.104	0.932	0.037	0.944	0.011

Augmentation risk analysis

As in our other analyses, we used the same Leslie matrix values as in previous stochastic models in order to produce a deterministic growth rate $\lambda = 1.006$ in the absence of stochastic variability in annual demographic rates. We then added a level of environmental variability (EV) in these rates equivalent to 25% of the mean rates of fecundity and survivorship (coefficient of variation, CV, of 0.25), and added reach-specific severe events according to their specific definitions. Finally, we are augmenting each reach with a specified number of Age 1 fish, assumed to be after the dispersal event. In reality, the bulk of the augmentation takes place around October, making the stocked fish approximately 18 months old. In the language of our demographic model, however, we are augmenting the populations immediately before the next spawning event, i.e., when the stocked fish are almost but not quite 24 months old. Therefore, we must consider the number of stocked fish to be an effective number that, due to intervening mortality, is less than the number actually added to the river in October. It is as yet unclear what level of total augmentation in October would equate to a given stocked population size just before the next spawning event; additional discussion will be undertaken to make this relationship more explicit.

Figure 9 shows the results of this augmentation analysis for Angostura as an example – the Isleta and San Acacia reaches show the same general dynamics. In the absence of augmentation, an isolated Angostura reach population shows a marked rate of population decline ($\lambda = 0.909$) with a 5.9% risk of extinction with 50 years. The effective augmentation of 5000 Age 1 fish boosts the growth rate to $\lambda = 0.998$, while the effective augmentation of a range of 10,000 to 20,000 fish further bolsters the growth rate to $\lambda = 1.009$ to $\lambda = 1.024$. The impact of each additional portion of fish appears to have a progressively smaller impact on the final population growth rate; this is most likely due to the occasional imposition of the habitat carrying capacity under conditions of growth between years that is substantially higher than the long-term expectation. When this happens, the population trajectory will begin to level out as we see in those instances of maximum augmentation.

Figure 9. Population trajectories for simulated populations of silvery minnows occupying the Angostura reach of the Middle Rio Grande river, under conditions of annual augmentation of Age 1 fish. Number of fish added annually are listed on the right side of each trajectory. This is an "effective augmentation", meaning that within the framework of the model, the fish are added immediately before the impending spring spawn. Since in reality the fish are stocked in October, there will be some level of mortality that is not being explicitly considered here. See accompanying text for additional information on model construction and interpretation.



Conclusions

We may conclude our preliminary analysis of Rio Grande silvery minnow population viability by returning to the original set of questions that provided the foundation for our study.

- *Can we build a series of simulation models with sufficient detail and precision that describe the dynamics of Rio Grande silvery minnow with reasonable accuracy?*

  It is the opinion of this Working Group that we are indeed capable of building such models. There may be more complex elements of the species' population biology that are being ignored in the analysis described here, such as more sophisticated mechanics around the operation of density dependence. It is unclear how much more clear our insight will be into the viability of silvery minnow populations with the addition of this complexity. Moreover, it is extremely important to remember that reliance on the absolute outcome predicted by any one modeling scenario must always be interpreted with extreme caution due to the inherent uncertainty in model input parameters. A comparative analysis between models, in which a single factor (or at most two factors) is studied while all other input parameters are held constant, provides a much more robust environment in which alternative management scenarios can be evaluated for their effectiveness in increasing the viability of the target species. This has been and will continue to be our approach in this and future analyses.

- *What are the primary demographic factors that drive growth of silvery minnow populations?*

  Our demographic sensitivity analysis indicates that the long-term dynamics of silvery minnow populations is strongly tied to the reproductive output (fecundity) of Age 0 fish, i.e., those that survive to their first spawning season. Both egg production and first-year survival of newly-hatched fish are critical elements of this fecundity parameter.

- *What are the predicted impacts of severe drying on silvery minnow populations?*

  As modeled here in this analysis, the severe drying event can have a major impact on the long-term dynamics of silvery minnow populations in downstream reaches of the Middle Rio Grande. Preliminary study of this phenomenon suggests that the frequency of such an event is likely to be a more important factor in determining the event's overall impact than the severity.

- *What are the predicted impacts of a water quality event on silvery minnow populations?*

  Introduction of chemical toxins into the waters of the Middle Rio Grande can also have significant impacts on silvery minnow populations in the more immediate vicinity of the event. Again, the frequency of such an event is likely to be a more important factor in determining the event's overall impact than the severity. More detailed research is required on the specific causes and characteristics of these events, as relevant to creating more realistic scenarios for the purposes described here.

- *How vulnerable to extinction are small, fragmented silvery minnow populations under current management conditions? How small must a population become to increase its risk of extinction to an unacceptable level under conditions of minimally acceptable population growth?*

  Unfortunately, the identification of a specific threshold size for a minnow population that defines some acceptable level of viability is beyond the scope of this current analysis. This is due to an incomplete understanding of the current biological and human sociological factors that shape the dynamics of the river and the minnows that live within. With this limitation, our conclusions regarding viable population size must be of a more qualitative nature – but are still valuable from the perspective of identifying productive population and/or habitat management strategies.

  The demography of silvery minnow populations is highly variable, most likely in response to large fluctuations in environmental conditions from one year to the next. As a result, smaller minnow populations are indeed more prone to demographic instability and, over time, extinction under these unpredictable conditions. It is very important to recognize that extinction can occur in a small population even when the population is expected to grow in the long term. Thoughtful analysis of PVA model output can give insight into threshold population sizes required to maintain an acceptable level of population stability.

- *What is the impact of dispersal on the viability of source and recipient reaches?*

  Because of the downstream flow of the Middle Rio Grande, and the restrictions to minnow movement imposed by diversion dams and other structures built along the course of the river, the metapopulation of silvery minnows in this area has some important characteristics that influence its viability. With one-way dispersal of individuals to downstream reaches, the upstream Angostura reach is an important source population that may become demographically compromised if threatened by external forces and subject to further declines due to dispersal of individuals to the Isleta and San Acacia reaches. Additional study of the dispersal dynamics of minnows throughout their habitat would be a valuable addition to future population viability efforts.

- *How effective can augmentation of silvery minnow individuals be as a long-term population management strategy?*

  Augmentation can lead to significant improvements to silvery minnow population dynamics in the long term. In addition to the more recognizable demographic benefits that such a strategy can provide, augmentation can also bolster a population's genetic variability through the introduction of new genetic material. This increase in genetic variability can lead to an increase in population fitness as well as an enhanced capability for adaptability to changing environmental conditions in the longer term.

  The extent of this benefit, however, is critically dependent on the number of fish added to the river, the timing of the event, and the survival of those introduced individuals to the next year's spawning event. Additional study of this strategy will be an important component of additional modeling efforts.

- *How effective can salvage of silvery minnow individuals be as a long term population management strategy?*
- *Which water management strategies work best towards the goal of increased viability of silvery minnow populations?*

  These important questions have not been considered in the present study. However, they will be addressed in detail in additional PVA efforts that will begin after the publication of the present analysis.

Future Directions for Additional Analysis

In order to construct a more realistic PVA framework, some additional thought and analysis must be directed towards selected aspects of the model's structure and input parameters. In particular, the following input parameters should be refined through additional data analysis:

- Distribution of suitable habitat by reach, thereby allowing the calculation of a more realistic minnow population size for each reach
- Frequency and severity of catastrophic water quality events
- Downstream dispersal rates
- Annual extent of variability in demographic rates and carrying capacity

Once the parameters identified above have been refined, the following issues and questions, to be considered explicitly within the continuing PVA efforts coordinated by the Collaborative Program's Biology and Hydrology Working Groups, were developed by working groups during the PHVA workshop. Follow-up modeling work will focus on these questions, with additional reports to be made available to all interested parties.

1. Determine demographic benefits of augmentation and salvage:
   a. What are the demographic benefits of stocking age-0 (less than 12 months) vs age-1 (12 – 24 months) fish?
   b. What season is best to stock fish (early Spring vs. Fall?)
   c. Which reach should fish be stocked in to maximize demographic benefits?
   d. What is the potential demographic benefit to releasing salvage fish in reaches upstream of the reach in which they are caught (current practice)?

   e. In what circumstances does augmentation or salvage have the greatest demographic benefit (e.g., low or high population density)?

2. What are the demographic benefits of expanding the range of silvery minnow into the Cochiti Reach of the Middle Rio Grande?

3. What are the demographic benefits of providing fish passage? Which fish passage structure provides the most immediate benefits to the silvery minnow population?

4. What are the demographic benefits of reducing downstream egg drift? How does egg and larval displacement affect extinction probability? (For example, this can be done by habitat restoration or manipulating shape of hydrograph)?

5. If habitat restoration reduces downstream displacement of eggs and larvae, where should habitat restoration be conducted to have greatest demographic benefit (e.g., upstream vs. downstream; wet vs. dry)?

6. If habitat restoration can improve survivorship in the first 45 days, or in the first year (by increasing egg entrainment or providing young-of-the-year habitat), where should habitat restoration be conducted to have greatest demographic benefit (e.g., upstream vs. downstream; wet vs. dry)?

7. What is the demographic benefit of providing greater frequency of adequate recruitment flows? (i.e., reducing environmental variability (EV) on the left side of distribution around vital parameters).

8. What are the relative demographic benefits of creating many small perennially wet reaches versus one large connected reach? Where should this reach be located to maximize demographic benefits (e.g., minimize P(E)).

9. What are the relative demographic benefits of managing to keep the river perennially wet only to San Acacia versus keeping the entire river wet for part of the year and then drying much of the river to Isleta? What are the relative extinction risks for each population?

10. What is the relative demographic benefit of applying available water in upper reaches versus lower reaches?

11. What is the relative demographic benefit of pumping in times when supplemental water is unavailable? Where and how much might be used? (upstream vs. downstream; single reach vs. many small reaches?).

12. What is the demographic effect of reducing the frequency and magnitude of catastrophic drying events?

13. What is the demographic effect of reducing the frequency and magnitude of catastrophic water quality events? What scenario might reasonably represent the future conditions?

14. What are the demographic benefits of creating additional populations within the silvery minnow historic range (e.g., Pecos River between Santa Rosa Dam and Sumner Reservoir)?

15. By implementing management strategies to address the identified threats, can the long-term lambda be increased to greater than 1? (Compare relative benefits of implementing all actions that have a positive demographic benefit and compare to current baseline).

16. Do results of PVA modeling support current Recovery Plan targets for down-listing and recovery?
    a. Can we reasonably expect to obtain densities of 5 silvery minnow/100m2 every year?
    b. Can we reasonably expect to have 500,000 fish in each reach at all times?
    c. If the answer to (a.) or (b.) is “no”, what are appropriate targets for recovery?

17. Have all identified threats in listing document be adequately addressed in PVA (e.g., predation…?).

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Appendix A:
Population Viability Analysis and Simulation Modeling

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Introduction

Thousands of species and populations of animals and plants around the world are threatened with extinction within the coming decades. For the vast majority of these groups of organisms, this threat is the direct result of human activity. The particular types of activity, and the ways in which they impact wildlife populations, are often complex in both cause and consequence; as a result, the techniques we must use to analyze their effects often seem to be complex as well. But scientists in the field of conservation biology have developed extremely useful tools for this purpose that have dramatically improved our ability to conserve the planet's biodiversity.

Conservation biologists involved in recovery planning for a given threatened species usually try to develop a detailed understanding of the processes that put the species at risk, and will then identify the most effective methods to reduce that risk through active management of the species itself and/or the habitat in which it lives. In order to design such a program, we must engage in some sort of predictive process: we must gather information on the detailed characteristics of proposed alternative management strategies and somehow predict how the threatened species will respond in the future. A strategy that is predicted to reduce the risk by the greatest amount – and typically does so with the least amount of financial and/or sociological burden – is chosen as a central feature of the recovery plan.

But how does one predict the future? Is it realistically possible to perform such a feat in our fast-paced world of incredibly rapid and often unpredictable technological, cultural, and biological growth? How are such predictions best used in wildlife conservation? The answers to these questions emerge from an understanding of what has been called "the flagship industry" of conservation biology: Population Viability Analysis, or PVA. And most methods for conducting PVA are merely extensions of tools we all use in our everyday lives.

The Basics of PVA

To appreciate the science and application of PVA to wildlife conservation, we first must learn a little bit about population biology. Biologists will usually describe the performance of a population by describing its demography, or simply the numerical depiction of the rates of birth and death in a group of animals or plants from one year to the next. Simply speaking, if the birth rate exceeds the death rate, a population is expected to increase in size over time. If the reverse is true, our population will decline. The overall rate of population growth is therefore a rather good descriptor of its relative security: positive population growth suggests some level of demographic health, while negative growth indicates that some external process is interfering with the normal population function and pushing it into an unstable state.

This relatively simple picture is, however, made a lot more complicated by an inescapable fact: wildlife population demographic rates fluctuate unpredictably over time. So if we observe that 50% of our total population of adult females produces offspring in a given year, it is almost certain that more or less than 50% of our adult females will reproduce in the following year. And the same can be said for most all other demographic rates: survival of offspring and adults, the numbers of offspring born, and the offspring sex ratio will almost always change from one year to the next in a way that usually defies precise prediction. These variable rates then conspire to make a population's growth rate also change unpredictably from year to year. When wildlife populations are very large – if we consider seemingly endless herds of wildebeest on the savannahs of Africa, for example – this random annual fluctuation in population growth is of little to no consequence for the future health and stability of the population. However, theoretical and practical study of population biology has taught us that populations that are already small in size, often defined in terms of tens to a few hundred individuals, are affected by these fluctuations to a much greater extent – and the long-term impact of these fluctuations is always negative. Therefore, a wildlife population that has been reduced in numbers will become even smaller through this fundamental principle of wildlife biology. Furthermore, our understanding of this process provides an important backdrop to considerations of the impact of human activities that may, on the surface, appear relatively benign to larger and more stable wildlife populations. This self-reinforcing feedback loop, first coined the "extinction vortex" in the mid-1980's, is the cornerstone principle underlying our understanding of the dynamics of wildlife population extinction.

Once wildlife biologists have gone out into the field and collected data on a population's demography and used these data to calculate its current rate of growth (and how this rate may change over time), we now have at our disposal an extremely valuable source of information that can be used to predict the *future* rates of population growth or decline under conditions that may not be so favorable to the wildlife population of interest. For example, consider a population of primates living in a section of largely undisturbed Amazon rain forest that is now opened up to development by logging interests. If this development is to go ahead as planned, what will be the impact of this activity on the animals themselves, and the trees on which they depend for food and shelter? And what kinds of alternative development strategies might reduce the risk of primate population decline and extinction? To try to answer this question, we need two additional sets of information: 1) a comprehensive description of the proposed forest development plan (how will it occur, where will it be most intense, for what period of time, etc.) and 2) a detailed understanding of how the proposed activity will impact the primate population's demography (which animals will be most affected, how strongly will they be affected, will animals die outright more frequently or simply fail to reproduce as often, etc.). With this information in hand, we have a vital component in place to begin our PVA.

Next, we need a predictive tool – a sort of crystal ball, if you will, that helps us look into the future. After intensive study over nearly three decades, conservation biologists have settled on the use of computer simulation models as their preferred PVA tool. In general, models are simply any simplified representation of a real system. We use models in all aspects of our lives; for example, road maps are in fact relatively simple (and hopefully very accurate!) 2-dimensional representations of complex 3-dimensional landscapes we use almost every day to get us where we need to go. In addition to making predictions about the future, models are very helpful for us to: (1) extract important trends from complex processes, (2) allow comparisons among different types of systems, and (3) facilitate analysis of processes acting on a system.

Recent advances in computer technology have allowed us to create very complex models of the demographic processes that define wildlife population growth. But at their core, these models attempt to replicate simple biological functions shared by most all wildlife species: individuals are born, some grow to adulthood, most of those that survive mate with individuals of the opposite sex and then give birth to one or more offspring, and they die from any of a wide variety of causes. Each species may have its own special set of circumstances – sea turtles may live to be 150 years old and lay 600 eggs in a single event, while a chimpanzee may give birth to just a single offspring every 4-5 years until the age of 45 – but the fundamental biology is the same. These essential elements of a species' biology can be incorporated into a computer program, and when combined with the basic rules for living and the general characteristics of the population's surrounding habitat, a model is created that can project the demographic behavior of our real observed population for a specified period of time into the future. What's more, these models can explicitly incorporate random fluctuations in rates of birth and death discussed earlier. As a result, the models can be much more realistic in their treatment of the forces that influence population dynamics, and in particular how human activities can interact with these intrinsic forces to put otherwise relatively stable wildlife populations at risk.

Strengths and Limitations of the PVA Approach

When considering the applicability of PVA to a specific issue, it is vitally important to understand those tasks to which PVA is well-suited as well as to understand what the technique is not well-designed to deliver. With this enhanced understanding will also come a more informed public that is better prepared to critically evaluate the results of a PVA and how they are applied to the practical conservation measures proposed for a given species or population.

The dynamics of population extinction are often quite complicated, with numerous processes impacting the dynamics in complex and interacting ways. Moreover, we have already come to appreciate the ways in which demographic rates fluctuate unpredictably in wildlife populations, and the data needed to provide estimates of these rates and their annual variability are themselves often uncertain, i.e., subject to observational bias or simple lack of detailed study over relatively longer periods of time. As a result, the elegant mental models or the detailed mathematical equations of even the most gifted conservation biologist are inadequate for capturing the detailed nuances of interacting factors that determine the fate of a wildlife population threatened by human activity. In contrast, simulation models can include as many factors that influence population dynamics as the modeler and the end-user of the model wish to assess. Detailed interactions between processes can also 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.

PVA models have also been shown to stimulate meaningful discussion among field biologists in the subjects of species biology, methods of data collection and analysis, and the assumptions that underlie the analysis of these data in preparation for their use in model construction. By making the models and their underlying data, algorithms and assumptions explicit to all who learn from them, these discussions become a critical component in the social process of achieving a shared understanding of a threatened species' current status and the biological justification for identifying a particular management strategy as the most effective for species conservation. This additional benefit is most easily recognized when PVA is used in an interactive workshop-type setting, such as the Population and Habitat Viability Assessment (PHVA) workshop designed and implemented by CBSG.

Perhaps the greatest strength of the PVA approach to conservation decision-making is related to what many of its detractors see as its greatest weakness. Because of the inherent uncertainty now known to exist in the long-term demography of wildlife populations (particularly those that are small in size), and because of the difficulties in obtaining precise estimates of demographic rates through extended periods of time collecting data in the field, accurate predictions of the future performance of a threatened wildlife population are effectively impossible to make. Even the most respected PVA practitioner must honestly admit that an accurate prediction of the number of mountain gorillas that will roam the forests on the slopes of the eastern Africa's Virunga Volcanoes in the year 2075, or the number of polar bears that will swim the warming waters above the Arctic Circle when our great-grandchildren grow old, is beyond their reach. But this type of difficulty, recognized across diverse fields of study from climatology to gambling, is nothing new: in fact, the Nobel Prize-winning physicist Niels Bohr once said "Prediction is very difficult, especially when it's about the future." Instead of lamenting this inevitable quirk of the physical world as a fatal flaw in the practice of PVA, we must embrace it and instead use our very cloudy crystal ball for another purpose: to make **relative**, rather than **absolute**, predictions of wildlife population viability in the face of human pressure.

The process of generating relative predictions using the PVA approach is often referred to as sensitivity analysis. In this manner, we can make much more robust predictions about the relative response of a simulated wildlife population to alternate perturbations to its demography. For example, a PVA practitioner may not be able to make accurate predictions about how many individuals of a given species may persist in 50 years in the presence of intense human hunting pressure, but that practitioner can speak with considerably greater confidence about the relative merits of a male-biased hunting strategy compared to the much more severe demographic impact typically imposed by a hunting strategy that prefers females. This type of comparative approach was used very effectively in a PVA for highly threatened populations of tree kangaroos (*Dendrolagus* sp.) living in Papua New Guinea, where adult females are hunted preferentially over their male counterparts. Comparative models showing the strong impacts of such a hunting strategy were part of an important process of conservation planning that led, within a few short weeks after a participatory workshop including a number of local hunters (Bonaccorso et al., 1998), to the signing of a long-term hunting moratorium for the most critically endangered species in the country, the tenkile or Scott's tree kangaroo (*Dendrolagus scottae*).

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 often underestimate the threats facing the population, or the total risk these threats collectively impose on the population of interest. To address this limitation, conservation biologists must try to engage a diverse body of experts with knowledge spanning many different fields in an attempt to broaden our understanding of the consequences of interaction between humans and wildlife.

Additionally, 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 (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (2003) for more details).

Finally, it is also important to understand that a PVA model by itself does not define the goals of conservation planning of a given species. 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.

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Rio Grande Silvery Minnow
Population and Habitat Viability Assessment

Section III
Working Group Report:
Short-Term Species Management (Alleviating Jeopardy)

Short-Term Species Management (Alleviating Jeopardy) Working Group Report

Working Group Participants:
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Brock Blevins, Omaha's Henry Doorly Zoo (Facilitator)
Marta Wood, Tetra Tech EMI (Recorder)

Issues and Problems

The group discussed the definition of "short-term" or how can jeopardy be alleviated (i.e., preventing extinction in the wild). Short-term could mean how to get through the year or it could mean determining minimum levels and achieving the baseline regardless of the time frame. Another perspective of short-term is the annual actions can that can be done yearly to maintain population stability in the wild.

The group was encouraged to think outside the box, and not be restricted by the constraints of the current Biological Opinion (BO); the PVA concepts and results could be used to offer some flexibility within the BO if legally appropriate. The PVA could be the bar providing the analytical support.

General statement: The focus topic is how to prevent extinction of the species in the short-term.

The following is a prioritized list of issues pertaining to the topic of preventing short-term species extinction. Two separate criteria were used to develop the overall priority: 1) urgency of resolving the issue; and 2) ability to influence the resolution of the issue (i.e. those issues over which the Collaborative Program actually has some degree of control).

1. <u>In the short term, both sustainability and recovery of the silvery minnow are challenged by a lack of habitat for adequate levels of recruitment and survival</u>. (Urgency = 29 / Influence = 31)
    - How can the habitat and the hydrograph be managed more effectively to support minnow recruitment and survival?
    - There is a change in the relationship between habitat availability and river flows.
    - There is a lack of available inundated habitat due to channelization.
    - There is a lack of habitat necessary for the survival of the minnow.
    - The inability of the river to move has altered the relationship between discharge and habitat availability.
    - Lack of habitat to support recruitment and survival of the minnow.

2. Current wild populations of silvery minnows may not be self-sustaining in the absence of active artificial population management. (Urgency = 24 / Influence = 30)
    - Difficulties in interpretation of past and current research on the species (behavior, ecology, population size, genetic structure, etc.).
    - How many and what age fish should be stocked where? How to maximize survival? How to be most effective?
    - Lack of knowledge - effects of salvage and augmentation.

3. Water supply and management flexibility are limited in sustaining silvery minnow populations. (Urgency = 30 / Influence = 21)
    - Some water available and know future supplies dwindling – how to best use the water we have now? Versus then?
        - Where should water be applied? Areas easiest to keep wet versus better habitat, etc?
    - Upstream reservoir storage – native water storage requires process in Abiquiu, Cochiti has tribal collaboration, etc.
    - Clarification of "water management":
        - Annual (hourly, weekly, and daily) acquisition of conservation/supplemental water and ensuring releases in the necessary time frames to met target requirements (species and compact).
    - Current management of available water is not optimal for the sustainability of the minnow.
    - Water is limited and is coming under increasing competition which limits management ability.
    - Limited amount of water constrains the ability to manage habitat.
    - Softening of targets, linked with institutional constraints, would be one way to get around many of management challenges. Uncertain physical system .
    - Fear of management consequences within the Collaborative Program drives many actions.

4. The current political, legal, and institutional constraints hinder the ability to actively manage the populations; and while considered vital, cannot be reasonably affected in the short-term. (Urgency = 14 / Influence = 11)
    - Changes in the operational system (COA, District, etc) and how to appropriately deal with those changes – unstable and continually changing operational environments; time limits to respond to those changes.
    - Legal issues.
    - Lack of engagement by decisions makers.
    - Agency or positional flexibilities – communication and management issues; communication of working level to upper level issues.
    - Uncertain budget.
    - Upstream reservoir storage.
    - Lack of adjudication.

5. Adverse water quality conditions dangerously affect the water but are difficult to control. (Urgency = 4 / Influence = 7)
    - Lack of control over point sources/input/discharges in terms of water quality and treatment plants.

General concerns raised during this discussion:

- The PVA results will inform the discussion but the brainstorming session is occurring without those results.

- Another concern was raised that there were no management or decision makers with authority available in this discussion group; the group can propose ideas but the appropriate level of decision-making management isn't represented.

Data Assembly and Analysis

The short-term discussion group spent the first portion of the discussion time reviewing the hydrograph.

- Total control would produce a system with zero variability, perhaps at multiple scales.
- A major issue is: what is the hydrograph going to look like in certain years for certain conditions?
    - A low hydrograph pulse during spawning versus one that is higher results in an importance difference in recruitment with that change.
    - The management actions need to be in place for when the pulses/hydrograph does not occur naturally.
- What is the range of the possible hydrograph in the model?
    - There is no field for "hydrograph" in the PVA model, but the model can determine the average recruitment rate in the river (i.e. the average number of offspring produced for each age class) and there is a direct correlation between recruitment and the hydrograph "pulse."
    - Understanding the relationship between recruitment and the spring hydrograph is key.
- The group discussed a $\lambda = 1$ versus using a $\lambda < 1$ which is a more realistic representation.
    - $\lambda = 1$ does allow for comparison with methods and management.
- The group discussed the sensitivity of parameters, expected demographic curves, hydrographs, and clarification of inputs into the PVA model.
    - Changing the value of F within the model is the only corresponding parameter to model adding water at certain times for spawning flows, or for adding a volume of water later in the year.
- The PVA lends credibility to the "intuitive" processes that are currently being done.
    - From the preliminary results, it appears more valuable to maximize F_0 every year (recruitment) versus increasing the survivability of older fish.
    - The PVA could be used to support a particular management strategy or action.

Habitat Management Issues

Facts

- There is a correlation of nursery habitat to inundation with the hydrograph.
- There is a significant relationship between October catch unit efforts and certain hydrologic variables; the higher volume and the longer duration of the spring flows generally lead to higher catch per unit rates.
- Eggs move downstream.
- The majority of fish are found within a known suite of habitat.
    - There are certain habitats where all life stages of fish can be found; and then there are certain habitats where only young larvae fish can be found.
- The geomorphology of the river has changed since the 1940s leading to a disconnected floodplain.
    - Reasons and causes of geomorphology changes include: changes in land use, changes in sediment supply, channelization, decreased lateral migration, increasing deposition, etc.
    - Assumption: Island connectivity (ability to flood) is assumed to be beneficial to the minnow habitat.

    - Assumption: Floodplain inundation is assumed to be beneficial to the silvery minnow.
- Low flow habitat is beneficial to the minnow.
- River drying and population decreases when river dries.
    - This can be measured.
    - Assumed loss of habitat to drying and all fish are wiped out; some probably move but the amount are unknown.
- Fish can't move upstream past diversions.
    - Assumption is that they need to move upstream or egg retention needs to be increased.
- General relationship between egg retention rate and hydrologic radius of the channel (width to depth ratio of the channel); egg retention goes up and width/depth ratio goes up.
- Sediment inputs to the river have decreased over time since 1960s to 1970s.
- Channel width has decreased.
    - Habitat complexity has decreased (variability in depth, variability in flow).
    - Diversity of low velocity habitat has declined.
        - Assumed to be correlation with decrease in width.
- Peak flows are limited currently by the amount of water that can be released in terms of flood control projects (e.g., channel capacity in Albuquerque) .
    - Assuming higher peak flows are optimal, and assume that there is some cap that the system will stabilize out or will no longer be beneficial. Assumed to be high enough that we don't see it within the system; assume that all the possible range of flows will be beneficial and that the cap cannot be reached realistically within the system.
- Different life stages are associated with or require certain habitat.
- Vegetation in the active channel has increased over the last decade or two (possible source: Bosque del Apache).
- Vegetation increase has resulted in the anchoring or stabilization of the channel
    - Assume that stabilizing the channel with vegetation is a problem.

<u>Assumptions</u>

- We can recreate/reconstruct the habitat effectively (i.e. useful) and the minnow will use that habitat for recruitment. Assumed increase in the amount of area available for recruitment. Assuming we know what is limiting; assuming we know where to build it (location), and what is needed.
    - Assumed increase in habitat area is sufficient to effect change.
    - Assumed going to have to maintain the created habitat (perpetual maintenance will be necessary).
- Minimizing the frequency of extreme events would be beneficial to the minnow
- Minnow like complex habitat versus less complex habitat.

<u>Information Gaps</u>

- How the fish use the habitat is unknown.

Population Management Issues

<u>Facts</u>

- We can currently produce 500,000 age 1 fish.
- Fall stocking is more successful or beneficial with the justification that the fish have the winter to adjust to the living conditions in the river but may have higher mortality. This also assumes that spring stocking doesn't give the fish enough time to become gravid.
- Genetic diversity has been eroded/declining and continues to decline (M. Osborne – Univ. New Mexico).

- Salvage is expensive to implement.
- Salvage uses a lot of water.

Assumptions

- Current genetic management and propagation methods activities are protecting/conserving the remaining genetic diversity of the captive and wild populations and slows the decline.
- Only benefit of recession is for salvage facilitation.
- Salvage is important in low population years.
- A population is dependent on productivity (the size of F0 or maternity and survivability) of age 0 fish, thereby making salvage important.
- Based on PVA model, more benefit to stocking age 0 fish.
- Salvage and augmentation help sustain the population.
- Mitigation against extremely bad years, reducing the demographic variability minimizing frequency of extreme events would be beneficial to the minnow.
- Small populations can recover genetically.
- Naturalized refugia improve the fitness of propagated fish compared to hatchery tanks.
- Fecundity of Age 1 fish is higher than fecundity of age 0 fish based on hatchery data.
- The output of the PVA is relevant; PVA provide a reasonable approximation of the minnow population dynamics (responses/behavior/trends).
- Small populations are generally more at risk than larger populations.

Information Gaps

- It is unknown what the effects of long-term captive breeding will be on the genetics of the wild population.
- It is unknown how many salvaged fish contribute to spawning the following year.

Water Quantity Management Issues

Facts

- Current supplemental water supplies are decreasing.
- Insufficient water is earmarked to keep the river wet.
- There will never be enough water to keep the river wet for the entire length all the time.
- Additional supplies of water and/or management need to be available to meet current Biological Opinion / flow requirements.
- There is no single solution to the water supply and management needs.

Assumptions

- Climate change will continue to depress snow pack.
- The way current water is managed is not optimal for the minnow.
- Reregulation within the constraints of Cochiti will be important for recruitment flows (reregulations discussions? Not really. Storage aspect of what we have, then reregulations possibilities which was done this year with the Cochiti deviations.)
- Water available is of the appropriate amount and quality.
- Available supplemental water is needed to maintain base flows. (fact: if 8000 acre-feet of water is used in the duration of a few days for recruitment flows, then there will be nothing left for the remainder of the year.)
- All supplemental water supply will be decreasing or declining.

Legal and Intuitional Constraints Issues

Facts

- We all have to comply with ESA and federal and state laws.
- Cochiti is a flow-through reservoir.
- The current litigation impacts water management.
- Senator Dominici is retiring (he is a senior Senator, so funding will be impacted).
- Federal budget is in shambles.
- There is no opportunity, in the short-term, to effect change in MRGCD systems management; the complexity and administration of MRGCD (including the complication of the pueblos) makes radical change difficult.
- All resource agencies are short funded and short staffed; resources are stretched; limited number of people.

Assumptions

- The compact cannot be changed substantially in the short term.
- Threats of litigation stifle creativity.
- Federal legislation changes may be needed to increase flexibility / change agency policy
- Risk taking will be discouraged in an election year.
- When the crisis is great enough, resource agencies will show up to work together to solve the problem.

Water Quality Management Issues

Facts

- North AMAFCA channel has discharged water detrimental to the fish (documented fish kill).
- Treatment plants have discharged concentrations of chemicals impacting the capability of the fish to survive.
- Contaminants known to be harmful to the aquatic species are known to be present in the river.

Assumptions

- The effect may not be far reaching.
- Fish health issues (like parasite load) could be impacted by lowered water quality. Have been observed in low water conditions various abnormality and fish health issues have been documented (and/or decreased fish health).

Identified Goals

Habitat Management

1. Maintain and improve habitat for the silvery minnow in the Middle Rio Grande in order to maximize recruitment and survival.
    - Evaluate existing habitat restoration practices/projects.

    We must develop an understanding of where and how habitat is needed. Thoughts on current habitat work: improving the understanding of where habitat restoration will have the greatest effect through planning, (limitations include land ownership, access, water availability).

Population Management

2. Manage silvery minnow populations in order to minimize the risk of species extinction.
    - Evaluate effectiveness of augmentation and salvage as population management strategies.
    - Evaluate the positive and negative impacts of artificial propagation and strategize to minimize the impacts.
3. Maintain genetic diversity in the silvery minnow captive population in order to minimize the risk of species extinction.

Water Quantity Management

4. Use a combination of available water and operational flexibility to meet the needs of the species.
    - Manage flows such that duration of inundation in a given spring runoff scenario is maximized.
    - Develop a suite of water management strategies to provide sufficient recruitment flow on a frequent (annual) basis (using native storage/flows and not supplemental water).
    - Maintain minimum baseline flow throughout the system for as long as possible (keep river intact from Cochiti to Elephant Butte without specific flow targets).
    - Create adequate conditions for spawning and recruitment using native water for, on average, 66% of years with no longer than 2 years between each event. (Specifics based on review of hydrographs to determine the 2-year restriction).

Legal and Institutional Constraints

5. Create institutional buy-in and Collaborative Program follow-through to support implementation of species management actions.
6. Maximize current and create new legal and institutional flexibility to manage for sustainability of the silvery minnow.
7. Obtain new funding to facilitate implementation of species management actions.

Water Quality Management

8. Minimize and/or mitigate adverse water quality conditions that affect small populations of the silvery minnow in the Middle Rio Grande.
    - Identify specific water quality problems, appropriate stakeholder, and possible strategies for reducing risk

Prioritized List of Short-Term Management Goals

1. Use a combination of available water and operational flexibility to meet the needs of the species.
2. Manage silvery minnow populations in order to minimize the risk of species extinction.
3. Maximize current and create new legal and institutional flexibility to manage for sustainability of the silvery minnow.
4. Maintain and improve habitat for the silvery minnow in the Middle Rio Grande in order to maximize recruitment and survival.
5. Create institutional buy-in and Collaborative Program follow-through to support implementation of species management actions.
6. Maintain genetic diversity in the silvery minnow captive population in order to minimize the risk of species extinction.
7. Obtain new funding to facilitate implementation of species management actions.
8. Minimize and/or mitigate adverse water quality conditions that affect small populations of the silvery minnow in the Middle Rio Grande.

Actions

The action steps identified by the working group will be listed for only the top five Goals identified in the previous section, as there was not sufficient time to adequately address all the Goals identified by the group.

During the initial discussions around action, there was concern that specific management scenarios will not be covered in the identification of actions. There ensued a discussion of how to proceed – how to include Recovery plan recommendations and PVA results. What scenarios can the PVA model test effectively? Our goal is to use the PVA model to test a variety of water & population management scenarios. Specifically, this group was interested in developing detailed PVA scenarios addressing management issues; for example, to develop a scenario that is intended to test the effect of X on Y which is relevant to Goal Z.

Based on this discussion, the group put together an Action Plan that groups the high-priority Goals into three distinct categories: 1) Management of minnow populations, habitat and water quantity; (2) Legal and institutional constraints; and (3) Management of water quality. The Action Plans listed below are presented in this order.

<u>1. Management of minnow populations, habitat and water quantity</u>

Generalized Action: Develop and expand the URGWOM and PVA models in order to evaluate the relative efficacy of alternative population and water management strategies. Efficacy of a given alternative is measured in terms of alleviating immediate risk of silvery minnow population extinction.
Responsible parties: A. Sanders, L. Towne, Hydrology Working Group; J. Parody, P. Miller, Biology Working Group
Timeline: Spring 2008

<u>Hydrologic Analysis</u>

A. Develop and analyze a suite of water management strategies that provide recruitment flows on a frequent basis.

B. Develop and analyze a suite of water management strategies that provide survival flows on a frequent basis.

C. Determine how extinction risk of overall population changes based on loss of different combination of reaches on an annual time step, with and without pumping added to model.

D. Investigate impact of cleaning up/revamping waste ways and outfalls to keep small volumes of water delivered at some small frequency (keeping a portion wet at all times); if done correctly this could keep a larger portion of the river wet consistently. Based on returning water to river at specific outfalls/locations (i.e. discontinue the loss of water through Bosque del Apache and upstream pumping). Develop models with and without pumping.

E. Evaluate the hydrologic impact of minimum flows being maintained over San Acacia and/or Isleta.

PVA Analysis

F. Evaluate the demographic impact of optimal designs of fish passages.

G. Evaluate the impacts of optimal designs of fish passages in order to evaluate the benefit of re-establishing silvery minnows in the Cochiti reach.

H. Evaluate optimal fish passage design to determine which reaches and areas should be seen as priority for habitat restoration in order to maximize minnow survivorship.
- Try to maintain a perennial connected reach, where fish passage should be constructed first.
- Look at viable habitat for the model instead of the coarse habitat that currently exists in the model.
- If the data collected represents 1 fish per square meter then it is appropriate, but there are some who advocate for refinement of the habitat model to better represent the fish per area equivalents.

I. Test sensitivity of different demographic vital rates by reach to see where is the relative benefit.
- Implement activities that effect survivorship – what would that mean for each reach and where would the maximum demographic benefit be obtained?
- If one could increase 45-day survivorship, where geographically would that be most beneficial?

J. Provide more detailed reach-specific habitat estimates and sync up CPUE with specific habitat types to estimate population by reach to use in the PVA model to determine relative extinction risk by reach
- Pp 81/82 of Recovery Plan: restore and protect habitat as necessary to protect the minnow.

K. Determine demographic benefit of specific augmentation and salvage protocols (i.e. age 0 versus age 1).
- Genetic analysis to determine genetic impact of the same scenario.
- Cost-benefits between the age classes.
- It is worth taking salvaged fish and placing in same reach versus all to Angostura reach?

  Part of reason not to do this is due to the other species of fish found in San Acacia that are not found in Angostura, in addition there are disease issues (highly stressed fish to upper reach) and there is a unique virus in San Acacia and Isleta.

L. Reevaluate the realism of current augmentation strategies in the PVA model compared to field observations.
    - Add element to analysis to incorporate the mortality of the augmented fish to the model.
    - Fish versus flow analysis – we have comparative years of flows with fish numbers but on top we have augmentation happening at the same time, and don't find a measured difference in the response of the fish in Oct even though there is augmentation on top of the flow regime itself. Data on face value doesn't indicate that augmentation will…can put a ton of fish out there (10,000) in April but if conditions aren't provided, it doesn't matter. Current modeling to include the flow component.

M. Evaluate the demographic impact of minimum flows being maintained over San Acacia and/or Isleta. P. Miller will work with R. Dudley to determine the underlying rule that specifies the fecundity rates as a function of X amount of water (fish crammed into smaller area so temp goes up, so fecundity does…?).

N. Test the relative benefit of providing recruitment flows annually or every other year.

O. Use PVA to evaluate which locations are best for habitat restoration to best effect egg entrainment.
    - Issue of X amount of habitat improvement means Y improvement in demographic – has to be calculated outside the PVA but feed back into the PVA.
    - Based on PVA results from vital rate sensitivity, design a study to determine amount of restoration needed.

P. Investigate the effect of downstream egg drift on metapopulation extinction risk.

Q. Use reach specific habitat estimates to refine pop estimates into PVA by reach.

R. Establish study design, personnel to evaluate proposed actions resulting from model
    - Develop testable hypothesis for fish response.
    - Identify required monitoring protocols, for both fish and river.

S. Use PVA to evaluate where the available water should be provided to maximize the demographic benefit to the minnow population.

T. Compare the effects of managed recession versus immediate drying. Concern that the PVA would not be able to determine what flows the fish are able to "follow".
    - Possible hypothesis testing by using pumps and a dry reach stocked with hatchery fish.

<u>2. Legal and Institutional constraints</u>

A. Identify and secure agreements/ commitments on water actions from stakeholders.
Responsible Parties: BOR/Leann Towne & John Poland
Timeframe: Feb 08

B. Investigate using native and upstream storage to maintain continuous flow in spring (pre-spawn flows) to E.B.
Responsible Parties: Corps/April
Timeframe: FY08 – FY13

C. Implement public outreach plan to obtain new funding; outreach to other non-government agency participation (environmental groups?).
Responsible Parties: Interstate Stream Commission/Grace and Public Information and Outreach work group

Timeframe: FY08
(Discussion on how to better manage/be more efficient with the funding that is available and increasing participation by current participants.)
TASK: Go through Recovery Plan to prioritize habitat restoration in terms of short-term actions that alleviate jeopardy (pp 84-88).

D. Develop dialogue & inclusion of diverse non-governmental entities or persons to get buy-in for proposed actions.
Responsible Parties: FWS/Jennifer Parody, BOR/Leann Towne, USACE/April Sanders

E. Work toward using allocated monies more effectively.
Responsible Parties: ESA Program Management Team & Executive Committee
Timeframe: FY08
(Discussion on possibly moving away from small restoration projects that might be costly but not long-term/no longevity; habitat restoration determinations of what is small but effective.)

F. Target outreach to new congressional delegates.
Responsible Parties: ISC / Grace / Rolf Peterson
Timeframe: FY09

G. After development of defendable water strategy, work on building trusting relationships on small, personal scale with additional agency representatives.
Responsible Parties: FWS/J. Parody, BOR/L. Towne, USACE/A. Sanders,
  - Improve transparency and communication with varying stakeholder to build buy in for new innovative strategies.
    - Semi-annual sessions or meetings between environmental groups and EC to improve transparency and communication; concerted, planned efforts to share with potential litigants.
    - More transparency with the NEPA processes.
  - Develop dialog & inclusion of diverse non-governmental stakeholders in order to get buy-in for the proposed action(s).

<u>3. Management of Water Quality</u>

A. Obtain permission to sample reaches currently unavailable (i.e. Cochiti Reach); Collaborative Program effort for pueblo grant to do restoration but stipulation that the information is shared.
Responsible Parties: State and whoever is currently sampling reaches
(Matter of consultation with tribes and the state; determine with state if it would be possible to have sampling points relocated to better represent reaches.)

B. Evaluate the need for consultation on point and non-point sources.
Responsible Parties: FWS/J. Parody to start with clarification and information gathering first.
(Discussion of the past attempts and possible responsible parties. FWS has tried but to no avail; there was discussion of Collaborative Program.)

C. Develop study plan to monitor water quality during episodic inflow/point-flow events.
Responsible Parties: State, Tribes, NMED, COA (storm water permits)
Timeframe: prior to Summer FY08

Rio Grande Silvery Minnow
Population and Habitat Viability Assessment

Section IV
Working Group Report:
Long-Term Species Management (Facilitating Recovery)

Long-Term Species Management (Facilitating Recovery) Working Group Report

Working Group Participants:
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Gina Dello Russo, US Fish and Wildlife Service
Kara Gillon, Defenders of Wildlife
Ondrea Hummel, US Army Corps of Engineers
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Nathan Schroeder, Pueblo of Santa Ana
Valda Terauds, US Bureau of Reclamation
Kathy Traylor-Holzer, Conservation Breeding Specialist Group (Facilitator)
Cassandra Brown, Tetra Tech EMI (Recorder)

Issues and Problems

The following is a prioritized list of issues of direct relevance to the topic of long-term management of silvery minnow to facilitate recovery, with priority given in terms of the greatest impact on silvery minnow recovery.

1. Management flexibility is limited by a lack of understanding and agreement of regulatory processes, both within and between agencies. Contributing factors include: staff turnover, complexity of the process, motivation, ownership, and risk tolerance**.**

   Discussion: This issue is complex because it seems like most people don't have a clear understanding of the socioeconomic framework. A lack of common understanding is limiting flexibility within the Collaborative Program. That lack of understanding could come from political constraints; because there is a lack of agreement within and between institutions and individuals. By within institutions, it is meant that staff turnover is causing different interpretations of different laws.

2. Flow within the Middle Rio Grande is often not adequate or at the right time to reproduce, recruit, and to complete the life cycle of the minnow. There is a lack of understanding in the spatial and temporal variability in the system. Specifically, how do we adapt to climate change and prolonged drought when providing for the minnow.

3. Increases in human population exacerbate problems with water quality, water availability and increases habitat degradation. No mechanism to avoid, minimize, or mitigate these effects on minnow and habitat.

   Discussion: Unchecked and unregulated land development and water use without long-term management and policy plans that connect the two will make long-term minnow management impossible. There is a lack of comprehensive land management planning and growth boundaries.

4. The minnow population in the Middle Rio Grande is not sustainable (long-term viability) under current conditions without intensive management. There is a lack of knowledge regarding how much viability can be increased for this population.

   Discussion: Need to come up with ways to achieve viability. The status quo isn't working. Constantly having to augment the population is not sustainability. Augmentation and salvage should eventually be less intensive. Is there a way that guidelines could be developed to determine the level of augmentation needed? Something like that could be tested in the PVA (augment every year or every 5 years, etc.). Later on in the process management could be included. There should be some way to coordinate the needs of the species to also meet other goals. What role is the population going to play in the long term sustainability of the species? Will the ultimate goal for the Middle Rio Grande always center on the population of the species?

5. Habitat fragmentation (between and within reaches, such as overbanking and fish barriers) and quality limit silvery minnow population long-term viability

   Discussion: Is fragmentation part of the viability statement? Fragmentation means they are less risk-tolerant. If fragmentation is dealt with, then the fish could move out of risky areas to help sustain themselves during dryer times. Fragmentation issue and life history have genetic consequences that are bad. Habitat fragmentation is mostly caused by dams and fish barriers. Lack of overbank flows is also an issue. Could habitat fragmentation be lumped with habitat quality? A problem is a lack of understanding of what habitat quality means and how to provide it.

6. The lack of involvement and ownership of their role in the current status of the minnow by stakeholders within the Middle Rio Grande, the contributing watershed, and throughout the historic range reduces political will that limits resources and narrows the range of potential contributions that could assist in long-term minnow recovery.

7. The current range of silvery minnow is severely restricted from historic and is not enough to ensure long-term viability of the species. Feasibility and effectiveness of applying Middle Rio Grande management actions in unoccupied range is unknown.

8. Degradation of water quality by increased human impacts in the Middle Rio Grande could negatively affect habitat quality and health of minnow populations; increases extinction risk.

   Discussion: Human impacts includes increased impervious surfaces, stormwater inputs, treatment plants, chemical spills, new and emerging contaminants.

Data Assembly and Analysis

1. Management flexibility is limited by a lack of understanding and agreement of regulatory processes, both within and between agencies. Contributing factors include: staff turnover, complexity of the process, motivation, ownership, and risk tolerance**.**

   Facts

   - There is a myriad of laws and agreements.
   - Mainstem Rio Grande exists between levees.
   - Reservoirs exist at Elephant Butte, Jemez Canyon, Cochiti, Abiquiu, El Vado, Heron, Galisteo
   - Basin – Rio Grande Compact, adjudication, imported/contract water
   - Different agencies have different and shifting priorities, missions, and authorities that they operate under.
   - Differing risk tolerance exists among stakeholders.

- Management flexibility with the laws-one agency by itself cannot implement something by itself-must be in cooperation with other agencies. Water management entities have to work with other affected entities.
- Due to flood risk, natural hydrograph cannot be moved without increased threat to human life/property.
- There are lots of assumptions about the Rio Grande compact.
- It is unknown exactly how much water is available.

Assumptions
- Crisis management actions are repeatable.
- Flexibility exists-organizing or capturing agreements so implementing management options can be streamlined in the future.
- Obstacles of long term implementation of crisis options under different conditions.
- It is possible to deal with flood control issues.
- Flexibilities are only pursued in a crisis, as opposed to tools to use for the long term.

2. Flow within the Middle Rio Grande is often not adequate or at the right time to reproduce, recruit, and to complete the life cycle of the minnow. There is a lack of understanding in the spatial and temporal variability in the system. Specifically, how do we adapt to climate change and prolonged drought when providing for the minnow.

Facts
- Water supply is highly variable, both seasonally and annually.
- The correlation between flow and habitat varies by reach.
- Long-term average - 80% of water comes from outside MRG (from Otowi gage).
- 2\3 of water comes from main stem with limited reservoir management options. Nearest regulating reservoir is ~ 2 days away from MRG , 5 from San Acacia (from Otowi gage)
- Total native water storage is only 15% of long term flow at Otowi.
- CO water management can impact the timing of water availability and flow in Middle Rio Grande.
- The minnow needs moving water (which does not necessarily mean continuous flow) year round to spawn and complete its life cycle.

Assumptions
- Traditional supplemental sources of water will decrease through time.
- ~3000 CFS in May for ~10 days at the Albuquerque gauge produces a spawning event.
- Through time, without floodplain management, ~ 3000 CFS may not be enough water to sustain spawning in the future-particularly in the upper reaches.
- Climate change will have an effect on the system.

Knowledge gap
- The range of flow attributes that allow the minnow to complete its life cycle.

Discussion
- Putting the model into GIS context, different catastrophes have different impacts on the fish. Within each reach, the GIS portion is not able to find where a catastrophe would be more or less likely. There are point sources of catastrophic input-some may be short impacts, but others may be longer term. Could try to estimate impacts throughout a particular reach, way the model is built, without GIS, available to look at each reach independently. A severe drying event is not local, it affects all three reaches to different degrees.

- Colorado does not divert from Nov. 1 to March 1, when estimates are made for year and put cuts on natural hydrograph. Colorado's water management has an impact on the silvery minnow recovery. They manage based on rights. When nobody is using water, they try to send as much as they can. First thing that comes through is contribution to compact. When New Mexico is meeting compact obligations, there is much more flexibility upstream.
- Water management could really become system\floodplain management, which includes sediment, species, vegetation, people, habitat management. Could we get to a point of looking at long-term flow management trying to balance upstream and downstream impacts? Evolving into a system wide approach to manage-climate change and prolonged droughts are on the table.
- Outside sources (San Juan Chama) of supplemental water will persist through time. During climate change and shortage, the yield could be less.
- Silvery minnow requires increases in flow in spring to spawn and sustainability in flow for recruitment.
- Ability to store and hold water is limited.

3. Increases in human population exacerbate problems with water quality, water availability and increases habitat degradation. No mechanism to avoid, minimize, or mitigate these effects on minnow and habitat.

   Facts
   - No mechanism to avoid, minimize and mitigate the effects of increased human population on the minnow.
   - Increased population and competition for water will result either in increased transfers (diminished stream flow) or increased depletions.
   - Diminished stream flow degrades water quality.
   - Disconnect between land use and water in various jurisdictions negatively impacts the entire basin ecosystem.
   - Threatened destruction, overutilization, disease, other natural man-made factors (from five factors of endangered species).

   Assumptions
   - Local human population will increase, leading to increased competition for, and consumption of, water.
   - Reallocation of water to new uses is a disincentive to water conservation among urban residents.

   Discussion
   - Urban residents will not conserve water because of dis-incentive (re-allocation to new uses) to conserve water (does not apply to agricultural users due to Senate bill #461).
   - An opportunity for municipal water users to contribute conserved water to river (also insecure water supply, etc.) is an idea for later in the workshop.

4. The minnow population in the Middle Rio Grande is not sustainable (long-term viability) under current conditions without intensive management. There is a lack of knowledge regarding how much viability can be increased for this population.

   Facts
   - No guaranteed\secured water supply.
   - There is poor congruence between quality of habitat and water availability.

Assumptions
- Limit the need for augmentation and salvage in the Middle Rio Grande.

Knowledge Gap
- Extent to which long-term viability can be improved in the river.
- Minimum amount of intensive management needed for a sustainable population.

5. Habitat fragmentation (between and within reaches, such as overbanking and fish barriers) and quality limit silvery minnow population long-term viability.

Facts
- The minnow habitat has been progressively fragmented.
- Aquatic habitat diversity (e.g. depth, velocity, substrate) has decreased (from aerial photographs, channel cross-sections).
- Habitat fragmentation affects genetic diversity.

Assumptions
- Management options such as fish ladders that restore habitat connectivity can improve minnow population viability.

Knowledge gap
- Minimum amount of population management necessary to sustain a viable population in the Middle Rio Grande.
- Extent to which long-term viability can be improved in the river.

6. The lack of involvement and ownership of their role in the current status of the minnow by stakeholders within the Middle Rio Grande, the contributing watershed, and throughout the historic range reduces political will that limits resources and narrows the range of potential contributions that could assist in long-term minnow recovery.

Fact
- Recent strategies (based on Big Bend) have been developed for approaching stakeholders.

Assumptions
- There will be resistance to silvery minnow population expansion among stakeholders.

7. The current range of silvery minnow is severely restricted from historic and is not enough to ensure long-term availability of the species. Feasibility and effectiveness of applying Middle Rio Grande management actions in unoccupied range is unknown.

Facts
- There is an overlap of range with the Pecos fish (blunt-nose shiner).
- Historic distribution is known.
- Difficult and time-consuming process in Pecos due to similarities to other fish species
- Will be reintroduced in Big Bend National Park section of the Rio Grande.
- The Middle Rio Grande will serve as source population for reintroduction.

Assumptions
- Non essential experimental population would be successful.
- Acting as a source population for reintroduction will not negatively impact minnow in the Middle Rio Grande.
- Water quality may play a part in the reason the minnow is almost gone.

- High levels of DDT would be more of a water quality issue at Big Bend.
- Potential areas for range expansion include: RG- Presidio to Amistad Reservoir, RG-Amistad reservoir to Falcon Reservoir, PR Sumner Dam to Brantley Reservoir, PR-Red Bluff Reservoir to Amistad Reservoir, RG- Elephant Butte to Presidio, PR- Brantley Dam to Red Bluff Reservoir.
- Population and range expansion will improve viability and recovery of the silvery minnow.

Knowledge Gap

- Funding source for reintroduction is unknown.
- Why the minnow was eradicated from the Big Bend area.
- Causes of range contraction are unconfirmed (if these conditions still exist).
- Feasibility and effect of applying Middle Rio Grande management actions in unoccupied range.

Identified Goals

1. *Management flexibility is limited by a lack of understanding and agreement of regulatory processes, both within and between agencies. Contributing factors include: staff turnover, complexity of the process, motivation, ownership, and risk tolerance.*

   1. Authorize the Collaborative Program within one year as a first step to stabilize annual funding.
   2. Improve understanding of water management processes by stakeholders.
      i. Provide an Executive Summary-water management processes
      ii. Provide an Executive Summary-supplemental water
   3. Improve communication and coordination within agencies.
   4. Improve communication and coordination among agencies.
   5. Make management flexibility more obvious including the process to implement agreements in order to streamline future implementation.

   Discussion:

   - Get a senator on the appropriations committee, or there will be no money ($120million). Educate the new person, stabilize the funding.
   - Need to look at who water has been leased from in the past. Getting an executive summary for how the water is moved down the river, maybe a summary of where/how the 8000 acre/feet comes from? There could be more than one executive summary-besides water management. There are so many aspects that the summary could be super thick. The recent decision makers guide has a decent explanation of what/who controls the water.
   - There needs to be some balancing of risk tolerance. The technical folks should be getting stuff done. If the EC says to do something, the workgroups should not be limited.
   - More communication within agencies between technical and management levels would be a good thing. Engage within agencies-communication meetings specifically for the MRG. These meeting tend to be hit and miss because everybody is so busy. There are symposiums, and people from the EC-don't show up. It ends up being the same people talking to the same people about the same thing.
   - The level of risk one person is willing to take could be different than that for another person. Managers may have a tolerance for risk that technical people don't. Or a manager could leave and the new manager's risk tolerance is different.

- Clearly identify and communicate flexibilities so that everybody is aware of impacts on flood control situations. The laws are all there, but the understanding of them is not.
- Main stem issues between levels for flood control reservoirs and other reservoirs and the basin as a whole.

2. *Flow within the Middle Rio Grande is often not adequate or at the right time to reproduce, recruit, and to complete the life cycle of the minnow. There is a lack of understanding in the spatial and temporal variability in the system. Specifically, how do we adapt to climate change and prolonged drought when providing for the minnow.*

6. Provide an adequate and secure water supply to allow the silvery minnow to complete its life cycle.
7. Determine the range of attributes of water flow required by the silvery minnow, including flow, timing, duration, quality and return interval.
8. Determine the role of these flow attributes on silvery minnow habitat and use the results for implementation and maintenance (look at surface water/groundwater interaction as part of this, including future scenarios).
9. Conduct an independent rigorous analysis of the long-term impacts of increasing connectivity between surface water and groundwater throughout the entire MRG system by looking at the infrastructure and delivery.
10. Develop strategies to ensure survival of the silvery minnow in worst-case scenarios.

Discussion:

- Need to get agencies to participate in watershed discussion-losing 10-18% of wet water because they are not involved.
- Need to find out the time, quantity, quality, return interval and duration of water that the minnow needs to live. During drought, lower peak in runoff, during those times, try to determine if something can be done within individual reaches to ensure fish survival.
- How to improve the natural habitat as a goal, the refuge is considering going after funding to look at infrastructure of the river. The Collaborative Program might benefit by looking at the structure-how can water delivery be improved? If the river needs to make an adjustment to be more stable, than what are the costs and benefits of that?
- Re-look at the entire MRG project. There are multiple places where the system is ready to burst, or break, and other places where the levee is way too high.
- Linking in seasonality of recruitment flow. Within the system a flow less than 3000 CFS during the 45-day recruitment period could be very detrimental. How important is it to manufacture those flows, or work with it in the model.
- Have in place strategies to ensure species survival during worst-case scenarios.
  - Investigate habitat mosaic within reaches.
  - Investigate non-random nature of drying.
  - Investigate including seasonality in model.
  - Investigate different flow schedules.
- The annual time-step models, calculate survival rates monthly, can vary monthly survival rates for later in the year. Does it make more sense to apply water during the recruitment period? If you could increase frequency of stream flows, is that more important than providing base flows year round? How many fish are produced in May and how many come back to spawn the next month is what really matters.

- Different qualities of water between reaches. Some places are always wet, others seem to go dry all the time. The model does take this into account. Going to lose the connectivity in the model, all the other stuff can be worked into it. This particular PVA doesn't look at genetic issues, so that needs to be thought of outside of the model.

3. *Increases in human population exacerbate problems with water quality, water availability and increases habitat degradation. No mechanism to avoid, minimize, or mitigate these effects on minnow and habitat.*

11. Synthesize information on ecosystem, human population, habitat, water, land use, and climate change to develop projections of future trends in order to implement adaptive management strategies (possible PVA scenario: AOP process changes, task work group).
12. Develop opportunities and incentives for municipal water users to contribute conserved water to the river (possible PVA scenario: promote existing mechanism for agricultural users to do this).
13. Investigate the impacts and long-term trends of transferring water rights upstream.

Discussion:
- Proposal on adaptive management does not consider status of species or the habitat.
- Some kind of an annual effort to update and manage the AOP (annual operating plan) could be beneficial.

4. *The minnow population in the Middle Rio Grande is not sustainable (long-term viability) under current conditions without intensive management. There is a lack of knowledge regarding how much viability can be increased for this population.*

14. Assess the long-term viability of the minnow in the Middle Rio Grande and feasible options to improve viability. This should include the range of potential conditions and projected future trends, including catastrophic events.
15. Minimize the need for intervention while maintaining a healthy minnow population.

Discussion:
- Catastrophic events can have serious effects on the population. In the last 10 years, there is very limited info on the severity of these events on the population.
- The impact of wastewater facilities, specifically, there effects on water quality, need to be evaluated in the PVA. These things could be tied to fish health. An increase in human population density leads to a higher risk factor of these events.

5. *Habitat fragmentation (between and within reaches, such as overbanking and fish barriers) and quality limit silvery minnow population long-term viability.*

16. Continue to move long-term management to an eco-system wide approach to:
    - Increase stakeholder involvement;
    - Move beyond single issue management.
17. Improve connectivity between and within reaches for the silvery minnow (possible PVA scenario: investigate impacts of increased connectivity).
18. Develop a comprehensive and consistent habitat quality monitoring program system-wide.

6. *The lack of involvement and ownership of their role in the current status of the minnow by stakeholders within the Middle Rio Grande, the contributing watershed, and throughout the historic range reduces political will that limits resources and narrows the range of potential contributions that could assist in long-term minnow recovery.*

   19. Once opportunities for expansion are identified, engage the full range of stakeholders.

   Discussion:
   - Only working with "throughout the historic range" part of number 6. The rest was given to the short-term group.

7. *The current range of silvery minnow is severely restricted from historic and is not enough to ensure long-term availability of the species. Feasibility and effectiveness of applying Middle Rio Grande management actions in unoccupied range is unknown.*

   20. Understand the role of additional populations on improving species viability (possible PVA scenario: Investigate the impact of range expansion on minnow population viability).

   Discussion:
   - Objective: To understand the role that additional species have on population viability. It's understood what the roles are, but analyzing it with the PVA and population demographics. Feasibility of using the techniques is unknown.

Top 5 long-term goals

1. Provide adequate and secure water supply to allow the silvery minnow to complete its life cycle. [Goal 6]
2. Continue to move long-term management to an ecosystem wide approach. [Goal 16]
3. Improve connectivity between and within reaches for the silvery minnow. [Goal 17]
4. Synthesize information on ecosystem, human population, habitat, water quality and quantity, land use, and climate change to develop projections of future trends in order to implement adaptive management strategies. [Goal 11]
5. Develop opportunities and incentives for municipal water users to contribute conserved water to the river. [Goal 12]

Actions

Actions are first provided for high-priority goals listed previously.

6. Provide an adequate and secure water supply to allow the silvery minnow to complete its life cycle.

   A. Seek the ability to store compact water in Abiquiu for strategic water reserve purposes.
   Responsible Parties: In progress by USACE, ABCWUA, and ISC

   B. Support ongoing efforts for long-term re-regulation of spring snowmelt run off at Cochiti reservoir for minnow recruitment purposes (bridging strategy).

   C. Investigate other possible activities at Cochiti that would promote long-term storage for consumptive use in the middle valley. Dependent on the results of the Cochiti baseline study currently being conducted by USACE and Cochiti Pueblo.
   *Timeframe:*Congress has approved the WRDA Bill, which improves the ability to move forward on contracts.

   Discussion:
   - Goal 11 (develop opportunities for municipal water users to contribute…) is being addressed as an action under this goal.
   - Is El Vado available to store water - in addition to Cochiti?
   - Albuquerque Bernalillo County Water Utility Authority through the San Juan Chama diversion project is putting in more water than depleting, which is part of the storage problem.
   - Possible to have a building incentive program as a way to get municipal water users involved, or could be as simple as implementing a check-off on the water bill (deferred to communication and outreach).
   - A base-line study for re-regulating spring flow runoff at Cochiti is already underway by USACE, but could be supported for the long-term by the MRGCD.
   - Promote existing mechanism for agricultural users to contribute conserved water to environmental uses.

16. Continue to move long-term management to an eco-system wide approach to:
   - Increase stakeholder involvement;
   - Move beyond single issue management.

   D. Inform the Collaborative Program on the benefits of an ecosystem wide approach beyond the two species, including minimizing the risk of future listings (e.g. minimize floodplain encroachment).
   Responsible Parties: Fritz Blake is currently developing a MRGEMP which could be presented to the Collaborative Program.

   E. Consider status and trends of ecosystem in AOP to address short-term and long-term water strategies.
   Responsible Parties: Leann Towne will take to BOR and April Sanders will take to USACE.

   F. Identify and document players, roles and responsibilities and opportunities for ecosystem management approach (land, water, wildlife, recreation, safety, sediment).
   Responsible Parties: Gina Dello Russo can begin the process with a questionnaire.

17. Improve connectivity between and within reaches for the silvery minnow.

   G. Projects are already in progress to improve connectivity at Isleta and San Acacia dams -there are current restoration programs as well.
   Responsible Parties: Collaborative Program HRW will be monitoring the implementation and effectiveness of habitat restoration projects to date, particularly in the Albuquerque Reach.

   H. Focus habitat restoration in areas that have perennial surface flow supported by groundwater:
      - In and around Belen,
      - Anostora Dam north to Cochiti,
      - Highway 60 at Bernardo down to Escondida,
      - San Marcial south (outside MRGESCP scope)
      - Elephant Butte State Park and Bureau Land (outside MRGESCP scope).

   Discussion:
   - Currently there are two fish passage projects; San Acacia an absolute barrier for upstream movement (BOR), and Isleta, an absolute barrier during irrigation seasons (USACE).
   - The Isleta barrier is a problem, because most of the fish movement is probably during warmer months.
   - Evaluate the projects/data already available for islands and point bars while looking for opportunities to do more.
   - Are there opportunities to work with the irrigation district- to create local flows and circulation-which is meant to increase outflow to keep river wet in areas that are normally going to be dry.
   - HRW has developed a SOW to produce monitoring plans for each reach-in order to compare different techniques for implementation and effectiveness.
   - HR work could be done specifically for recruitment in areas with good connectivity (In and around Belen, Anostora Dam north to Cochiti, hwy 60 at Bernardo down to Escondida, San Marcial south) HR could promote recruitment of the minnow, bar and island restoration and backwaters etc. These locations would also be good to do some PVA modeling.

11. Synthesize information on ecosystem, human population, habitat, water, land use, and climate change to develop projections of future trends in order to implement adaptive management strategies (possible PVA scenario: AOP process changes, task work group).
   I. Develop an adaptive management working group to evaluate all aspects of the ecosystem
   Responsible Parties: Bring to EC to approve preliminary discussion.

1. Authorize the Collaborative Program within one year as a first step to stabilize annual funding.

   J. Non-fed stakeholders in the EC should review current language and modify as necessary in concert with other stakeholders, and then take to DC to support authorization.
   Responsible Parties: R. Schmidt-Peterson will discuss with S. Farris to take to EC.

2. Improve understanding of water management processes by stakeholders.
   i. Provide and executive summary-water management processes.
   ii. Provide an executive summary-supplemental water.

   K. Create executive summary of the water management process and make easily available (compile from existing documents).

L. Provide easy access to the Reclamation supplemental water process. Post on MRGESCP website-needs to be updated and maintained.
Responsible Parties: V. Terauds will make sure that there is a link to the website.
Timeframe: End of December, 2007

M. Conduct an annual field trip to orient new participants and others on issues associated with facilities and habitat in the basin.

3. Improve communication and coordination within agencies.
4. Improve communication and coordination among agencies.

See communication and collaboration Working Group Report for action steps for these goals.

5. Make management flexibility more obvious including the process to implement agreements in order to streamline future implementation.

N. Document the roles, responsibilities, and opportunities for flexibility for creating habitat or providing water to sustain habitat-partially available in Middle Rio Grande Water Assembly Regional Water Plan (appendix).
Responsible Parties: R. Schmidt-Peterson, L. Towne, and A.Puglisi will make contacts to each signatory to compile information. Outside reviewer needed for assessment of information (Utton Law Center suggested).
Resources: Should be less than $10,000
Possible Outcome: Symposium on legal and policy issues that include this compilation (could be conducted annually).

O. Use compiled data to map out the steps needed to implement the options and assess the reliability of those providing water for long-term management.
Responsible Parties: R. Schmidt-Peterson, L. Towne and A. Puglisi will initiate contacts to compile data and document processes.
Timeframe: Summer 2008

Discussion:
- Documenting various jobs and constraints of each signatory, in order to create a better understanding of flexibility within agencies.
- Management opportunities differ between mainstem Rio Grande between levees, reservoirs and basins.
- A similar document exists in the appendix of the MRG water assembly section of the regional water plan.
- Hiring a private contractor to compile data was brought up and rejected-consensus was reached to have somebody make calls, then have an outside, unbiased water expert review it, such as Dick Kreiner
- An annual symposium on legal policies and constraints with a compilation at the end could help to document various signatories roles.

7. Determine the range of attributes of water flow required by the silvery minnow, including flow, timing, duration, quality and return interval.

P. Compile a comprehensive list of our available tools to evaluate the range of attributes.

Q. Identify strengths, weaknesses, and gaps.

Responsible Parties:

- V. Terauds will contact URGWOPS to begin compilation for water flow.
- J. Remshardt to contact other groups to begin compilation for biological factors.
- V. Terauds will take list to SWM to request analysis with liaison with science group to assist with biological component.

*Timeline:*Compile list by March 1, 2008

Discussion:

- URGWOPS (Upper Rio Grande Water OPerationS) hiring contractors are tools that are available in order to determine water flow. The problem with URGWOPS is that it can model the flow, but not the biology component.
- Compile what URGWOPS started with, and update from there USACE has most of the GIS component.
- The timeline for this could be around the SOW, which is around the end of March. The timeline for this is the end of Feb 08. SWM can compare the list, but it will need to be a joint discussion between SWM and ScW.

8. Determine the role of these flow attributes on silvery minnow habitat and use the results for implementation and maintenance (look at surface water/groundwater interaction as part of this, including future scenarios).

R. Conduct airborne LIDAR survey to determine relative elevation of islands and bars in the river.

Responsible Parties:

- O. Hummel will find the most recent LIDAR data available, then discuss with Habitat Restoration workgroup and take to EC.
- R. Schmidt-Peterson will pull together survey data for Albuquerque Reach.

*Timeline:*January 2008-depends on data available and needed.

S. Perform HEC-RAS analysis to determine recruitment habitat availability at different flows and ideal sustainability.

Responsible Parties: R. Schmidt-Peterson, O. Hummel and V. Terauds will find out the most current analysis and bring to workgroups to discuss, then take to EC.

Timeline: January, 2008 – will depend on result of action R.

Discussion:

- Mark Horner has already examined higher flow flood times out into the floodplain (2005 study).
- Could be way to look at islands and bars using aerial photography.
- USGS study on habitat depending on flow velocity, could expand on it by using HEC-RAS analysis.
- When habitat needs are defined water requirements could change.
- Updating water needs based on what the minnow needs by estimating resources until it is known if there are other types of surveys available.

9. Conduct an independent rigorous analysis of the long-term impacts of increasing connectivity between surface water and groundwater throughout the entire MRG system by looking at the infrastructure and delivery.

T. Develop a Scope of Work with diverse group input with a budget to conduct analysis (SWM has already developed a SOW for a workshop to evaluate alternatives for the San Acacia Reach).
Responsible Parties: G. Dello Russo and R. Schmidt-Peterson with MRGCD, district and USACE involvement.
Timeframe: Summer 2008

10. Develop strategies to ensure survival of the silvery minnow in worst-case scenarios.

U. Develop a protocol for a worst case scenario (minnow disappears in the wild) as part of existing captive propagation management plan.
Responsible Parties: M. Osborne to take to committee meeting.
Timeframe: Spring 2008-discuss at next captive propagation genetics working group meeting.

Discussion:
- Go through the state engineer to purchase senior surface water right. Pump it, and apply it in certain areas up and down the river-can pump for short periods of time without it really being felt by the system.
- The ISC, OSC position- if you sell your water rights, you can't use water on that land at all.
- In times of severe drought, would be relying on captive breeding instead of egg collection for genetic diversity.
- Need to plan for a worst-case scenario, which could happen in a matter of months-need to get a contingency plan in place to avoid the time crunch.

13. Investigate the impacts and long-term trends of transferring water rights upstream.

Discussion:
- SWM is currently developing a Scope of Work to use models to investigate the impacts of water rights transfers.

14. Assess the long-term viability of the minnow in the Middle Rio Grande and feasible options to improve viability. This should include the range of potential conditions and projected future trends, including catastrophic events.

V. Complete and evaluate the results of the PVA. Future synthesis will continue to be needed to update the plan based on new available info and conditions.
Responsible Parties: PVA technical team

Discussion:
- PVA in conjunction with other modeling tools.

15. Minimize the need for intervention while maintaining a healthy minnow population.

W. Use PVA result to guide management strategies.
Responsible Parties: PVA technical team

18. Develop a comprehensive and consistent habitat quality monitoring program system-wide.

    Discussion:
    - Currently being done at Albuquerque and Isleta reaches, there is a proposal (SOW being developed) to extend system wide. Ondrea and Gina are already participating. The outcome should be a prioritization of areas for additional monitoring work.

19. Once opportunities for expansion are identified, engage the full range of stakeholders
    Covered under goals 4 and 10.

20. Understand the role of additional populations on improving species viability (possible PVA scenario: Investigate the impact of range expansion on minnow population viability).

    X. Investigate the impact on viability of additional populations by using the PVA at Big Bend, Cochiti and other possible sites.

Rio Grande Silvery Minnow
Population and Habitat Viability Assessment

Section V
Working Group Report:
Communication and Collaboration

Communication and Collaboration Working Group Report

Working Group Participants:
(Note: Some participants attended only a subset of the sessions)
Rick Billings, HDR (representing ABCWUA)
Scott Bulgrin, Pueblo of Sandia
Michelle Cummer, US Fish and Wildlife Service
Kathy Dickinson, US Bureau of Reclamation
Grace Haggerty , Interstate Stream Commission
Estevan Lopez, Interstate Stream Commission
Leslie McWhirter, US Army Corps of Engineers
Ann Moore, New Mexico Attorney General's Office
Steve Platania, American Southwest Icthyological Researchers
April Sanders, US Army Corps of Engineers
Matt Schmader, City of Albuquerque Open Space
Subhas Shah, Middle Rio Grande Conservancy District
Ann Watson, Pueblo of Santo Domingo
Dennis Hosack, CBSG (Facilitator)
Rachelle Schluep (Recorder)

Issues and Problems

Approximately twenty different issue statements were created by this working group, which were ultimately classified into four major themes. These themes were then prioritized as presented below, with the ranking indicated by the numerical score accompanying each theme.

<u>Sociological (18)</u>

A lack of trust within the Collaborative Program hinders collaboration; decreases willingness to share information and contribute resources; and inhibits open communication, active listening, and independent initiatives outside of the collaborative process.

- Complaints of data ownership/privacy of data.
- Lack of trust.
- Have plenty of meetings, but still lack communication; inability to talk openly.
- More emphasis on listening (less talking).
- Lack of consistent participation.

<u>Decision-Making (17)</u>

The absence of effective Executive Committee leadership results in: a lack of unity around a common vision, decisions being changed, a lack of clear goals a lack of inclusion, independent agency activity, and inactivity.

- Objectives of each agency have to be clearly stated for good collaboration.
  - Why are you at the table and what are each agency's primary objectives?
- Lack of coordination between agencies.
- Lack of understanding of the various legal constraints (numerous sources of legal constraints).
- Lack of communication between disciplines (i.e. scientists vs. water experts; scientists vs. Collaborative Program bureaucracy; between scientists themselves {ScW workgroup}); between agencies and within agencies.

- Agencies within the Collaborative Program won't accept decisions – continue to bring up issue in different forums to try and change decisions ("bad" decisions).
- Agencies going off on their own outside the collaborative process when they don't like the Collaborative Program's decisions. Lack of trust and disagreement with the Program agenda.
- Misrepresentation of agency objectives/ misrepresentation of agency agreement with Collaborative Program processes and decisions.
- There are Program goals and objectives on the Collaborative Program web site and in the MOU that everyone signed: there are many "visions", but not a common **unity.**

Scientific (14)

A lack of central repository for deliverables (reports, data, maps, etc.) leads to complaints about information sharing. There is also a disconnect between disciplines (water, habitat, science, and decision makers) due in part to the absence of data synthesis, timely discourse of scientific information, and clear recommendations on scientific issues.

- Sharing data difficulties – knowing the right level of data sharing.
- Complaints of data ownership/privacy of data.
- Lack of communication between disciplines (i.e. scientists vs. water experts; scientists vs. Collaborative Program bureaucracy; between scientists themselves {ScW workgroup}); between agencies and within agencies.
- Disconnect between scientists and Collaborative Program decision makers/bureaucracy.
- Agencies going off on their own outside the collaborative process when they don't like the decisions made by the Collaborative Program; Why: lack of trust and non-agreement with the Program agenda.

Outreach (5)

Outreach is not currently a priority. While the Executive Committee of the Collaborative Program assigned outreach as a priority, there has not been a concurrent time commitment to work on outside issues. This results in lack of support (public, political, monetary) and implementation of the outreach program.

- Lack of public outreach (more transparency); increased public visibility.
- Lack of inclusion/priority of northern reaches (i.e. Cochiti).
- Lack of communication about the Collaborative Program (public outreach) to state and federal government leadership and legislators.

Data Assembly and Analysis

1. A lack of trust within the Collaborative Program hinders collaboration; decreases willingness to share information and contribute resources; and inhibits open communication, active listening, and independent initiatives outside of the collaborative process.

   Facts

   - About 20 diverse groups.
   - More than one set of values (among those groups).
   - More than one mandate (among those groups).
   - All operate under regulations: tribal, state, federal.
   - Personalities and interpersonal skills/biases influence dynamics.
   - Varying levels of background, institutional knowledge (years involved with program) and education.

Assumptions

- Various ulterior motives.
- Educational prejudices among constituencies.
- Organizational biases.
- Scientific integrity based on organization, education.

2. The absence of effective Executive Committee leadership results in: a lack of unity around a common vision, decisions being changed, a lack of clear goals a lack of inclusion, independent agency activity, and inactivity.

Facts

- The Executive Committee revisits previous decisions.
- Certain signatories participate less.
- Alternates often attend Collaborative Program meetings and workshops.
- Participants are not all well versed in Collaborative Program issues/documents.
- Communication within an organization may not be effective (believed to be primarily due to the size or structure).
- Action agencies bear primary responsibility for ESA compliance.
    - Conversely, the action agencies do not own the resources (water) necessary for ESA compliance.

Assumptions

- Leaders can make people do things.
- If an executive does not show up that it is not a priority to that entity.
- Alternates do not as readily make decisions (versus executive).
- Primary executive committee members do not attend because it is not a priority for them.
- Written goals mean common vision, consensus, or unity.
- Reorganization would increase Collaborative Program effectiveness.
- No permanent funding authorization for Collaborative Program creates an unstable environment.
- Executive Committee leadership is a shared responsibility.

3. A lack of central repository for deliverables (reports, data, maps, etc.) leads to complaints about information sharing. There is also a disconnect between disciplines (water, habitat, science, and decision makers) due in part to the absence of data synthesis, timely discourse of scientific information, and clear recommendations on scientific issues.

Facts

- Funding has been provided (in FY09) to begin development of a central repository.
- Annual symposium is provided by the Collaborative Program to distribute information.
- The annual symposium is not well attended particularly by decision makers.
- Workgroups can require raw data for contracted projects, they can not require data be submitted for projects funded through a grant.
- Individual disciplines typically meet monthly.
- Interdisciplinary meetings are task oriented.

  Discussion: There are four workgroups within the Collaborative Program: science, habitat, species and water management, and public outreach. The individual groups meet frequently but only occasionally with each other – and when they do it is usually to work on a single item. Interdisciplinary meetings (joint workgroup meetings) are task oriented.

Assumptions

- Disciplines do not care about the work or results of other disciplines.
- Sometimes scientists are hired by an organization to further that organizations agenda.
- Workgroups convey concise, useful, accurate, and timely information to the EC.
- Collaborative Program decision-makers will use the work group information to further the Program.
- Assumption that the data can readily be synthesized and generate clear results.
- Scientific studies provide clear results in a short period of time.
- The science makes the management easy and obvious.

4. Outreach is not currently a priority. While the Collaborative Program Executive Committee assigned outreach as a priority, there has not been a concurrent time commitment to work on outside issues. This results in lack of support (public, political, monetary) and implementation of the outreach program.

Facts

- Public Information and Outreach workshop has developed and the EC has approved an FY 2008 Action Plan.
- Outreach costs money, takes time, and effort.
- To be effective, an outreach program needs to be long-term.
- The Collaborative Program has hired a contractor and a web site is under construction.

Assumptions

- The public does not really care about/hates the silvery minnow.
- Increasing outreach efforts will lead to increased funding.
- The presence of endangered species/effects of ESA threatens land and water owners.
- The Collaborative Program does not have a positive image with elected officials.
- It is difficult to convey scientific information to the public, especially through the media.

Note

Long-term Species Management (Facilitating Recovery) working group was not able to get to the following problem statement, and asked for assistance from the Communication and Collaboration group:

- The lack of involvement and ownership of their role in the current status of the minnow by stakeholders within the MRG, the contributing watershed, and throughout the historic range reduces political will that limits resources and narrows the range of potential contribution that could assist in long-term minnow recovery.
    - Group recommendation: Contact the mid-region council of governments which includes council that includes municipalities and state and local groups from Sandoval to Valencia county; the council is an overall umbrella that can reach a lot of stakeholders; may be a good communication network to reach ~80% of the stakeholders identified.

The Long-term group representative brought up two issues: (1) short-term: internal group inclusion; (2) long-term: external group inclusion – TX, CO, other MRG stakeholders.

Short-term: internal group inclusion

- Inclusion: getting more people involved; giving more people a seat at the table.
    - Can be worked on using action steps.
    - Within current realm of stakeholders, need to make sure we are really listening to everyone.

Long-term: external group inclusion

- The Recovery Plan includes TX and CO and is outside the scope of the Collaborative Program; when the Plan was first drafted, it included representatives from TX and CO.

Identified Goals

1. *A lack of trust within the Collaborative Program hinders collaboration; decreases willingness to share information and contribute resources; and inhibits open communication, active listening, and doing your own thing outside of the collaborative process.*

   1. Define the parameters of trust and accountability and determine the parameters by which that definition is violated.
      Mechanism: Partnering agreement: not an intergovernmental commitment, but a statement by which a group agrees to operate; outlines the common goals of a group and identifies how members will be held accountable for violation of partnership parameters.

   2. Develop more multi-organization projects that require collaboration to complete successfully (vs. single organization projects).
      - Compliance steps need to be looked at more as collaboration than a hindrance; working together from the beginning to make it the best possible project (i.e. permitting); early coordination is the key.
      - Example: second phase of the ISC HR construction project – began with early coordination meetings at the ISC building; multiple stakeholders involved in the upfront planning of the projects made the process much smoother; best projects are those that have multi-agency buy-in from the beginning.
      - What happens when there is buy-in from the MRGESCP member in an organization, but no buy-in occurring on a higher level in that organization? – **No good answer to this question**
      - Organizations working together to make the project run smoothly.
      - Based in early collaboration (group meetings at the onset of a project).

   3. Develop policies that encourage, and in some instances, require Collaborative Program participant transparency (open dialogue).
      - Recent Taos workshop – discussion of why organizations are involved in the Collaborative Program; smaller groups discussed their reason for being in the Program and what they benefit from being in it.
      - Need concise statements about why organizations are in the Collaborative Program and what their organizations bring to it.

   4. Develop opportunities for Collaborative Program participants to attend team-building exercises.

2. *The absence of effective Executive Committee leadership results in: a lack of around a common vision, decisions being changed, a lack of clear goals a lack of inclusion, independent agency activity, and inactivity.*

   5. Agree to and distribute a common Collaborative Program vision statement and mission statement that can then be articulated by ALL participant.
      - Vision statements should motivate people; mission statements need to have actions stated in the definition.

6. Collaborative Program participant actions are driven by this vision/mission statement.

7. Follow the recently agreed process for articulating, finalizing and adhering to Program decisions.
   - This has to do with a specific portion of the meeting process (decision making); need to use this same goal to expand to other meeting processes as well.
   - Example: Program Management Team (PMT) not able to articulate the decisions made during a meeting (decisions written on flip charts at the front of the room); there is uncertainty with the PMT and EC members at the table as to whether a decision has been made and exactly how the decision should be stated.
   - Adhering to decisions will be accomplished by not revisiting the decisions made.

8. Leaders need to ensure that all members have a chance to participate and are being heard (lack of inclusion of the people present or lack of members at the table?).
   - Example: Why should environmental groups participate in the Collaborative Program if their point/objective is not being heard or considered in decision-making?
   - Workshop group should not speak for entities that are not present.

Discussion

- If the Collaborative Program mission cannot be articulated by every member, then it does not currently exist.
- By establishing a vision with only current Collaborative Program members, may formulate a statement that only suits the current members and not agencies/organizations not currently represented by the Program (i.e. environmental groups).
- Pueblo point of view: Why should we come to the table? They don't listen to us anyway.
  - Outside consultants are hired by the pueblos to assist with environmental work; consultants have urged pueblos to sit at the Collaborative Program table;
  - Upper level pueblo members agree at times that pueblos should be involved in the Collaborative Program, then change their minds later;
  - Cultural biases involved as well;
  - Could the Collaborative Program package membership in such a way to present to the pueblos a "win-win" situation for pueblos – Answer: pueblos could be receptive to this approach.

3. *A lack of central repository for deliverables (reports, data, maps, etc.) leads to complaints about information sharing. There is also a disconnect between disciplines (water, habitat, science, and decision makers) due in part to the absence of data synthesis, timely discourse of scientific information, and clear recommendations on scientific issues.*

9. Complete and implement the central data repository project (database of Collaborative Program reports, data, maps, etc.).

10. Develop a technical Program assessment (TPA) process that synthesizes data, provides for interdisciplinary discourse resulting in future action recommendations and measures progress; internal and external components to be considered.
    - External independent peer review group (funded by the Collaborative Program, but not members of Program) to assess what can be done with the information collected by the Program.
    - Internal review example: PVA has taken data from the Collaborative Program and synthesized it in a way that helps the Program move forward.

<u>*Discussion*</u>: Lessons from the San Juan Program (provided by S. Platania):

- Researchers were divided into groups; it was the charge of smaller groups to synthesize the data that related to their group topic; everyone received additional funding to be part of the process; one person was responsible for writing the synthesis of the group discussion.
- Every 5 years, take information and as individuals synthesize the data into 5-year blocks; as a Collaborative Program, synthesize the 5-year results.
- This was not a failed effort because you can learn from your mistakes.
- <u>Key problem</u> – need to go in with focused questions; did not focus the first time as tightly as needed; ended up synthesizing each groups information, but not synthesizing data between groups; running into the problem of not making the statistically significant link between habitat and the presence of fish.
- Disagreement as to what the synthesis could answer; start by asking the questions to determine the data gaps.
- There is a perception that there is a lot of data out there that should lead to a lot of questions being answered.

4. *Outreach is not currently a priority. While the Collaborative Program Executive Committee assigned outreach as a priority, there has not been a concurrent time commitment to work on outside issues. This results in lack of support (public, political, monetary) and implementation of the outreach program*.

11. Develop a strategy on how to assess and address diversity and inclusion in the Collaborative Program.
    - Number of formal signatories vs. number of members (non-voting) involved in Program.
    - The current legislation calls for a certain number of signatories and the By-laws document calls for a different number of signatories; according to the By-laws, only 20 seats on the EC
    - Currently, there are two tiers of active participants.
    - The Collaborative Program needs to increase membership on the work group level; suggestion that work groups identify additional stakeholders that would be beneficial to be included in the Program.
    - Need to look at the pros and cons of staying as is or adding additional organizations to the Program.

12. Increase Program resources ($$, dedicated staff) that are focused on accomplishing Collaborative Program outreach goals.
    - Steps in the current outreach plan has EC members involved in the process of outreach; i.e. EC members using status to promote goals of Program in external forums; taking EC member on field project tours.

The working group then prioritized this list of Goals in order to come up with the top five statement of primary importance for future efforts.

1. Define the parameters of trust and accountability and determine the parameters by which that definition is violated (Goal 1).
2. Agree to and distribute a common Collaborative Program vision statement and mission statement that can then be articulated by ALL participants (Goal 5).
3. Develop a Technical Program Assessment (TPA) process that synthesizes data, provides for interdisciplinary discourse resulting in future action recommendations and measures progress; internal and external components to be considered (Goal 10).
4. Develop more multi-organization projects that require collaboration to complete successfully (vs. single organization projects) (Goal 2).
5. Increase Collaborative Program resources (money, dedicated staff) that are focused on accomplishing Program outreach goals (Goal 12).

Actions

Actions are first provided for high-priority goals listed previously.

1. Define the parameters of trust and accountability and determine the parameters by which that definition is violated.
   Mechanism: Partnering agreement: not an intergovernmental commitment, but a statement by which a group agrees to operate; outlines the common goals of a group and identifies how members will be held accountable for violation of partnership parameters.

   A. During the next 6 months, hold one facilitated meeting of the Executive Committee to develop and agree to a partnering agreement.
      Responsible parties: M. Schmader (City of Albuquerque)
      Timeframe: 6 months; 80 hrs staff time (1 person)
      Estimated budget: $5000 (split between Action A and B)

   B. A partnering agreement is developed at the facilitated EC meeting (in the next 6 months) and includes: (1) ground rules; (2) collaboration principles (definition and what is brought to the collaboration); (3) establishing a set of common values; (4) stated goal; (5) a mission statement; and (6) a vision statement.
      Note: To include accountability and consequences.
      Responsible parties: M. Schmader
      Timeframe: 300 hrs staff time (8 people)
      Estimated budget: $5000 (split between Action A and B)

   C. EC developed PA is shared with subgroups within 3 months of acceptance.
      Responsible parties: M. Cummer (US Fish and Wildlife Service)
      Timeframe: 50 hrs staff time (50 people)
      Estimated budget: Covered under already existing staff costs

   D. In 2008, plan & carry-out (without PMT or TT help) two team building activities (i.e. bowling, river trip, ropes course, dodgeball, kickball).
      Responsible parties: G. Haggerty (Interstate Stream Commission)
      Timeframe: 400 hrs staff time (50 people)
      Estimated budget: Covered under already existing staff costs

E. Develop a group recognition process for the Collaborative Program and recognize at least two significant contributions during 2008.
Process would include the following recognition categories: field work, outreach, project completion, etc.
Need ways to encourage Collaborative Program members that would lead to team building and recognition.
Responsible parties: Lesley McWhirter (US Army Corps of Engineers)
Timeframe: 40 hrs staff time (2 people)
Estimated budget: ~$200

5. Agree to and distribute a common Collaborative Program vision statement and mission statement that can then be articulated by ALL participants.

F. Addressed in action “b” from Goal 1 under Sociology category.
Responsible parties: M. Schmader (City of Albuquerque)
Timeframe: Addressed above
Estimated budget: No cost

10. Develop a Technical Program Assessment (TPA) process that synthesizes data, provides for interdisciplinary discourse resulting in future action recommendations and measures progress; internal and external components to be considered.

G. During 2008, review existing technical program assessments to determine essential elements and procedures.
Responsible parties: L. McWhirter (US Army Corps of Engineers)
Timeframe: 160 hrs staff time (4 people)
Estimated budget: Covered under already existing staff costs

H. Make recommendations regarding implementation of TPA to the Collaborative Program by mid-2009.
Responsible parties: G. Haggerty (Interstate Stream Commission)
Timeframe: 500 hrs staff time (20 people)
Estimated budget: ~$2000

2. Develop more multi-organization projects that require collaboration to complete successfully (vs. single organization projects).

I. At least one RFP in FY08 will include “collaboration” as a Collaborative Program proposal evaluation criterion; at least 2 RFPs will include “collaboration” as a Program proposal evaluation criterion in FY09.
- Need to have an explanation of the collaborators role in the proposal.
- Needs more emphasis on what we are doing within the Program/agencies to accomplish goals; things that are multi-organizational that if not accomplished each year, can have negative ramifications (i.e USACE – Cochiti deviation, working with pueblos).
- Hard time getting traction on work to be done that does not fall under Program SOW.
- Can the Collaborative Program influence projects happening outside the Program? – Only if the project organizers are open to opinions/advice from the Program.

Responsible parties: Kathy Dickinson/Jericho Lewis (BOR)
Timeframe: 40 hrs staff time (6 people)
Estimated budget: Covered under already existing staff costs

12. Increase Collaborative Program resources ($$, dedicated staff) that are focused on accomplishing Program outreach goals.

    J. Develop at least 2 alternatives for increasing the resources focused on implementing the outreach plan by June 2008.
    Responsible parties: K. Dickinson (Bureau of Reclamation)
    Timeframe: 10 hrs staff time (5 people)
    Estimated budget: Covered under already existing staff costs

    K. Produce a decision paper regarding alternatives by August 2008.
    Responsible parties: K. Dickinson (Bureau of Reclamation)
    Timeframe: 8 hrs staff time (3 people)
    Estimated budget: Covered under already existing staff costs

    L. Present paper to Executive Committee and request decision by September 2008.
    Responsible parties: K. Dickinson (Bureau of Reclamation)
    Timeframe: 20 hrs staff time (40 people)
    Estimated budget: Covered under already existing staff costs

6. Collaborative Program participant actions are driven by this vision/mission statement.

    M. Produce large-scale version of the PA during 2008.
    Responsible parties: M. Cummer (US Fish and Wildlife Service)
    Timeframe: 1 hr staff time (contractor)
    Estimated budget: ~$1000

    N. Post partnering agreement at all Collaborative Program meetings and functions beginning in 2008.
    Responsible parties: M. Cummer (US Fish and Wildlife Service)
    Timeframe: No time
    Estimated budget: Covered under already existing staff costs

11. Develop a strategy on how to assess and address diversity and inclusion in the Collaborative Program.

    O. Executive Committee, Coordination Committee, and work groups should be provided with a list of current, historical, and potential members and their potential contributions (3 lists) and mutual benefit in 2008.
    Responsible parties: G. Haggerty (Interstate Stream Commission)
    Timeframe: 20 hrs staff time (2 people)
    Estimated budget: Covered under already existing staff costs

    P. Develop list of potential additional stakeholders who could be invited to be part of the Executive Committee in 2008.
    Responsible parties: L. McWhirter (US Army Corps of Engineers)
    Timeframe: 20 hrs staff time (6 people)
    Estimated budget: Covered under already existing staff costs

    Q. Develop pros/cons/fixes of participant alternatives in 2008.
    Responsible parties: M. Cummer (FWS)
    Timeframe: 20 hrs staff time (6 people)
    Estimated budget: Covered under already existing staff costs.

R. Present alternatives to Coordination Committee and Executive Committee in 2008.
Responsible parties: K. Dickinson (Bureau of Reclamation)
Timeframe: 20 hrs staff time (1 person)
Estimated budget: Covered under already existing staff costs

S. Executive Committee selects preferred alternatives in 2008.
Responsible parties: Amy Louise (NMISC)
Timeframe: 20 hrs staff time (1 person)
Estimated budget: Covered under already existing staff costs

Appendix
As a "homework assignment" one evening during the workshop, each group member was asked to provide a list of three Collaborative Program agencies that they would most like to partner with, and to provide criteria for decision.

Who would you like to work with? – Eleven different organizations in the Collaborative Program were identified as groups people liked to work with; if the Program was a group that really worked well together as a whole, then it would have been hard to pick just three (no one asked to write down more than that).

City of Albuquerque - 4
Pueblos - 4
US Bureau of Reclamation - 4
US Army Corps of Engineers - 3
New Mexico Department of Game and Fish - 3
Environmental groups - 3
US Fish and Wildlife Service - 3
Bureau of Indian Affairs - 1
ABCWUA - 1
University of New Mexico - 1
Middle Rio Grande Conservancy District - 1

Rio Grande Silvery Minnow
Population and Habitat Viability Assessment

Appendix I
List of Workshop Participants

Appendix I

Rio Grande Silvery Minnow
Population and Habitat Viability Assessment

Workshop Participants

Name	Affiliation	E-mail Contact
Chris Altenbach	City of Albuquerque - Biopark	caltenbach@cabq.gov
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Marta Wood	Tetra Tech EMI	marta.wood@ttemi.com

Appendix II

IUCN Position Statement on Translocation of Living Organisms

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

FOREWORD

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

DEFINITIONS:

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

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

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

PART I

INTRODUCTIONS

BACKGROUND

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

The establishment of introduced alien species has broken down the genetic isolation of communities of co-evolving species of plants and animals. Such isolation has been essential for the evolution and maintenance of the diversity of plants and animals composing the biological wealth of our planet.

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

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

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

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

Intentional Introduction

General

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

Introductions to Natural Habitats

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

Introduction into Semi-natural Habitat

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

Introductions into Man-made Habitat

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

Planning a Beneficial introduction

6. Essential features of investigation and planning consist of:
    - an assessment phase culminating in a decision on the desirability of the introduction;
    - an experimental, controlled trial;
    - the extensive introduction phase with monitoring and follow-up.

THE ASSESSMENT PHASE

Investigation and planning should take the following factors into account:

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

Special attention should be paid to the following questions:

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

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

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

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

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

THE EXPERIMENTAL CONTROLLED TRIAL

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

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

THE EXTENSIVE INTRODUCTION

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

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

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

ACCIDENTAL INTRODUCTIONS

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

consider what measures can be taken to restrict mixing of species from different zones through such large developments.

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

WHERE ALIEN SPECIES ARE ALREADY PRESENT

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

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

BIOLOGICAL CONTROL

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

MICRO-ORGANISMS

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

PART II

THE RE-INTRODUCTION OF SPECIES*

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

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

The basic programme for re-introduction should consist of:

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

THE FEASIBILITY STUDY

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

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

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

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

THE PREPARATION AND RELEASE OR INTRODUCTORY PHASES

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

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

FOLLOW-UP PHASE

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

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

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

PART III

RESTOCKING

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

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

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

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

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

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

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

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

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

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

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

PART IV

NATIONAL, INTERNATIONAL AND SCIENTIFIC IMPLICATIONS OF TRANSLOCATIONS

NATIONAL ADMINISTRATION

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

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

Accidental introductions

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

Penalties

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

INTERNATIONAL ADMINISTRATION

Movement of Introduced Species Across International Boundaries

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

The Stockholm Declaration

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

International Codes of Practice, Treaties and Agreements

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

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

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

Regional Development Plans

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

Scientific Work Needed

5. A synthesis of current knowledge on introductions, re-introductions and re-stocking is needed.
6. Research is needed on effective, target specific, humane and socially acceptable methods of eradication and control of invasive alien species.
7. The implementation of effective action on introductions, re-introductions and re-stocking frequently requires judgements on the genetic similarity of different stocks of a species of plant or animal. More research is needed on ways of defining and classifying genetic types.
8. Research is needed on the way in which plants and animals are dispersed through the agency of man (dispersal vector analysis).

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

IUCN Responsibilities

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

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

Such information would include information in the following categories:

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

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

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

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