American Fisheries Society Guidelines for Introductions of Threatened and Endangered Fishes

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ABSTRACT

Introductions of threatened and endangered fishes are often an integral feature in their recovery programs. More than 80% of threatened and endangered fishes have recovery plans that call for introductions to establish a new population or an educational exhibit, supplement an existing population, or begin artificial propagation. Despite a large number of recent and proposed introductions, no systematic procedural policies have been developed to conduct these recovery efforts. Some introductions have been inadequately planned or poorly implemented. As a result, introductions of same rare fishes have been successful, whereas recovery for others has progressed slowly. In at least one instance, the introduced fish eliminated a population of another rare native organism. We present guidelines for introductions of endangered and threatened fishes that are intended to apply when an introduction is proposed to supplement an existing population or establish a new population. However, portions of the guidelines may be helpful in other situations, such as establishing a hatchery stock. The guidelines are divided into three component: (1) selecting the introduction site, (2) conducting the introduction, and (3) post- introduction monitoring, reporting, and analysis, Implementation should increase success of efforts to recover rare fishes.

Introduction

"On 3 August 1968, we collected 30 or 40 individuals from among the inundated prickly pear and mesquite near the flooded spring, which by that time was covered with about 7 m of clear water."- Peden (1973)

The above quote described the collection of Amistad gambusia, *Gambusia amistadensis,* as its habitat was being flooded. Fortunately, most translocations of endangered fishes do not occur under such a feverish pace as did this collection of Amistad gambusia. This gambusia was known only from Goodenough Spring, Texas, which was inundated by reservoir impoundment. The original stock of 30 to 40 individuals was taken to the Brackenridge Field Laboratory at Austin, Texas. In 1979, portions of the stock were transferred to Dexter National Fish Hatchery in New Mexico for propagation. But in 1979, all stocks were examined and found to consist solely of mosquitofish, *Gambusia affinis*, which had somehow contaminated the population during the preceding years (Hubbs and Jensen 1984). The species was extinct.

Unlike the tragic scenario of the Amistad gambusia, most recovery programs for endangered or threatened fishes are conceived and executed under more favorable circumstances. The Fish and Wildlife Service is required to develop recovery plans for those species listed as endangered or threatened pursuant to Section 4(f) of the Endangered Species Act of 1973. In recent years, introductions have become a prominent feature of most recovery programs for rare fishes.

With the widespread use of introductions as a method to recover rare fishes, the need for standardized procedures has become clear, The purpose of this paper is to present a standardized procedure and encourage its use through acceptance by the American Fisheries Society. Also, we encourage documentation and analysis of introduction attempts so that future efforts will have greater opportunity to benefit from these experiences.

Background

Results of introductions of endangered and threatened fishes are seldom reported in the literature. Even less frequently are introductions analyzed to determine causes of successes or failures. Three noteworthy exceptions exist. Hoover and St. Amant (1983) reported that only two of 12 introductions of the endangered Mohave tui chub, *Gila bicolor mohavensis*, led to established populations. Johnson (1985, and personal communication) reported that beginning in 1982, numerous reintroductions involving millions of young razorback suckers, *Xyrauchen texanus,* have been conducted in Arizona. It wasn't until 1985, however, that the first razorbacks reintroduced into the wild survived. Although none of these are considered established, a vital first step toward this goal has been achieved. Minckley and Brooks (1985) documented an approximate 30% success rate for attempts to establish a variety of rare Arizona fishes. Excellent discussions of the techniques and problems associated with introducing rare fishes following chemical treatment to eliminate exotics can be found in Meffe (1983) and Rinne et al. (1981).

We examined recovery plans for 39 endangered or threatened fishes in the United States to determine the prevalence of, and reasons for, introductions in the recovery efforts (Table 1). Only those species with recovery plans signed and approved by the Fish and Wildlife Service were analyzed. Recovery programs for 32 of the 39 fishes (82%) call for one or more forms of introductions in addition to habitat protection, research, monitoring and other types of recovery actions. Recovery plans for endangered or threatened fishes without proposed introductions were unusual. They include two cyprinids (Borax Lake chub, *Gila boraxobius,* and Kendall

warm springs dace, *Rhinichthys osculus thermalis),* two cavefishes (Ozark cavefish, *Amblyopsis rosae,* and Alabama cavefish, *Speoplatyrhinus poulsom),* and three darters (slackwater, *Etheostoma baschungi;* fountain, *E. fonticola;* and snail darters, *Percina tanasi).* A fourth darter, the Bayou darter, *E. rubrum,* has provisions for introductions only if the loss of the existing population appears imminent. Introductions of fountain and snail darters occurred prior to recovery plan development.

Typically, those species without proposed introductions have a highly restricted range, with habitats that are quite unusual and hard to duplicate. In such cases, it is prudent to focus recovery efforts on protecting the existing habitat rather than expanding the species beyond its natural range. Fishes from homogeneous habitats, such as warm springs, may contain little of the genetic variability that could assist the species in adapting to new environments (Vrijenhoek et al. 1985). Additional problems can arise when phenotypic changes occur in introduced stock as a result of relocating a species into habitat that differs greatly from the species' natural habitat. Such problems were encountered when the Devil's Hole pupfish, *Cyprinodon diabolis,* was introduced from its limestone cavern known as Devil's Hole to a cement refuge below Hoover Dam. Because the refuge was in an environment exposed to more daylight, primary productivity was greater and food more abundant. Factors other than a greater food supply likely were involved, but the result was a refuge population of pupfish with larger, more brightly- colored bodies and changes in several mensural characteristics (Williams 1977). An unusual, melanistic population of threespine stickleback, *Gasterosteus aculeatus,* from Holcomb Creek, California, was considered to be possibly a new evolutionary form native to the area (Bell 1982), but now is considered to be the result of phenotypic changes in an introduced population. The Holcomb Creek population's allozyme pattern is identical to that of sticklebacks from the lower Santa Clara River (D. G. Buth, personal communication). Buth (personal communication) hypothesizes that the sticklebacks in Holcomb Creek were introduced inadvertently with trout from the Fillmore Hatchery located on the Santa Clara River. In other animal groups, most notably birds, the problem of rapid evolutionary change in introduced populations of endangered species is an increasing cause for concern (Conant 1988).

Recovery plans list five reasons for introductions: (1) information and education, (2) establishing a genetic reserve or for artificial propagation, (3) use as a biological control agent, (4) supplement existing populations, and (5) establish new populations. A secondary consideration in establishing new populations of certain rare trouts (e.g., Apache trout, *Satmo apache,* and Gila trout, S. *gilae)* has been the creation of a sport fishery. Concerns and procedures for conducting an introduction will vary greatly with its intended purpose.

Establishing new populations and supplementing existing stocks often are the primary means for recovering many threatened or endangered western fishes. Through 1986, the following numbers of introductions were made for those purposes: Little Kern golden trout, *Salmo aguabonita whitei,* 43; greenback cutthroat trout, *Salmo clarki stomias,* 32; Colorado squawfish, *Ptychocheilus lucius,* 14; desert pupfish, *Cyprinodon macularius,* 13; Pecos gambusia, *Gambusia nobilis,* 32; and Gila topminnow, *Poeciliopsis occidentalis,* 97.

In some circumstances, our ability to introduce endangered and threatened species has been facilitated by regulations that enable the designation of "experimental population" (see 27 August 1984 *Federal Register),* designed to lessen local opposition to introducing endangered or threatened species. Experimental populations are classified as "essential," or more likely, "nonessential." All experimental populations are classified as threatened, which allows for the species to be taken (i.e., killed or captured) pursuant to special regulations. Further, most nonessential experimental populations are not subjected to the rigorous interagency consultation requirements of Section 7 of the Endangered Species Act.

Guidelines

Within this paper and suggested guidelines, the terms "introduction" and "introduced" are used in their broadest context (sensu Shafland and Lewis 1984) and include any fishes moved by man regardless of whether the organism is moved outside or within its native range.

The following guidelines for conducting introductions of endangered and threatened fishes were developed by the American Fisheries Society's Western Division Endangered Species Committee. The guidelines are intended to apply when an introduction of an endangered or threatened fish is proposed to supplement an existing population or to establish a new population. Portions may be useful when introducing fish for artificial propagation, maintenance of a genetic reserve, educational exhibits, or other purposes. Unforeseen circumstances, such as the imminent and unpredicted loss of a population, may require emergency procedures that deviate from portions of the guidelines. Fisheries managers are urged to plan in advance and develop procedures for dealing with such emergencies.

Individuals conducting introductions should be familiar with all applicable regulations pertaining to the rare fishes) in question. Applicable local, state, and federal permits must be obtained. The permitting process often is lengthy, and applications should be submitted as early as feasible. Permits should include procedures for adequate monitoring and preservation of any mortalities.

The guidelines are divided into three components: (1) selecting the introduction site, (2) conducting the introduction, and (3) post- introduction activities.

1. Selecting the Introduction Site

A. Restrict introductions to within the native or historic habitat whenever possible.

For a broadly ranging species, such as the Colorado squawfish, the historic habitat includes the mainstem Colorado River and many of its major tributaries, from the Green River of Wyoming to the Gila River of Arizona. On the other hand, a single-spring endemic, such as the Devils Hole pupfish, has a historic distribution of narrowest proportions.

Any attempt to introduce an endangered or threatened fish outside of its historic range should be viewed with great caution. The historic habitat of a species is herein considered to be those localities from which the species is known plus any interconnected waters from which it could reasonably have occurred. Introductions outside of a species historic habitat may be necessary, but should be considered only when all locations within the historic range are unsuitable and/or unrestorable, when extant historical habitat is clearly threatened with imminent loss, or when the introduction is proposed within a controlled site (such as a hatchery).

B. Restrict introductions to a protected site.

Any site selected to receive introductions should be secure from imminent or future threats of habitat destruction. In order to protect the habitat, some form of management agreement with the landowner or land management agency is advisable. Placing the site in land dedicated to protecting the species, whether public or private ownership, is preferable.

C. Restrict introductions to sites where the potential for dispersal has been determined and is acceptable.

Depending on the introduction goal it may be advisable to choose sites with little or no opportunity for further dispersal of the introduced population. This is especially true for releases made outside the historic habitat where additional range expansion may not be desired. Conversely, some introductions are intended to expand an existing population within its historic range. In such cases, further dispersal routes may be a prerequisite for site selection.

D. Restrict introductions to sites that fulfill life history requirements of the species.

Adequate food, spawning, and rearing habitat for all life stages should be available. Habitat variables should be measured (Orth 1983) and water quality analyzed (U.S. Environmental Protection Agency 1976) to establish baseline habitat conditions and to determine the presence of any harmful substances. Water quality should be similar to that observed in undisturbed natural habitat.

E.� Restrict introductions to sites that contain sufficient habitat to support a viable population.

To maintain population viability, sufficient individuals must be present to prevent serious inbreeding and loss of genetic variation by random drift. The number of individuals actually contributing to recruitment of the next generation (i.e., effective population size), however, is usually only a fraction of the total population size (i.e., census population size). Allendorf and Ryman (1987), for example, recommended an effective population size of 200 for sustaining hatchery stocks of salmonids. In the wild, a much larger census population would be needed to compensate for unbalanced sex ratios, age structure, etc. Sufficient habitat would be needed to maintain a viable population in the face of floods, drought or other stochastic events. Because of these factors, habitat necessary to support many thousands of individuals could be required to maintain an effective breeding population of 200.

F. Prohibit introductions into areas where the endangered or threatened fish could hybridize with other species or subspecies.

Many rare fishes, particularly those of isolated drainages in the West, have had little opportunity to develop reproductive isolating mechanisms to prevent hybridization with closely related taxa. Some groups of fishes, such as the suckers (family Catostomidae), readily hybridize and intergeneric hybrids are common. Introductions should not proceed when the subject species could hybridize with a fish already present in the habitat.

An exception to this guideline would apply to a limited number of taxa and situations. If hybrids with the taxon to be introduced are known or are suspected to occur at the introduction site, and if the incidence of hybridization is low and is a natural occurrence in the area, then such sites can be considered for the introduction. Some catostomids and some chubs of the genus Gila, for example, exhibit limited hybridization with naturally sympatric taxa.

G. Prohibit introductions into areas where other rare or endemic taxa could be adversely affected.

If an introduction is proposed outside the species historic range, pre- introduction surveys should be conducted to determine the presence of rare invertebrate, fish or other aquatic species that might be adversely affected by release of the endangered or threatened fish. Appropriate taxonomists in entomology, malacology, or other invertebrate zoological specialties should be consulted. If an introduction is proposed within the species' historic range, the need for surveys of other rare aquatic species may be advisable, especially if physical modification of habitats is proposed as part of the introduction effort. Such surveys could have prevented loss of a population of hydrobiid snail species endemic to the Fish Slough area in eastern California. The snail population was eliminated during habitat modification efforts associated with introduction of the Owens pupflsh into Fish Slough (Landye 1983). For introductions within the species historic range that do not include physical manipulation of habitats, surveys for other rare species, while potentially valuable, should not be required.

2. Conducting the Introduction

A. Choose introduction stock from appropriate source.

For rare fishes with more than one population, a source for the introduction stock must be selected. It is important to realize that each isolated population of a rare fish is likely to be a unique gene pool with specific adaptations to local conditions (Meffe 1986). Fishery managers, therefore, may have a choice of unique stocks to select from, or perhaps to mix. The availability of life history and genetic information on the candidate source stocks will greatly facilitate the proper selection.

Selection criteria will vary with the intended purpose of the introduction, but consideration may be given to selecting the most genetically pure stock, the rarest stock, the stock closest geographically to the introduction site, or the stock closest ecologically. Meffe (1987) pointed out that populations at the edge of a range may have lower genetic variance than do those near the center. It is possible that individuals from centrally located populations may display a higher fitness in characters such as growth rate, survivorship, fecundity, etc. (Meffe 1987). This phenomenon was well documented in an electrophoretic analysis of 21 populations of the Sonoran topminnow, *Poeciliopsis occidentalis*. Vrijenhoek et al. (1985) demonstrated that the source topminnow population being used for restocking was genetically invariant and displayed a very low fecundity. This study prompted a switch in the source population used for restocking efforts.

Mixing of naturally isolated stocks to establish a population should be discouraged because it may reduce genetic fitness by loss of closely- linked or coadapted genes (Dobzhansky 1970). That is, genes that are coadapted within one population may be broken up by hybridization and combined into gene complexes that do not function well together (Meffe 1986). Evidence of this phenomenon was observed when isolated stocks of Atlantic salmon, *Salmo solar,* were mixed (Stahl 1981). Often, the first generation hybrids are robust, but subsequent generations lose fitness as the coadapted gene complexes are broken up. Meffe (1986,1987) presented good reviews of the problems of mixing isolated stocks of rare fishes and recommended against it in nearly all cases.

B. Examine taxonomic status of introduction stock.

Introduction stock should be examined prior to transport by an appropriate taxonomist in order to insure that only the desired form is present. If the taxonomy is questionable but the introduction nonetheless proceeds, a subsample of the stock should be preserved for future analysis.

C. Examine introduction stock for presence of undesirable pathogens.

Unwanted parasites and diseases frequently have been introduced through fish transfers (Hoffman and Schubert 1984). Samples of the introduction stock should be examined by a qualified fish pathologist prior to shipment. Ideally, the sample should be quarantined for at least two weeks so that parasites may complete their life cycle or become numerous enough to detect (Hoffman and Schubert 1984). Stock held in culture facilities often are subjected to crowded conditions that may produce higher parasite loads. Culture stocks should be regularly inspected for undesirable parasites and diseases. If sufficient introduction stock is available, Ossiander and Wedemeyer (1973) recommended a sample of at least 60 fish to determine the presence or absence of a pathogen in the population.

The authors recognize that conditions may not allow for the necessary quarantine and inspection of the introduction stock. In a crisis situation where the last population of a species is imminently threatened, for example, no time may be available for a quarantine. Also, the transfer of wild stock *within* a drainage presents a lower risk of introducing a new parasite or disease. In such cases, a quarantine may not be required.

D. Obtain introduction stock of sufficient number and character.

An introduced population should be founded with enough individuals to adequately reflect the genetic composition present in the source population. Estimating the precise number of individuals necessary to accurately reflect the source population may be enigmatic. In general, a population of fish from a homogeneous habitat (such as a small stenothermal spring) may possess a narrower range of genetic variability than a population from a heterogeneous habitat (such as a eurythermal stream) (Vrijenhoek et al. 1985). Therefore, a smaller number of individuals may be required to encompass the available genetic variability from a constant environment habitat compared to a variable environment. If the source population is not threatened by imminent loss, no more than 10% of the available stock should be utilized annually for introductions.

Other important considerations include sex ratio and age structure of the introduction stock. A sex ratio near 1:1 and a range of age classes should increase the chance of a successful translocation. No ideal number exists, although researchers have suggested that 25 males and 25 females of the proper age and condition is an absolute minimum to establish salmonid populations in highly controlled hatchery settings (Allendorf and Ryman 1987; Ryman and Stahl 1980). Less controlled environments, where each individual does not contribute equally in reproduction, require a greater number of fish.

Collection techniques should disrupt natural habitats as little as possible. Spring systems often are particularly sensitive to small amounts of human disturbance.

E. Carefully and quickly transport stock.

A stress response usually results when fish experience fright, discomfort, or pain (Schreck 1981). Transported stock are most commonly stressed by physical handling and by confinement of large numbers of individuals in small containers. Loss of mucus or scales, disturbance to integument or damage to internal organs can lead to shock, increased susceptibility to infection, immune system suppression and/ or delayed mortality (Mazeaud et al. 1977; Schreck 1981). The detrimental effects of repetitive stress are cumulative (Schreck 1982). Therefore, an adequate recovery period should be provided between each stressful event. Stress also can impair a fish's ability to learn for up to several weeks (C.B. Schreck, personal communication). This could block imprinting processes needed for adult homing or migration. Stress can be reduced by darkness or the use of anesthetics (Schreck 1981).

A general discussion of handling live fish is presented by Stickney (1983). In addition, Johnson (1979) presented data on numbers and weights of fish that can safely be transported in plastic bags containing water saturated with oxygen.

F. Introduce stock under most favorable conditions.

Stock should be introduced during favorable weather and hydrologic conditions. Thermal stock should be avoided by equalizing the transport water temperature to that of the habitat. Further, introducing stock at the proper time of day can reduce initial predation losses. For example, because sight- feeding predators would be less active at night, introductions into waters containing such predators should occur during dark conditions.

G. Document the translocation.

It is vital that the procedures and location of introductions be made available in the scientific literature. Simply filing the appropriate data in a handy institutional cabinet is insufficient to allow necessary accessibility. Introduction data should be made available through regularly distributed scientific literature, or through administrative reports of the lead agency. At a minimum, the following should be reported: identity of those conducting the introduction, taxon involved, source of the introduction sample, numbers of introduced individuals and their sex, age and/or size distribution, date of introduction, and precise location of the receiving habitat.

3. Post- Introduction Activities

A. Conduct systematic monitoring of introduced populations.

Regular surveys should be conducted to determine initial survival, recruitment of young, and persistence through environmental stochasticity (such as floods, drought, or fire). During the first year, quarterly monitoring may be warranted. If the population becomes established, annual monitoring should be continued for many years to determine long- term survivorship. Life history studies of introduced populations are advisable. Rapid evolution of life history strategies has been documented in introduced populations of guppies, *Poecilia reticulata*, as a result of new predators and/or novel habitats (Rezruck and Bryga 1987).

B. Restock if warranted.

In some cases, it may be advisable to supplement the initial stocking of the endangered or threatened fish in order to facilitate establishment or increase gene flow. Subsequent electrophoretic analysis of the introduced population would reveal loss of genetic variation by founder effect, genetic bottlenecks, inbreeding or drift. As such, genetic studies of introduced populations are an underutilized tool available to the fishery manager (G. K. Meffe, personal communication). The supplemental stock should be collected from the same source as the original introduction in order to maintain genetic fitness as described above (see also Meffe 1987; Meffe and Vrijenhoek 1988). The same care should be taken in acquisition of individuals for the restocking effort as was taken in selection of the original introduction stock. In some cases of failure, restocking still may be advisable. If failure occurs, however, the casual factors) should clearly be identified and eliminated prior to restocking.

C. Determine cause of failures.

If an introduction fails, efforts should immediately be initiated to determine the cause or causes. Understanding failed introductions ultimately may be more important in promoting recovery than certain successes.

D. Document findings and conclusions reached during the post- introduction process.

Results of monitoring efforts and causes of failures should be made available in the scientific literature or administrative reports and widely distributed.

Conclusions

The management of endangered fishes has entered an exciting, albeit demanding, era. The principles of conservation genetics offer important new tools to help recover rare species. Application of these principles to the fishery sciences is just beginning (Meffe and Vrijenhoek 1988; Ryman and Utter 1987), and offers a strong challenge to fishery managers. The process of establishing a new population of threatened or endangered fish is complicated by economic, regulatory, and genetic concerns, all often overridden by an urgent need to act in the face of crisis. Fishery managers face an enormous task in preserving our native fish diversity. The authors hope these guidelines will assist the managers in this worthy endeavor.

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