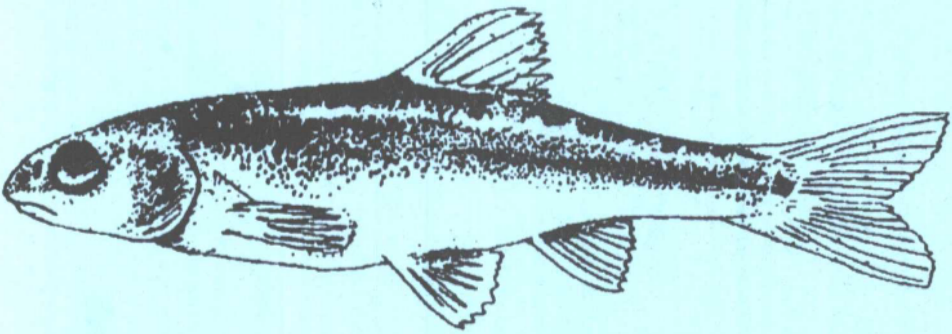
Spikedace



Meda fulgida

Recovery Plan

September 1991

U. S. Fish and Wildlife Service
Phoenix, Arizona

SPIKEDACE, *Meda fulgida*

RECOVERY PLAN

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for

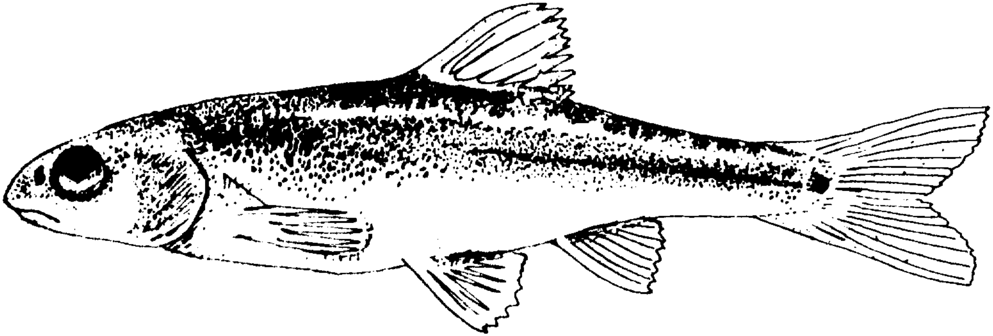
Region 2

U.S. Fish and Wildlife Service

Albuquerque, New Mexico

Approved: ______________________________
Regional Director, U.S. Fish and Wildlife Service

Date: 9/27/91



Spikedace, *Meda fulgida*

Frontispiece

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Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Spikedace Recovery Plan. Albuquerque, New Mexico. 38 pp.

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The fee for the plan varies depending on the number of pages in the plan.

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EXECUTIVE SUMMARY

Current Species Status: The spikedace is a threatened fish which has been extirpated from most of its historic range in the Gila River Basin. It is presently found only in the upper Gila River in New Mexico, and in Aravaipa and Eagle creeks and the upper Verde River in Arizona. All existing populations are under threat.

Habitat Requirements and Limiting Factors: This fish inhabits riffles and runs in shallow flowing waters over gravel, cobble, and sand bottoms. The primary habitat for adults consists of shear zones where fast water meets slow water. Major threats include dams, water diversion, watershed deterioration, groundwater pumping, channelization, and introduction of non-native predatory and competitive fishes.

Recovery Objective: Protection of existing populations, restoration of populations in portions of historic habitat, and eventual delisting, if possible.

Recovery Criteria: This plan sets forth mechanisms to obtain information necessary to determine quantitative criteria for describing a spikedace population capable of sustaining itself in perpetuity. Delisting is dependent upon establishment of such populations.

Actions Needed:

1. Protection of existing populations.
2. Monitoring of existing populations.
3. Studies of interactions of spikedace and non-native fishes.
4. Quantification of habitat and effects of habitat modification.
5. Enhancement of habitats of depleted populations.
6. Reintroduction of spikedace into historic range.
7. Quantification of characteristics of a self-sustaining population.
8. Captive propagation.
9. Information and education.

Total Estimated Cost of Recovery: Cost of recovery estimated over a minimum 20 year recovery period yields a minimum total cost of $115,000.00 per year. This estimate is in 1989 dollars. The estimate does not include land or water acquisition. Although acquisition is a potential recovery action, it is not possible to estimate costs until areas to be acquired, if any, are identified.

Date of Recovery: Until work is completed to allow quantification of delisting criteria, it is not possible to predict a date of recovery. However, based on the evaluation period of 10 years for determination of success of reintroduced populations, recovery of this species could not occur in less than 20 years.

TABLE OF CONTENTS

I. INTRODUCTION

The spikedace (*Meda fulgida*) is a small, stream-dwelling fish endemic to the Gila River system of Arizona and New Mexico, USA (Miller and Hubbs 1960, Minckley 1973); the species also likely occurred in the past in the San Pedro River in Sonora, Mexico (Miller and Winn 1951). Although the biology of this unique, monotypic genus is relatively well known among Southwestern stream fishes (Barber et al. 1970, Anderson 1978, Schreiber and Minckley 1981, Barber and Minckley 1983, Propst et al. 1986), substantial gaps still exist and the basic ecology of spikedace remains in need of further study. The spikedace was apparently not considered imperiled by Miller (1961), although it had by 1937 been locally extirpated from much of the Salt River, Arizona, and elsewhere (Miller 1961). Marked reduction in its over-all range was noted by Barber and Minckley (1966) and widespread depletions were reported by Minckley (1973). Once widely distributed among moderate-sized, intermediate-elevation streams in the Gila River system, at least upstream of Phoenix, Arizona, the spikedace is now restricted to scattered populations in relatively short stream reaches. Minckley (1985), Propst et al. (1986) and Rhode (1980) figured historic and recent distributions of the species.

The spikedace was proposed (U.S. Fish and Wildlife Service [FWS] 1985) and subsequently listed (FWS 1986) as a threatened species under authority of the Endangered Species Act of 1973, as amended. Listing was justified on the basis of reductions in habitat and range due to damming, channel alteration, riparian destruction, channel downcutting, water diversion, and groundwater pumping, and continued threats to its survival posed by ongoing habitat losses and non-native, predatory and competitive fish species (FWS 1985). Critical habitat was initially proposed (FWS 1985, Appendix), but a subsequent rule (FWS 1986) deferred its designation until 18 June 1987. Although that date has passed, proposed critical habitat is still in force, providing limited protection. Final designation of critical habitat is under administrative review.

The spikedace is classified by the State of Arizona as a threatened species, which are those whose continued presence in Arizona could be in jeopardy in the near future (Arizona Game and Fish Department 1988) and by the State of New Mexico as a group 2 endangered species, defined as those ". . . whose prospects of survival and recruitment within the State are likely to become jeopardized in the foreseeable future" (New Mexico Department of Game and Fish 1988). The latter listing provides protection under the New Mexico Wildlife Conservation Act. The species can be taken only under a special collection permit in both States. Neither state listing otherwise protects spikedace or the habitats it occupies. Deacon et al. (1979), Williams et al. (1985), and Johnson (1987), also recognized the spikedace as imperiled.

Description

The spikedace (Frontispiece) is a small, sleek, stream-dwelling member of the minnow family (Cyprinidae). Its following description is summarized from Girard (1857), Miller and Hubbs (1960) and Minckley (1973):

The body is slender, almost spindle-shaped, and slightly compressed laterally. Scales are present only as small plates deeply embedded in the skin. There are two spinose rays at the leading edge of the dorsal fin, the first being obviously the strongest, sharp-pointed, and nearly as long as the second. The eyes and mouth both are large. Barbels are absent. There are seven rays in the dorsal fin, and the anal fin usually has nine. Pharyngeal teeth are in two rows, with the formula 1,4-4,1.

Coloration is bright silvery on the sides of the body, with vertically-elongated, black specks. The back is olive-gray to brownish, and usually is mottled with darker pigment. The underside is white. Males in breeding condition become brightly golden or brassy, especially on the head and at the fin bases.

Distribution and Abundance

Historical. The spikedace is endemic to the upper Gila River basin of Arizona and New Mexico, USA (Figure 1). The species was abundant in the San Pedro River, Arizona, and although never collected in that stream in Sonora, Mexico, probably occurred there also (Miller and Winn 1951). Distribution in Arizona was widespread in large and moderate-sized rivers and streams, including the Gila, Salt, and Verde rivers and their major tributaries upstream of the present Phoenix metropolitan area, and the Agua Fria, San Pedro, and San Francisco river systems (Minckley 1973, Rhode 1980). Populations transplanted from Aravaipa Creek into Sonoita Creek, Santa Cruz County in 1968, and 7-Springs Wash, Maricopa County in 1970, have since been extirpated (Minckley and Brooks 1985). Distribution in New Mexico was in both the San Francisco and Gila rivers (Koster 1957, Propst et al. 1986, Sublette et al. 1990), including the East, Middle, and West forks of the latter. There are no records of spikedace transplants in New Mexico.

There are substantial spatial and/or temporal gaps in quantitative data from which to assess the historical abundance of spikedace. Generally, the species must have been common and likely locally abundant in preferred habitats. Although habitat suitable for spikedace was probably not continuous, it was widespread throughout the species' range. Like most western cyprinids, population abundances and distributions of spikedace probably fluctuated in natural response to local and regional environmental conditions. Recent examples of such variation in the species abundance have been recorded in Aravaipa Creek, Arizona (Minckley and Meffe 1987) and the Red Rock reach of the Gila River, New Mexico (Marsh and Propst, unpublished data).

Present. The spikedace occurs in Arizona only in Aravaipa Creek, tributary to San Pedro River in Graham and Pinal Counties; Eagle Creek, tributary to Gila River in Graham and Greenlee Counties; and upper Verde River in Yavapai County (Figure 1). All three streams support at least moderate-sized, sustaining populations in relatively undisturbed reaches. The Eagle Creek population, considered "quite small" by FWS (1986) has since been found to be more substantial (Brooks, Marsh, Minckley, unpublished data). In New Mexico, spikedace now are restricted to the mainstem Gila River and its East, Middle, and West Forks; a few individuals may occasionally be encountered in lowermost reaches of perennial tributaries (Figure 1). Propst et al. (1986) considered only the population occupying the Cliff-

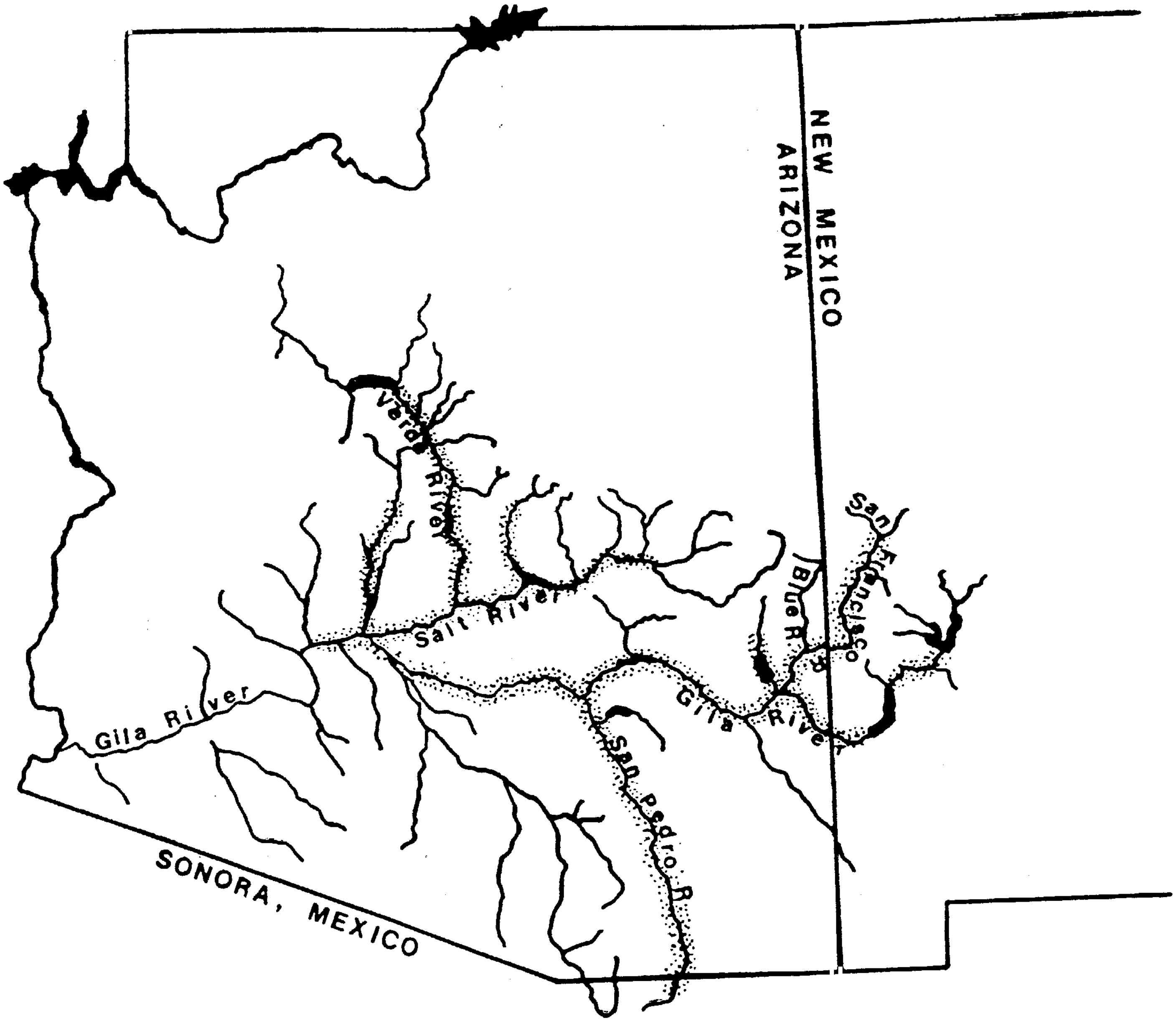

FIGURE 1. HISTORIC AND PRESENT DISTRIBUTION OF SPIKEDACE
(Historic distribution is represented by stippled areas; present distribution is represented by solid black.)

Gila Valley, New Mexico, comparable in abundance to that of earlier years; others have been substantially diminished. Undiscovered populations of spikedace may occur in places which have not been surveyed or completely inventoried, especially within expansive, remote portions of San Carlos Apache and Fort Apache Indian Reservations, on U.S. Forest Service lands, or in Sonora where the Gila River drainage remains inadequately studied.

Both distribution and abundance of spikedace have become dramatically reduced in the past century, with major changes occurring in recent decades (Minckley 1973, Propst et al. 1986). Major rivers and streams, such as lower reaches of the mainstem Gila, Salt, and Verde rivers that once supported substantial populations in several places have been recently depleted. Past changes in range and density must have occurred in response to natural spatial and temporal variations in the environment, but the current threatened status of spikedace appears a direct or indirect result of man's activities.

Life History

Biology of spikedace has been studied intensively in only a few places, but those investigations have provided a relatively broad base of information summarized below. In Arizona, only the population in Aravaipa Creek has received substantial attention (Barber and Minckley 1966, 1983; Barber et al. 1970, Minckley 1981, Schreiber and Minckley 1981, Turner and Tafanelli 1983, Rinne and Kroeger 1988), in part because that stream retains an intact native fauna in relatively pristine habitat. In New Mexico, Anderson (1978) examined spikedace populations primarily from a reach of the Gila River downstream from the community of Cliff and the lowermost East Fork of the Gila. Investigations by Propst et al. (1986) and Propst and Bestgen (1986) concentrated on the mainstem Gila River in the Cliff-Gila Valley, in part because that was one of the few places where the species was abundant enough to provide necessary information, and collected ecological data from several other localities in the upper Gila system. Most other work on spikedace has been survey-type monitoring to assess distribution, or status of local populations of fish communities (e.g. Jester et al. 1968, LaBounty and Minckley 1973, Anderson and Turner 1977, Ecology Audits 1979, Barrett et al. 1985, Bestgen 1985, Montgomery 1985, Propst et al. 1985), and does not contribute significant new information.

<u>Habitat.</u> Spikedace occupy flowing waters, usually less than a meter deep, and as adults often aggregate in shear zones along gravel-sand bars, quiet eddies on the downstream edge of riffles, and broad, shallow areas above gravel-sand bars (Propst and Bestgen, 1986, Rinne and Kroeger 1988). Smaller, younger fish are found in quiet water along pool margins over soft, fine-grained bottoms. In larger rivers (e.g., Salt River canyon), spikedace often were in the vicinity of tributary mouths. The fish use shallower, strongly-flowing areas in springtime, often over sandy-gravelly substrates. Specific habitat associations vary seasonally, geographically, and ontogenetically (Anderson 1978, Rinne 1985, Propst et al. 1986, Propst and Bestgen 1986, Rinne and Kroeger 1988, Rinne 1991).

<u>Reproduction.</u> Spikedace breeding in spring (April-June) is apparently initiated in response to a combination of stream discharge and water temperature; timing varies annually and geographically (Anderson 1978, Barber et al. 1970, Propst et al. 1986). Males patrol in shallow, sandy-gravelly riffles where current is moderate. There is no indication of

territoriality, although males generally remain evenly spaced within an occupied area. Receptive females move into the area, often from up-or downstream pools, and are approached at once by up to six males, two of which remain immediately alongside and slightly behind the female. Gametes are presumably deposited into the water column or on or near the substrate. No fertilized ova have been recovered; however, because they are adhesive and demersal based on eggs stripped and fertilized in the laboratory (P. Turner, pers. comm.), they likely adhere to substrates. Sex ratio among reproductive adults is not constant, varying from near unity among younger fish to a greater abundance of females among older individuals. Females may be fractional spawners, with elapsed periods of a few days to several weeks between spawnings. Fecundity of individual females based on gonad examination ranges from 90 to 250 ova, and is significantly correlated with both length and age. Ovum diameter at spawning is near 1.5 millimeters (mm). No specific information incubation times or size at hatching is available.

Growth. Growth varies annually with water temperature (and thus geographic location), and among year classes (Anderson 1978, Barber et al. 1970, Propst et al. 1986). Generally, young grow rapidly during summer and autumn, attaining 35 to 40 mm standard length (SL)[1] by November. Winter growth is slow in some places, negligible in others. Fish average near 40 mm SL at the end of one year, and 50 to 63 mm SL at the end of the second year. Maximum size is near 65 mm in Aravaipa Creek, Arizona, and 68 mm SL in the upper Gila River, New Mexico. Longevity typically is one to two years; a few fish reach age three and exceptional individuals may survive four years. Growth of males and females appears similar, although there may be differences within particular year classes (Propst et al. 1986).

Foods. Spikedace are carnivores that feed mostly upon aquatic and terrestrial insects entrained in stream drift (Anderson 1978, Barber and Minckley 1983, Propst et al. 1986). Kinds and quantities consumed vary with spatial and temporal availability of foods. Among aquatic forms, larval ephemeropterans, hydropsychid trichopterans, and chironomid dipterans are most important. Prey body size is small, typically ranging from 2 to 5 mm long. At times of emergence, pupal, imagine or adult stages of benthic insects, especially ephemeropterans, are consumed in large quantities. Other foods, including larval fishes, are occasionally eaten, but these constitute a minor component of the diet. Diversity of diet is greatest among smaller (post-larval) spikedace, which consume a variety of small, soft-bodied animals, while adults specialize on larger, drifting nymphal and adult ephemeropterans.

Co-occurring fishes. Among native fishes, loach minnow (*Tiaroga cobitis*), speckled dace (*Rhinichthys osculus*), Sonora sucker (*Catostomus insignis*), and desert sucker (*Pantosteus clarki*) are commonly in the same habitats occupied by adult spikedace. Longfin dace (*Agosia chrysogaster*) may also occur with spikedace in shallow, sandy, laminar-flowing reaches. Larval and juvenile spikedace in quiet habitats along stream margins may encounter small desert and Sonoran suckers, small loach minnow, larval and adult longfin dace, and perhaps small roundtail chub (*Gila robusta*).

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[1]Standard and total (TL) lengths of spikedace are convertible by the expression SL = 0.85TL - 0.12 (r^2 = 0.99, n = 100)(Marsh, unpublished data).

Introduced red shiner (Cyprinella lutrensis) occupies habitats similar to those occupied by spikedace, and may sometimes be taken in the same seine haul as spikedace. The red shiner now occurs at all places known to be formerly occupied by spikedace, with the exception of the San Francisco River above Frisco Hot Springs, and the two species overlap spatially (the native upstream, the exotic downstream, and a zone of contact between) in upper reaches of both the Gila and Verde rivers. These facts have led to extensive speculation about the nature of the relationship between the two species (FWS 1985, 1986, Minckley 1973, Minckley and Carufel 1967, Minckley and Deacon 1968, Propst et al. 1986, Bestgen and Propst 1986, Marsh et al. 1989). Various theories which have been put forth include: 1) red shiner invade previously unoccupied niches; 2) red shiner invade vacant niches left by spikedace (and other native minnows) extirpated due to habitat alteration; and, 3) red shiner invade areas occupied by spikedace and displace spikedace through competition and/or predation. Studies of spikedace in the upper Gila River led the investigators to conclude that the second theory was the most likely mode in that system (Propst et al. 1986, Bestgen and Propst 1986). In the upper Verde River, limited data indicate that the two species are maintaining a relatively stable region of sympatry and appear to be coexisting. A recent study of spikedace and red shiner interaction in various portions of its range and in laboratory experiments found apparent displacement of spikedace by red shiner based on shifts in habitat use by spikedace in the presence of red shiner (Marsh et al. 1989).

Among other non-native fishes, channel catfish (Ictalurus punctatus) of all sizes, and small flathead catfish (Pylodictis olivaris) frequent riffles occupied by spikedace, especially at night when catfishes move onto riffles to feed. Largemouth (Micropterus salmoides) and smallmouth (M. dolomieui) bass in some habitats, and introduced trouts (Salmonidae) at higher elevations, may also co-occur with spikedace. Interaction between the native and these non-native fishes is likely as prey and predators; however, importance of such relationships is yet to be established.

Reasons for Decline

Habitat destruction or alteration and interaction(s) with non-native fishes have acted both independently and in concert to extirpate or deplete spikedace populations. In the San Pedro and Aqua Fria rivers, plus major reaches of the Salt and Gila rivers, dewatering and other such drastic habitat modifications resulted in demise of spikedace, and most other native fishes. Downstream reaches of the Verde, Salt, and mainstem Gila rivers have been affected by impoundments and highly-altered flow regimes. Spikedace do not persist in reservoirs, and populations occupying tailwaters are subjected to impacts ranging from dewatering to altered chemical and thermal conditions. Stream channelization, bank stabilization, or other instream management for flood control or water diversion, have also directly destroyed spikedace habitats.

Natural flooding of desert streams and rivers may play a significant role in life histories of native fishes because they rejuvenate habitats (Propst et al. 1986), but perhaps more importantly because desert fishes effectively withstand such disturbances while non-native forms apparently do not (Meffe and Minckley 1987, Minckley and Meffe 1987). Activities that alter natural flow regimes may thus have negative impacts on native fishes.

Both historic and present landscapes surrounding spikedace habitats have been impacted to varying degrees by domestic livestock grazing, mining, agriculture, timber harvest, or other development (Hastings and Turner 1965, Hendrickson and Minckley 1985). These activities contribute to habitat degradation by altering flow regimes, increasing watershed and channel erosion and thus sedimentation, and adding contaminants such as acutely- or chronically-toxic materials, or nutrient-enriching fertilizers to streams and rivers. These perturbations may affect fishes in a variety of ways, such as direct mortality, interference with reproduction, and reduction in requisite resources such as invertebrate foods. In one example, a wastewater spill at the Cananea Mine, Sonora, Mexico, killed aquatic life including all fishes throughout a 100-km reach downstream (Eberhardt 1981).

Non-native fishes, introduced for sport, forage, bait, or accidentally, impact upon native fishes. Ictalurid catfishes, and centrarchids, including largemouth bass, smallmouth bass, and green sunfish (*Lepomis cyanellus*), prey upon native fishes. At higher elevations, introduced salmonids (brown trout, *Salmo trutta*, and rainbow trout, *Oncorhynchus mykiss*) may similarly influence spikedace populations. Red shiner may be particularly important as regards spikedace, because the two species where allopatric occupy essentially the same habitats, and where sympatric there is some evidence that there is displacement of the native to habitats which otherwise would scarcely be used (Marsh et al. 1989). Moreover, the concomitant reduction of spikedace and expansion of the shiner is powerful circumstantial evidence that red shiner may have displaced spikedace in suitable habitats throughout much of its former range.

Undoubtedly, demise of spikedace has been a result of combined effects of habitat change and introduced fishes. Because relative importance of the two factors has yet to be established, both must be considered in management toward recovery of this threatened species.

II. RECOVERY

Objective

The primary objective of this recovery plan is to identify steps and delineate mechanisms considered necessary to protect existing populations and restore depleted and extirpated populations of spikedace and their habitats, and to ensure the species' non-endangered, self-sustenance in perpetuity. Realization of this objective will constitute justification for delisting of the spikedace. This plan will require modification as new information becomes available; only at that time can quantitative criteria for delisting be elaborated. Interaction with non-native fishes and habitat modification, whether acting independently or in concert, are both considered contributory to decline and extirpation of spikedace. This plan recognizes the need to deal with both impacts in order to achieve the recovery objective.

Stepdown Outline

1. Protect existing populations of spikedace.

    1.1 Identify extent of existing populations and level of protection afforded to each.
    1.2 Prioritize existing populations as to need or imminent need for protection.
    1.3 Designate critical habitat.
    1.4 Enforce existing laws and regulations affecting spikedace.
        1.4.1 Inform as necessary appropriate agencies of applicable management/enforcement responsibilities.
        1.4.2 Assure compliance with Section 7 of the Endangered Species Act.
        1.4.3 Assure compliance with Section 9 of the Endangered Species Act.
    1.5 Discourage detrimental land and water use practices.
    1.6 Insure perennial flows with natural hydrographs.
    1.7 Curtail transport and introduction of non-native fishes.
        1.7.1 Discourage seining and use of live bait in streams occupied by spikedace.
    1.8 Examine efficacy of barrier construction to preclude invasion by non-native fishes.
    1.9 Identify important, available private lands and water rights not already protected.
    1.10 Acquire important lands and associated water rights as they become available.
    1.11 Protect acquired lands.

2. Monitor status of existing populations.

    2.1 Establish and implement standard monitoring locations for extant populations.
    2.2 Establish and implement standard techniques and their application.
    2.3 Establish and maintain a computerized database for tracking of monitoring and reintroduction information.

- 2.4 Determine range of natural variation in absolute abundance and age-class structure.
  - 2.4.1 Develop standard methods for quantifying abundance.
  - 2.4.2 Conduct bi-annual (spring, autumn) population estimates.
- 2.5 Monitor community composition.
  - 2.5.1 Apply standard locations and techniques (2.1, 2.2).
  - 2.5.2 Determine range of natural variation in relative abundances of community members.
- 2.6 Determine genetic characteristics of existing populations.

3. Identify nature and significance of interaction with non-native fishes.

- 3.1 Direct interaction (predation, displacement).
  - 3.1.1 Field investigations and experimental manipulations.
  - 3.1.2 Laboratory studies.
- 3.2 Indirect interaction (mediated by other fishes of the community).
  - 3.2.1 Field investigations and experimental manipulations.
  - 3.2.2 Laboratory studies.

4. Quantify, through research, spikedace habitat needs and the effects of physical habitat modification on life cycle completion.

- 4.1 Substrate.
- 4.2 Velocity and depth.
- 4.3 Water Temperature.
- 4.4 Water Chemistry.
- 4.5 Interactions among 4.1-4.3.
- 4.6 Watershed size and flood frequency and volume.

5. Enhance or restore habitats occupied by depleted populations.

- 5.1 Identify target areas amenable to management.
- 5.2 Determine necessary habitat and landscape improvements.
- 5.3 Implement habitat improvement.

6. Reintroduce populations to selected streams within historic range.

- 6.1 Identify stocks amenable to use for reintroduction.
- 6.2 Identify river or stream systems for reintroduction.
  - 6.2.1 Determine suitability of habitat.
  - 6.2.2 Enhance habitat as necessary (4, 5.3).
  - 6.2.3 Assess status of non-native fishes in the watershed.
  - 6.2.4 Assure closure of potential immigration routes to preclude reinvasion by non-native fishes.
  - 6.2.5 Reclaim as necessary to remove non-native fishes.
- 6.3 Reintroduce spikedace to selected reaches.
- 6.4 Monitor success/failure of reintroductions.
- 6.5 Determine reasons for success/failure.
- 6.6 Rectify as necessary cause(s) of failure and restock.

7. Determine quantitative criteria for describing a self-sustaining population.

- 7.1 Acceptable levels of natural variation.
  - 7.1.1 Absolute numbers.
  - 7.1.2 Age-class structure.
  - 7.1.3 Reproduction.

7.1.4 Recruitment.
7.2 Minimum stock size.
7,3 Environmental variables.
7.3.1 Physical characteristics.
7.3.2 Chemical characteristics.
7.3.3 Biological community.

8. Plan and conduct investigations on captive holding, propagation and rearing.

8.1 Determine wild stocks suitable for contribution to hatchery stocks.
8.2 Collect and transfer wild stocks to suitable facility.
8.3 Develop procedures and facilities for holding and maintaining.
8.4 Evaluate potential techniques for propagation.
8.5 Assess life-cycle requirements in hatchery environment.
8.6 Supply individuals as needed for reintroduction, research, public education, etc.

9. Information and education.

9.1 Public sector.
9.1.1 Local media and target campaigns.
9.1.2 States of Arizona and New Mexico.
9.1.3 National exposure.
9.1.4 Assist appropriate Mexican agencies and organizations in information and education.
9.1.5 Open communication among States, Federal agencies, and local residents and water users.
9.2 Professional information.
9.2.1 Open circulation of information among concerned parties.
9.2.2 Periodic information-exchange meetings.
9.2.3 Presentations at professional, scientific meetings.
9.2.4 Publication in peer-reviewed, open literature.

Narrative

1. **Protect existing populations of spikedace.**

Remaining populations of spikedace in Verde River, Aravaipa Creek, and Eagle Creek, Arizona, and upper Gila River and its major tributaries in New Mexico, plus other potential locations, continue to be threatened by habitat modification or destruction, predation by introduced fishes, inadequacy of existing regulations, and continued introduction and dispersal of non-native fishes. Recovery of the species cannot be accomplished without first identifying and protecting remaining populations.

1.1 **Identify extent of existing populations and level of protection afforded to each.**

Undiscovered populations of spikedace may occur in unsurveyed or incompletely inventoried habitats; these populations should be identified so that the present distribution and range of the species is known. General areas which should be thoroughly sampled to determine potential occurrence of spikedace include the Gila River drainage in Sonora, Mexico, and lands in the United States controlled or owned by the U.S. Forest Service and San Carlos and White Mountain Apache Indian tribes. After geographic locations of all populations are known, the existing level of protection afforded by any public or private entity should be determined for each population. Completion of these preliminaries will enable prioritization of the various habitats/populations as regards implementation of specific recovery activities outlined below.

1.2 **Prioritize existing populations as to need or imminent need for protection.**

Populations of spikedace that occupy relatively undisturbed habitat and are afforded substantial protection by one or more governmental or private entities (e.g., Aravaipa Creek, Arizona) are considered in less imminent need of additional protection than those in degraded habitats or which are minimally protected. Prioritization of all known populations as regards need for protection should be accomplished so steps toward the species recovery can proceed in a logical manner. Recovery activities for populations in most imminent danger of decline or extirpation should be accomplished first.

1.3 **Designate critical habitat.**

Critical habitat (Appendix A) was proposed by FWS (1985), but formal designation was deferred until 18 June 1987. That designation has not yet occurred, and although the existing proposal continues in force, it provides only limited protection. Pending outcome of 1.1 (above), it may be appropriate to consider additional stream reaches for inclusion in the designated critical habitat. Existing information on the spikedace in Eagle Creek is sufficient at this time to recommend consideration of a portion of that creek (Appendix A) for addition to the legally designated critical habitat. Much land adjacent to streams or stream reaches occupied by spikedace is under full or partial jurisdiction and/or presumed protection by U.S. Bureau of Land Management (Aravaipa Creek, Gila River);

The Nature Conservancy (Aravaipa Creek, Gila River); New Mexico Department of Game and Fish (West and Middle Forks Gila River); New Mexico State Land Office (Gila River); New Mexico Museum of Natural History (East Fork Gila River); National Park Service Gila Cliff Dwellings National Monument, administered by U.S. Forest Service (West Fork Gila River); U.S. Forest Service, Gila National Forest, including Gila Wilderness Area, Lower Gila River Bird Habitat Management Area, and Gila River Research Natural Area (Gila River); U.S. Forest Service, Prescott National Forest (Verde River); State of Arizona (Verde River); U.S. Forest Service, Apache-Sitgreaves National Forests (Eagle Creek); and San Carlos Apache Indian Reservation (Eagle Creek). However, protection of spikedace on Federal and other lands will be greatly enhanced when the species' critical habitat is formally designated and compliance with the Endangered Species Act is fully implemented. Other significant stream reaches occupied by spikedace flow through privately-owned lands, and with exception of reaches owned by conservation organizations, receive minimal or no protection.

1.4 **Enforce existing laws and regulations affecting spikedace.**

Failure of any entity to recognize and comply with laws and regulations that protect spikedace and its habitat may contribute to its imperiled status, result directly or indirectly in further population declines, and impede recovery of the species.

1.4.1 **Inform as necessary appropriate agencies of applicable management/enforcement responsibilities.**

Where not so informed, agencies and their personnel should be made aware of their responsibilities regarding laws protecting listed species and their habitats, and the appropriate roles each agency would play to most effectively insure their protection.

1.4.2 **Assure compliance with Section 7 of the Endangered Species Act.**

Federal agencies should comply with Section 7 of the Endangered Species Act and should consult with the U.S. Fish and Wildlife Service on any project that has potential to affect spikedace.

1.4.3 **Assure compliance with Section 9 of the Endangered Species Act.**

Compliance of all private and public entities with the Section 9 prohibitions and implementing regulations regarding take of a threatened species should be insured.

1.5 **Discourage detrimental land and water use practices.**

Wise use of water and land can benefit both the user and the physical and biotic natural resources of the area. Practices which are detrimental to or destructive of habitats and extant populations of spikedace should be discouraged in all places. Information and education should be provided that will enable all users, especially private landowners, to be aware of detrimental practices and their acceptable alternatives.

1.6 Insure perennial flows with natural hydrographs.

Spikedace cannot exist in dewatered places, and populations can be expected to decline or disappear from stream reaches which are intermittent or ephemeral. Permanence of flows of sufficient quantity and quality must be assured to maintain integrity of spikedace populations and their habitats. Also, Southwestern stream fishes apparently are enhanced relative to non-native species where streams are characterized by a natural hydrograph (Minckley and Meffe 1987). Formal agreements that stream flows will not be modified by activities such as damming or diversion that substantially alter natural flow regimes should thus be an integral part of insuring perennial flows. For example, U.S. Bureau of Land Management is in the final stages of applying for an instream flow water right for Aravaipa Creek, Arizona.

1.7 Curtail transport and introduction of non-native fishes.

Where they do not already exist, appropriate regulations should be promulgated that discourage transport and stocking of non-native fishes, especially red shiner, into habitats from which they have access to stream reaches occupied by spikedace. State, Federal or other fish management agencies and private entities should discontinue stockings of non-native, warmwater sport, forage, or bait fishes into or upstream from streams occupied by spikedace, and upstream from the first absolute barrier to upstream fish movement into spikedace habitats.

Operation and future siting of State, Federal, or private facilities that hold, propagate, rear, or participate in other fish or aqua-cultural activities with non-native fishes should ensure that escapement to waters occupied by spikedace is precluded.

1.7.1 Discourage seining and use of live bait in streams occupied by spikedace.

Introductions of non-native fishes may occur as a result of intentional or inadvertent release of bait fishes used for sport angling. Where sport fishes and spikedace are known to co-occur or in areas of sport fishing which are not separated by barriers from stream reaches occupied by spikedace, responsible resource agencies should discourage or disallow use of live bait. Furthermore, bait fish seining should not be allowed to occur in stream reaches occupied by spikedace, which could be unknowingly taken and unnecessarily destroyed.

1.8 Examine efficacy of barrier construction to preclude invasion by non-native fishes.

Construction of fish barriers should be considered as a preventive measure for protection of existing populations of spikedace from contamination by non-native fishes. For example, a cooperative effort has determined that construction of such a barrier on Aravaipa Creek, Arizona would protect upstream populations of native fishes, including spikedace, from invasion by red shiner and other non-native fishes. Other streams occupied by spikedace may also be amenable to such management, and responsible agencies should fully evaluate efficacy of this action.

1.9 **Identify important, available private lands and water rights not already protected.**

Although a significant proportion of lands adjacent to presently occupied spikedace habitat already receive some degree of protection from State, Federal, or private entities, other lands through which potentially important stream reaches pass have no such benefit. Unwise land- or water-use practices in and adjacent to occupied reaches could have detrimental impacts upon spikedace residing in the same drainage. Obviously, fishes must have sufficient water to survive and flourish. Thus, water rights associated with important stream reaches must be acquired. The U.S. Fish and Wildlife Service should designate the appropriate agencies to identify these areas and their water rights, determine their ownership, and assess the potential availability of necessary water rights.

1.10 **Acquire important lands and associated water rights as they become available.**

A variety of mechanisms exist by which lands, management rights, and/or water rights may be acquired by State, Federal, or private entities inclined to do so in behalf of protecting spikedace and its habitat. Acquisition of these lands and water rights will add to assurance that existing populations and their habitats are secure.

1.11 **Protect acquired lands.**

Once important lands and stream reaches are known and in appropriate ownership, they can be administered and managed in ways consistent with perpetuation of spikedace populations and habitats.

2. **Monitor status of existing populations.**

Standardized, long-term monitoring is necessary to detect changes in population status, assess success of recovery-management actions, and determine when applicable criteria for delisting have been fulfilled. The U.S. Fish and Wildlife Service and States of Arizona and New Mexico, advised by the Desert Fishes Recovery Team, should specify a standardized monitoring program, based upon biological considerations plus practical constraints, to address elements outlined below.

2.1 **Establish and implement standard monitoring locations for extant populations.**

Stream and river reaches representing typical habitats actually or potentially occupied by spikedace populations in Arizona and New Mexico should be selected for routine monitoring. Only when data are obtained from standard areas can natural or other changes in habitat or population status be determined.

2.2 **Establish and implement standard techniques and their application.**

Techniques for assessing spikedace habitat and population status should be consistent spatially, temporally, and among investigators. Standard monitoring techniques should be developed and implemented to insure that results are comparable among years, populations, and groups involved in this monitoring. In some instances, use of specific techniques may be restricted, for example, use of motorized equipment, and such constraints should be considered in selection of methodologies.

2.3 Establish and maintain a computerized database for tracking of monitoring and reintroduction information.

Adequate data tracking would allow management actions to be based on the best up-to-date information and would insure rapid assessment of recovery progress. A centralized, computerized database should be established that will contain all available historic information on distribution and abundance of spikedace throughout its range. All monitoring data on existing populations, plus information on establishment and monitoring of reintroduced populations should be placed into this database as soon as the information is available.

2.4 Determine range of natural variation in absolute abundance and age-class structure.

Populations of spikedace vary substantially, both spatially and temporally, in response to dynamics of individual populations and natural changes in their environment. Changes in status of spikedace populations can be attributed to other than natural causes only when the range of variation expected from intact populations in relatively unperturbed habitats has been assessed. Population status is most readily assessed by knowing absolute abundance of individuals in the population, and distribution of individuals among age-classes (cohorts) and their sex ratio.

2.4.1 Develop standard methods for quantifying abundance.

Several techniques are available for determination of absolute abundance of fishes, including depletion sampling, mark-and-recapture, etc; these may be modified or others developed specifically for application to spikedace. Such techniques should be adjusted as dictated by experience, and uniformly applied thereafter.

2.4.2 Conduct bi-annual (spring, autumn) population estimates.

Population estimates should be conducted at times of year that are most likely to provide managers with the most useful information as regards status of spikedace. Spring sampling allows assessment of adult reproductive condition, while autumn sampling provides opportunity to evaluate year-class strength, survival, and recruitment relative to the spawning population. Both are necessary to adequately determine population status.

2.5 Monitor community composition.

Populations of spikedace may be subject to influences of other members of the fish community. Changes in status of other species, especially non-native kinds, may serve notice that spikedace status also may be expected to change. At least a minimum of predictability of change within a normal range of variation is necessary to manage populations of spikedace, and any information that will enhance that capability may enable management decisions and implementation before potential negative impacts are realized.

2.5.1 **Apply standard locations and techniques (2.1, 2.2).**

Techniques for assessing status of the fish community should be compatible with those specifically selected for spikedace monitoring, and should be standardized as regards time, place, and methods.

2.5.2 **Determine range of natural variation in relative abundances of community members.**

A most easily obtained and readily interpreted datum is relative abundance of fish community constituents. However, change caused by other than natural factors cannot be reliable assessed unless an indication of the range of normal variation experienced by communities in relatively unperturbed habitats is first known. Baseline data already available should be augmented by information from future, routine sampling of fishes.

2.6 **Determine genetic characteristics of existing populations.**

Baseline information on the genetic characteristics of existing spikedace populations should be gathered to elucidate relationships and degree of variation among populations and to provide guidance in protection, propagation, and reintroduction programs (Echelle 1988; 6.1, 6.3, and 8.1, below). Results of an initial survey will be required to insure that any genetic differences among populations are considered in the implementation of this plan.

3. **Identify nature and significance of interaction with non-native fishes.**

Impacts of non-native fishes on spikedace cannot be alleviated or otherwise managed until the mechanism(s) of such interactions are known and an assessment as to the qualitative and quantitative significance of the interaction has been completed.

3.1 **Direct interaction (predation, displacement).**

Research has shown that certain non-native fishes prey intensively upon native fishes (e.g., Meffe 1983, 1985). Likewise inferential evidence suggests that introduced fishes displace native species (e.g., Minckley and Deacon 1968, Marsh et al. 1989). These kinds of interaction thus appear most fruitful for investigation in the case of spikedace. Other potential mechanisms of interaction should also be investigated where data suggest they may be important.

3.1.1 **Field investigations and experimental manipulations.**

Evidence of direct interaction is most convincing when derived from studies on *in situ* populations. Because spikedace and potentially detrimental non-native fishes co-occur in several places (e.g., Gila and Verde rivers, Eagle Creek), these habitats and communities should be selected for intensive field studies. Experimental manipulations in which selected species are variously included or excluded among available habitats would provide a powerful tool for evaluating interactions (e.g., Power et al. 1985). Appropriate study reaches, specific experimental designs, etc., should be determined by consensus among knowledgeable individuals.

3.1.2 **Laboratory studies.**

Some aspects of direct interaction among spikedace and non-native fishes can be determined best under controlled, laboratory conditions. These studies would provide a framework and direction for applied field investigations (3.1.1).

3.2 **Indirect interaction (mediated by other fishes of the community).**

Effects of non-native fishes upon spikedace may not be caused by direct interaction, but rather indirectly by the effect of non-native fishes on other members of the fish community. Regardless, prudent management of spikedace populations cannot be implemented until the nature and significance of each is evaluated.

3.2.1 **Field investigations and experimental manipulations.**

Field studies and in-stream experiments would be necessary to qualitatively and quantitatively describe indirect interactions among spikedace and non-native fishes (see 3.1.1).

3.2.2 **Laboratory studies.**

Studies of spikedace, other native fishes, plus non-native species, under controlled, laboratory conditions, could identify a range of biological and habitat parameters important to indirect interactions; these then could be applied toward intensive field studies (3.2.1).

4. **Quantify, through research, spikedace habitat needs and the effects of physical habitat modification on life cycle completion.**

Localized depletion or extirpation of spikedace may be caused by changes in proximal physical habitat acting on one or more life history stage or function. Likewise, widespread depletion or extirpation may be caused by far-reaching alterations of watershed characteristics acting on one or more life history stage or function. Qualitative and quantitative relationships among specific kinds of habitat modification and spikedace biology must be established before management can be directed toward correcting and removing the cause(s) of deleterious habitat conditions. Such analyses will be dependent upon prior determinations of spikedace habitat needs and usage. Research must consider all life history stages as well as variations in seasonal and diurnal use.

4.1 Substrate.

Erosion and siltation which result in filling of interstitial spaces of gravel riffles occupied by spikedace may interfere with successful egg deposition and incubation, and thus impact recruitment, population abundance, and age-class structure (Propst et al. 1986). Substrate armoring which renders suitable egg incubation sites unavailable to spikedace may have similar effects. Quantitative relationships must be established so that conditions characterizing suitable habitats can be described, changes can be assessed, and management strategies for reclamation of impaired habitat can be assessed and implemented.

4.2 **Velocity and depth.**

Land- and water-use practices that alter water velocity and depth may affect spikedace, which have demonstrated specializations for these parameters (Turner and Tafanelli 1983, Rinne 1985, Propst et al. 1986, Rinne and Kroeger 1988). Available data should be reviewed and augmented so that preferenda can be determined, and tolerance limits established.

4.3 **Water temperature.**

Water- and land-use practices may influence thermal regimes in habitats occupied by spikedace. Relationships among spikedace life history and temperature are poorly known, and must be established as regards optima, preferenda, and tolerated extremes, so that conditions characterizing suitable habitats can be described, changes can be assessed, and management strategies for reclamation of impaired habitat can be evaluated and implemented.

4.4 **Water chemistry.**

Water- and land-use practices may influence various chemical parameters of the waters occupied by spikedace. Preferenda and tolerance limits of spikedace life history stages need to be established for basic parameters, such as pH, turbidity, alkalinity, and dissolved oxygen, so that the effects of changes in those parameters may be assessed.

4.5 **Interactions among 4.1-4.3.**

Water- and land-use practices may affect one or several environmental parameters important to successful spikedace life cycle completion. Thus, synergistic or antagonistic effects of changes in substrate, velocity, depth, and water temperature should be assessed to determine combinations representing optima, preferenda, and tolerance limits.

4.6 **Watershed size and flood frequency and volume.**

It has been speculated that spikedace may be limited to occupation of streams with a certain minimum watershed size and/or water volume (Propst pers. comm.), based on the absence of spikedace from small tributary streams even if habitat is apparently available. Impoundment and/or diversion of upstream waters, watershed vegetation alteration resulting in changing runoff patterns, and other human actions functionally modify both watershed size and water volume. Flooding has been shown to be a major factor in the relationship of native to non-native fishes (Minckley and Meffe 1987, Propst et al. 1986). Flood frequency and volume is frequently modified in southwestern streams during the course of water development. Relationships between watershed characteristics and spikedace biology must be established so that conditions characterizing suitable habitats can be described, effects of changes can be assessed, and management strategies can be prepared and implemented.

5. Enhance or restore habitats occupied by depleted populations.

Management strategies developed to minimize or eliminate negative impacts resulting from habitat modifications and/or interactions with non-native fishes should be applied to habitats in which spikedace populations have been depleted. Such management provides opportunity for continued study of relationships between spikedace and its biological and physical environment, to assess efficacy and modify specific practices of management implementation, and contributes toward recovery of the species.

5.1 Identify target areas amenable to management.

Some habitats occupied by depleted populations of spikedace, and their adjacent landscapes, may be amenable to restoration, while others may be in a state of continuing degradation such that they cannot reasonably be revived to suitable condition. These former places should be identified so that management can be implemented that will enhance or restore them to pre-impact condition.

5.2 Determine necessary habitat and landscape improvements.

Habitat improvements can be effected only when physical characteristics necessary for spikedace occupation, reproduction, and self-sustenance are known. Moreover, habitat restoration likely will require removal of conditions which have led to degradation. Some stream and river reaches may "self-improve" if natural forces are allowed to reign in absence of sources of perturbation. Examples include curtailment of overgrazing, stabilization of bankline or other erosion sites, altered timber management strategies, etc. Moreover, depletion or removal of non-native fishes, if identified as significant deterrents to survival or enhancement of spikedace, may be necessary.

5.3 Implement habitat improvement.

Once sources of impacts and habitat parameters in need of improvement have been identified, measures should be implemented to remove impacts and restore damaged habitats to conditions suitable for occupation by spikedace. Where removal of non-native fishes is indicated, measures should be adopted to preclude future invasion and establishment in the area by such fishes. This may require installation of barriers to up- or downstream movement, or alternatively may demand repeated management to remove non-natives.

6. Reintroduce populations to selected streams within historic range.

One of the most critical goals to be achieved toward spikedace recovery is establishment of secure, self-reproducing populations in habitats from which the species has been extirpated. Successful implementation of this management goal will provide a clear indication that both the biology of the species and the impacts resulting in its demise are well enough understood and management strategies effective enough that attainment of recovery is probable.

6.1 <u>Identify stocks amenable to use for reintroduction.</u>

Stable, self-sustaining populations with capacity to contribute individuals for reintroduction without sustaining unnecessary depletion should be identified. To the extent practicable, local stocks with affinities to those formerly occupying target streams should be utilized (e.g., Aravaipa Creek for San Pedro, Gila River for San Francisco). Results of a genetic survey (2.6, above) will be used as guidance in selecting appropriate donor stock. If it is determined that extant populations do not have capacity to supply adequate numbers of individuals for reintroduction, hatchery-produced fish may be required (8, below).

6.2 <u>Identify river or stream systems for reintroductions.</u>

Among streams from which spikedace have been extirpated, the San Pedro River system, Arizona, probably represents the most amenable, for several reasons, to its reestablishment. San Pedro River is the type locality for spikedace (Girard 1857), but it and 10 other native fishes were extirpated as a result of drastic habitat destruction, plus introduction of exotic fishes, over the last 100 years (Eberhardt 1981, Minckley 1987). Not only the mainstream San Pedro may be readily amenable to restoration for spikedace, but also certain perennial reaches of major tributaries (e.g., Redfield Canyon, Babocomari River) may have potential for reestablishment of the species. Aravaipa Creek, which is home to one of the most secure remaining spikedace populations in Arizona, is tributary to the San Pedro. The San Francisco River and Mescal Creek (tributary to the Gila River), plus other yet-to-be-identified locations, should also be evaluated as potential recipients of reintroduced populations.

6.2.1 <u>Determine suitability of habitat.</u>

Specific stream reaches that fulfill known requirements plus areas amenable to restoration should be identified. Causes and sources of former and continuing habitat degradation and the cause of the original extirpation need to be evaluated, and extant ichthyofaunas must be assessed.

6.2.2 <u>Enhance habitat as necessary (4, 5.3).</u>

Habitats amenable to physical restoration should be subject to management implementation to restore them to pre-impact condition. This may require modification or discontinuance of certain land- or water-use practices if it is determined that these continue to contribute to habitat degradation.

6.2.3 <u>Assess status of non-native fishes in the watershed.</u>

Non-native fishes pose potential threats to reestablishment of spikedace. These may occupy the stream reach selected for reintroduction, tributaries, and isolated waters within the watershed. Assessment should be made of distribution, community composition, and relative abundances of non-native fishes.

6.2.4 **Assure closure of potential immigration routes to preclude reinvasion by non-native fishes.**

Stream reaches identified to receive plantings of spikedace should be isolated as much as practicable from non-native fishes, which might preclude or otherwise interfere with successful reestablishment of the native. Closure of immigration routes might include construction of barrier dams or other structures to insure that downstream populations of exotics do not access habitats occupied by reintroduced stocks of spikedace.

6.2.5 **Reclaim as necessary to remove non-native fishes.**

Non-native species in places from which they could invade spikedace habitat, or those occupying target areas themselves, should be removed or depleted as completely as possible. Removal from live stream reaches would likely be accomplished by piscicide application, while other waters, such as cattle tanks, could be reclaimed by either drainage or pumping, piscicide treatment, or a combination thereof.

6.3 **Reintroduce spikedace to selected reaches.**

Spikedace should be collected, transported, and reintroduced into selected stream reaches after habitat restoration and exotic species removals have been accomplished. Stocking should be of numbers of individuals necessary to assure maintenance of reasonable genetic heterogeneity of the reintroduced population (Echelle 1988).

6.4 **Monitor success/failure of reintroductions.**

Reintroduced spikedace populations should be periodically monitored; location, time of year, and methods (2., above) should be standardized so data are comparable with previous information for other populations and can be used to assess changes in status.

6.5 **Determine reasons for success/failure.**

Success of reintroductions will be indicated by establishment of reproducing, sustaining populations of spikedace with characteristics of abundance, age-class structure, and recruitment in the range of natural variation determined from extant stocks. Causes of reintroduction failure, indicated by aberrancies in population characteristics or extirpation, must be identified and evaluated. These could be a result of incomplete implementation of identified management strategies, or due to other natural or anthropogenic factors. Using monitoring data, preliminary evaluation of success should be made five years after reintroduction. Failed populations should then be reassessed and decisions regarding rectification of problems, restocking, or abandonment made. Populations which are questionable or successful at that time should be monitored for an additional five years before being judged successful or not.

6.6 **Rectify as necessary cause(s) of failure and restock.**

Identified sources of failure should be rectified. This may require implementation of the same, or refinements of, strategies identified previously, or implementation of additional ones. Additional reintroduction-stocking may be indicated once sources of initial failure are identified and removed. In some instances, repeated sequences of reintroduction, monitoring, assessment, and refinement may be necessary before local goals are satisfied.

7. **Determine quantitative criteria for describing a self-sustaining population.**

Recovery goals call for protecting existing populations, restoration of depleted stocks, reestablishment of spikedace in places from which the species has been extirpated, and insurance that the animal has opportunity to self-sustain in perpetuity. Attainment of each can be determined only from quantifiable criteria applied to populations under consideration. In particular, acceptable levels of natural variation within certain parameters of stable, reproducing populations must be determined (see Meffe and Minckley 1987). Absolute and relative abundance, age-class structure and sex ratio, and recruitment are variables most likely to provide needed data as regards population status. These must be interpreted within a context of security of the habitat and watershed against future detrimental change, and of integrity of the fish community as regards invasion and establishment of non-native species.

7.1 **Acceptable levels of natural variation.**

Populations behave in response to normal variations in their physical and biological environments. Thus, population density, for example, can be expected to vary naturally in time and space. Determination that a population is "healthy" can be made only when the range of normal variation of key population parameters is known.

7.1.1 **Absolute numbers.**

Presence/absence data provide valuable information, and usually can be assessed expediently. However, such data may not generally be useful for evaluating change in populations status relative to normal environmental variation. Absolute abundance can be determined by any of several methods, such as depletion sampling or mark-and-recapture studies. When standardized as to location, time of year, and method, data are comparable among samples and populations and can be used to establish "mean" conditions and acceptable limits of normal variation.

7.1.2 **Age-class structure.**

Age-class structure can readily be determined from measurements of individuals sampled during population abundance estimation. Relative health of the population is indicated by a normal distribution of individuals among age-classes, i.e., natural mortality acts to diminish the number of individuals in each successive, older age-class. Obvious aberrancies, such as complete failure of a year class or absence of an age-class, or markedly skewed sex ratio, likely indicate substantial pressure on the population, and may require remedial action.

7.1.3 **Reproduction.**

Populations can perpetuate themselves only if reproduction replaces individuals lost to natural (or other) sources of mortality. Spikedace reproduction should be assessed by determination that the population includes an adequate stock of reproductive fish of both sexes in a "normal" ratio, and that egg deposition, embryo incubation, and larval hatch are successful.

7.1.4 **Recruitment.**

Larval fish must have opportunity to grow, mature, and eventually contribute their gametes to future generations. Thus, dynamics of a healthy population require that an appropriate number of offspring survive to reproduce. Assessment of recruitment would be in concert with evaluations of absolute numbers and age-class structure.

7.2 **Minimum stock size.**

For each population in time and space, there is a minimum size (number) of reproductive fish necessary for perpetuation of the stock. When numbers dwindle below this minimum stock size, natural (and other) sources of mortality will eventually result in extirpation, even though diminished reproduction and recruitment may occur for a time. While it is probably impractical to attempt to quantify minimum stock size for all present and future populations of spikedace, some consensus should be achieved among knowledgeable individuals as to what represents reasonable minimum stocks for spikedace in various habitats. Depletion of a population near or below that minimum should be taken as indication that one or more environmental factor(s) is negatively impacting the population. Further investigation to determine and rectify the cause would be necessary. A self-sustaining population would not dwindle below minimum stock size.

7.3 **Environmental variables.**

Self-sustenance in perpetuity requires that habitat at all times meet at least the minimum requirements for life-cycle completion by the species. Some habitats may support spikedace populations for a period of time, then fail. It thus is important that characteristics which describe suitable, long-term habitat be known.

7.3.1 **Physical characteristics.**

Basic habitat parameters include depth, current velocity, substrate, water temperature, etc. These, plus others determined significant, must be available within tolerance ranges acceptable to spikedace.

7.3.2 **Chemical characteristics.**

Fishes require varying levels of certain chemical substances to insure completion of all life history functions. For example, dissolved oxygen must remain above certain minima for fishes to survive. Also, levels of environmental chemicals, both natural and anthropogenic, must be maintained such that they do not induce acute or chronic symptoms of toxicity among spikedace, or otherwise interfere with life cycle completion.

7.3.3 **Biological community.**

Maintenance of spikedace populations in perpetuity requires that the composition and integrity of the biological community of which it is a member also be maintained. Spikedace existence depends in various ways on parts of that community (e.g., aquatic insect food resources). Moreover, perturbation of the community may indicate future changes about to occur in spikedace status. Invasion by exotic forms, especially non-native fishes, may have severe impacts upon spikedace and other native fishes. Attempts should thus be made to assess, at least in general terms, the nature and condition of the biological communities that characterize habitats occupied by spikedace.

8. **Plan and conduct investigations on captive holding, propagation and rearing.**

Captive holding, propagation, and rearing programs are important aspects of recovery plans for most southwestern fishes. At present, it does not appear necessary that such plans be instituted in behalf of spikedace. The species continues to occupy in substantial numbers a variety of dispersed habitats, and probability of protecting existing populations and environments appears high. However, conditions could change rapidly and existing populations could be severely depleted or extirpated. In such event, availability of a viable hatchery plan could be indispensable to maintenance of the species. Hatchery-produced fish may also be necessary to support reintroductions of sufficient numbers in attempts to reestablish populations in historic habitats.

8.1 **Determine wild stocks suitable for contribution to hatchery stocks.**

An assessment should be made as to which extant populations are most capable of contributing individuals for captive programs without suffering unnecessary depletion which could impair status of the parent stock. Consideration should be given to maintaining genetic integrity of captive stocks in the context of existing wild populations (Echelle 1988; 2.6, above).

8.2 **Collect and transfer wild stocks to suitable facility.**

Adult spikedace should be collected and transferred to an appropriate facility where investigations on holding, captive propagation, and maintenance may be pursued.

8.3 **Develop procedures and facilities for holding and maintaining.**

Standardized techniques and facilities should be developed by which spikedace of all sizes and ages can be safely held and maintained without threat of excessive mortality.

8.4 **Evaluate potential techniques for propagation.**

Stream minnows may reproduce voluntarily if placed into suitable artificial habitat. Or, the species may require artificial induction, maturation, expression and fertilization of gametes, and incubation of embryos. Techniques should be found that are effective and efficient, and which minimize mortality to adult fish.

8.5 Assess life-cycle requirements in hatchery/environment.

Certain environmental requirements may need to be met to insure successful life cycle completion in the hatchery. For example, specific temperatures may be necessary for spawning and normal larval development, or a certain sex ratio may be required if fish are to spawn voluntarily. Such factors should be determined and optimized where practicable.

8.6 Supply individuals as needed for reintroduction, research, public education, etc.

Spikedace propagated and reared in a hatchery can serve many purposes. Fish can be transported to selected sites for reestablishment of extirpated populations. Research programs to answer basic questions of spikedace life history and ecology undoubtedly could utilize captive-reared individuals. And, progeny from hatchery stocks could be distributed to schools, museums, zoos, etc., where they could be displayed along with appropriate literature or other information on spikedace in particular and endangered species in general. In each instance where hatchery fish were used, wild populations would be protected against any potential damage which could result from removal of individuals.

9. Information and education.

Free exchange of information and ideas among individuals representing scientific, managerial, and private concerns, and the public sector including citizens groups, should be recognized as essential for a successful recovery program. Information on goals, plans, and progress of recovery implementation should be readily available to all interested parties. Awareness of the general public, in whose behalf the Endangered Species Act was conceived and passed into law, is critical to this plan and to conservation of all imperiled species.

9.1 Public sector.

Spikedace represents a National resource of value to all people. Because the laws designed to protect this animal, and by which this recovery plan is enabled, originated with desires of the public, it is essential that they be offered every opportunity to be informed and to participate in all aspects of spikedace recovery. Public support has capability to greatly enhance and thereby assure success of spikedace recovery; such support is derived from informed people.

9.1.1 Local media and target campaigns.

Because people who reside in proximity to habitats occupied by spikedace are often those who express greatest interest in, and may be most affected by, activities associated with recovery, they should be informed of and provided opportunity to participate in all aspects of recovery. Local media including television, radio, newspapers, and circulars should be provided regular, timely, and accurate summaries of plans and progress toward spikedace recovery. They should be encouraged to express their opinions, and thereby provide input to improve the plan and enhance probability of success.

9.1.2 States of Arizona and New Mexico.

Media with statewide distribution and readership in Arizona and New Mexico should be targeted for receipt of periodic information on spikedace recovery. In this way a larger audience with interest in the program can be accessed, and their support encouraged through education.

9.1.3 National exposure.

Federal laws that protect threatened and endangered plants and wildlife are of interest to all residents of the Nation. It, thus is appropriate that they be allowed to assess efficacy of that legislation through information received on projects throughout the country. In this way, persons with interests in species conservation in general can be assured an opportunity to be informed on a diversity of plans and programs.

9.1.4 Assist appropriate Mexican agencies and organizations in information and education.

A significant portion of the San Pedro River is in Mexico, and stream reaches within that Country may be occupied by undiscovered populations of spikedace. Moreover, health of aquatic biota including possible reintroduced populations of spikedace in portions of that river in the United States may be dependent upon conditions upstream in Mexico. It, thus is important that appropriate Mexican agencies and organizations be apprised of recovery efforts, and that assistance be provided to these groups to enhance awareness in Mexico of continuing threats to this threatened species.

9.1.5 Open communication among States, Federal agencies, and local residents and water users.

It is imperative that all parties interested in or affected by recovery actions in behalf of spikedace be afforded an opportunity to comment on and participate in that program. While unanimity is unlikely to ever be the case, meaningful progress is best assured when all have access to complete information.

9.2 Professional information.

Professional information, including results of field and laboratory research, monitoring data, trip reports, agency reports, and open literature must be readily available to all professionals involved in spikedace recovery. Ideas must be exchanged freely so that optimal strategies may be outlined and implemented. A central clearing house and repository for such information, with capability to distribute it as necessary, should be designated.

9.2.1 Open circulation of information among concerned parties.

All persons working on spikedace and/or their habitats should be encouraged to make information available to other concerned parties. They should be made aware of the clearing house (9.2) and requested to submit their findings there for distribution.

9.2.2 **Periodic information-exchange meetings.**

Face-to-face meetings of interested professionals and the public should be encouraged on a regular basis, or in response to special circumstances. Such meetings provide opportunity to discuss ideas and resolve difficulties that otherwise could be difficult to accomplish.

9.2.3 **Presentations at professional, scientific meetings.**

Preliminary or refined research or monitoring data should be presented at local, regional, and National scientific-gatherings so that a broader professional audience may have opportunities to comment on and thereby potentially enhance recovery of spikedace.

9.2.4 **Publication in peer-reviewed, open literature.**

Participants in studies of spikedace at all levels should be encouraged to publish their findings as appropriate within the peer-reviewed, open literature. Such publication indicates that results have had benefit of critical review and meet the standards of excellence to which professionals subscribe. It also enhances the credibility of individuals involved, and thus contributes to overall success of the recovery program.

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III. IMPLEMENTATION SCHEDULE

Definition of Priorities

Priority 1 - Those actions that are absolutely essential to prevent the extinction of the species in the foreseeable future.
Priority 2 - Those actions necessary to maintain the species' current population status.
Priority 3 - All other actions necessary to provide for full recovery of the species.

General Categories for Implementation Schedules

Information Gathering - **I or R**

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Other - **O**

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

Acquisition - **A**

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Management - **M**

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Abbreviations used

FWS - USDI Fish and Wildlife Service
- FWE - Fish and Wildlife Enhancement
- FR - Fisheries Resources
- WR - Wildlife Resources
- LE - Law Enforcement
- DFRT - Desert Fishes Recovery Team
- PA - Public Affairs

AZG&F - Arizona Game and Fish Department
NMG&F - New Mexico Department of Game and Fish
FS - USDA Forest Service
BLM - USDI Bureau of Land Management
BR - USDI Bureau of Reclamation

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS REGION	PROGRAM	OTHER	FISCAL YEAR COSTS (EST.) FY1	FY2	FY3	COMMENTS
I-1	Identify all populations and determine level of protection	1.1	1	3 years	2	FWE FR	AZG&F NMG&F FS BLM	4,000	4,000	4,000	
I-1	Prioritize populations based on need for protection	1.2	2	1 year	2	FWE	DFRT			500	Task will be conducted by the DFRT
O-3	Designate critical habitat	1.3	1	1 year	2	FWE		1,000			Final rule is under review
O-2	Enforce laws and regulations	1.4	1	Ongoing	2	FWE LE	FS BLM BR AZG&F NMG&F	5,000	5,000	5,000	
M-3	Discourage detrimental land and water uses	1.5	1	Ongoing	2	FWE	FS BLM BR AZG&F NMG&F	5,000	5,000	5,000	
A-7	Insure natural flows	1.6	1	Ongoing	2	FWE WR	FS BLM BR		----unknown----		Could involve the purchase of instream flows
M-4	Curtail introductions of non-native fishes	1.7	1	Ongoing	2	FR FWE	NMG&F AZG&F				
M-4	Identify need for and construct barriers	1.8	1	Ongoing	2	FWE	BR AZG&F NMG&F BLM FS	100,000	100,000	100,000	
I-2	Identify available unprotected private lands and water rights	1.9	2	Ongoing	2	FWE	WR DFRT NMG&F AZG&F	3,000	3,000	3,000	

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS REGION	FWS PROGRAM	OTHER	FISCAL YEAR COSTS (EST.) FY1	FY2	FY3	COMMENTS
A-1 through A-6	Acquire available lands and associated water rights	1.10	2	Ongoing	2	WR	FWE FS BLM	----unknown----			
O-2 & O-3	Protect acquired lands	1.11	2	Ongoing	2	WR FWE LE	BLM FS	----unknown----			
I-1	Establish standard monitoring locations and techniques	2.1 2.2	1	1 year	2	FWE	FS BLM NMG&F AZG&F DFRT	1,500			
I-1 & I-2	Establish and maintain computerized database	2.3	2	Ongoing	2	FWE	AZG&F	2,000	2,000	2,000	
R-1	Determine natural variation in abundance and age-class structure	2.4	1	3 years	2	FWE	AZG&F NMG&F FS BLM	10,000	10,000	10,000	
R-1	Determine standard methods for quantifying abundance	2.4.1	1	2 years	2	FWE	NMG&F AZG&F FS BLM	2,500	2,500	2,500	
I-1	Conduct bi-annual population estimates	2.4.2	1	Ongoing	2	FWE	NMG&F AZG7F FS BLM	3,000	3,000	3,000	
I-1	Monitor community composition including range of natural variation	2.5 2.5.1 2.5.2	1	Ongoing	2	FWE	NMG&F AZG&F FS BLM	5,000	5,000	5,000	Tasks 2.4.2 tc 2.5.2 would be done simultaneously
I-14	Determine genetic characteristics of existing populations	2.6	1	2 years	2	FWE	AZG&F NMG&F FS	8,000	8,000		

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS REGION	PROGRAM	OTHER	FISCAL YEAR COSTS (EST.) FY1	FY2	FY3	COMMENTS
R-9 & R-10	Determine significance of interaction with non-native fishes	3.1 through 3.2.2	2	3 years	2	FWE	AZG&F NMG&F FS BLM	25,000	25,000	25,000	
R-3	Quantify effects of physical habitat modification	4.1 through 4.6	2	3 years	2	FWE	NMG&F AZG&F FS BLM	25,000	25,000	25,000	
M-3	Identify management areas and determine necessary habitat improvements	5.1 5.2	2	1 year	2	FWE	DFRT NMG&F AZG&F FS BLM			5,000	To be done following completion of tasks 4.1 to 4.4
M-3	Implement habitat improvement	5.3	3	Ongoing	2	FWE	AZG&F NMG&F FS BLM		----unknown----		
M-2	Identify stocks to be used for reintroduction	6.1	3	1 year	2	FWE	DFRT			2,000	
M-2	Identify and prepare sites for reintroduction	6.2 through 6.2.5	3	3 years	2	FWE	DFRT NMG&F AZG&F FS BLM		----unknown----		Cost will depend upon kind and amount of work
M-2	Reintroduce into selected reaches and monitor	6.3 6.4	3	Ongoing	2	FWE	NMG&F AZG&F FS BLM				$7,000/yr once reintroduction
M-2	Determine reasons for success/failure and rectify as necessary	6.5 6.6	3	Ongoing	2	FWE	DFRT AZG&F NMG&F BLM FS				Evaluation will begin 5 years after reintroduction

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS REGION	RESPONSIBLE AGENCY FWS PROGRAM	RESPONSIBLE AGENCY OTHER	FISCAL YEAR COSTS (EST.) FY1	FY2	FY3	COMMENTS
R-1	Determine quantitative criteria for describing a self-sustaining population	7.1 through 7.3.3	2	3 years	2	FWE	AZG&F NMG&F FS BLM DFRT	20,000	20,000	20,000	
M-1	Select stocks to be used for hatchery brood stock	8.1	3	1 year	2	FWE FR	DFRT NMG&F AZG&F			1,000	
M-1	Collect hatchery stocks	8.2	3	1 year	2	FWE FR	AZG&F NMG&F			3,000	
M-1	Hold and maintain stocks in a hatchery	8.3	3	Ongoing	2	FR FWE					$10,000/yr once stocks are taken
M-1	Evaluate and assess propagation techniques and life-cycle requirements	8.4 8.5	3	1 year	2	FR FWE	DFRT NMG&F AZG&F			8,000	
M-1	Supply hatchery reared fish as needed	8.6	3	Ongoing	2	FR FWE	AZG&F NMG&F				$1,500/yr once begun
O-1	Provide information and education relative to the species to the public sector	9.1 through 9.1.5	2	Ongoing	2	FWE PA FR	NMG&F AZG&F FS BLM BR	3,000	3,000	3,000	
O-1	Ensure all professional information is made available	9.2.1 through 9.2.4	2	Ongoing	2	FWE FR	BR AZG&F NMG&F BLM FS	2,500	2,500	2,500	Costs include information publication in scientific journals

IV. APPENDIX A: PROPOSED CRITICAL HABITAT

Proposed critical habitat for spikedace, Meda fulgida, in Arizona and New Mexico, as originally proposed by FWS 1985 (all reaches figured in FWS 1985). Legal descriptions (township, range, and section) are not included here; format modified from original publication. Additional stream reaches may be appropriate for consideration as future additions to the designated critical habitat. Any such additions will be subject to the standard rulemaking process, including publication of a proposal in the Federal Register and a public review period.

Arizona:

1. Graham and Pinal Counties: Aravaipa Creek, the perennial stream portion (approximately 24 kilometers [km] long). This area includes Bureau of Land Management and privately owned lands.

2. Yavapai County:
   a. Verde River, approximately 57 km of river extending from approximately 0.8 km below the confluence with Sycamore Creek upstream to Sullivan Lake. This area includes U.S. Forest Service, private, and State lands.
   b. Sycamore Creek, approximately 1.5 km of stream near the confluence with the Verde River. This includes U.S. Forest Service and privately owned lands. (Note: although originally proposed by the FWS [1985], this stream segment is not expected to be included in a final rule formally designating critical habitat.)

New Mexico:

1. Grant and Catron Counties: Gila River, three sections of river totaling approximately 73 km in length. The first section, approximately 50 km long, extends from the mouth of the Middle Box canyon upstream to the confluence with Mogollon Creek. A second section, approximately 11.5 km long, extends up the West Fork from the confluence with the East Fork. The last section, approximately 11.5 km long, extends up the Middle Fork from its mouth upstream to the confluence with Big Bear Canyon. These river sections flow through U.S. Forest Service, Bureau of Land Management, New Mexico Department of Game and Fish, and privately owned lands.

In addition to the above areas which have been formally proposed for critical habitat designation, the following reach of Eagle Creek is recommended by this plan for addition to the designated critical habitat.

Graham and Greenlee Counties: Eagle Creek, approximately 38 km of stream extending from the Phelps Dodge Corporation diversion dam upstream to the mouth of Sheep Wash. The stream flows through San Carlos Apache Indian, U.S. Forest Service, and private lands. This population was undiscovered at the time critical habitat was originally proposed by FWS [1985]. Because of the relatively unperturbed character of the stream segment and viable spikedace population found there, it is a recommendation of this plan that the reach be proposed for designation as critical habitat.

V. APPENDIX B: COMMENTS

Appendix B is combined for two recovery plans; the spikedace and the loach minnow. It contains a list of plan reviewers, copies of comment letters received, and Service responses to those comments. Comments for both plans were solicited at the same time, and all comment letters address both plans. Therefore, to reduce paper consumption, Appendix B has been printed under separate cover from the body of either recovery plan. Appendix B was distributed along with copies of the plans to a mailing list of interested parties, including Federal and State agencies and parties who submitted comments. Further distributions of either recovery plan will be made without Appendix B, unless it is requested. Separate copies of Appendix B are also available upon request.