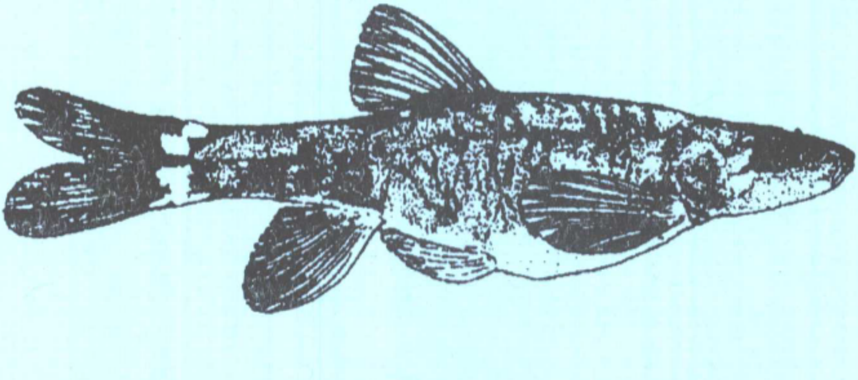
Loach Minnow



Tiaroga cobitis

Recovery Plan

September 1991

U. S. Fish and Wildlife Service
Phoenix, Arizona

LOACH MINNOW, *Tiaroga cobitis*

RECOVERY PLAN

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for

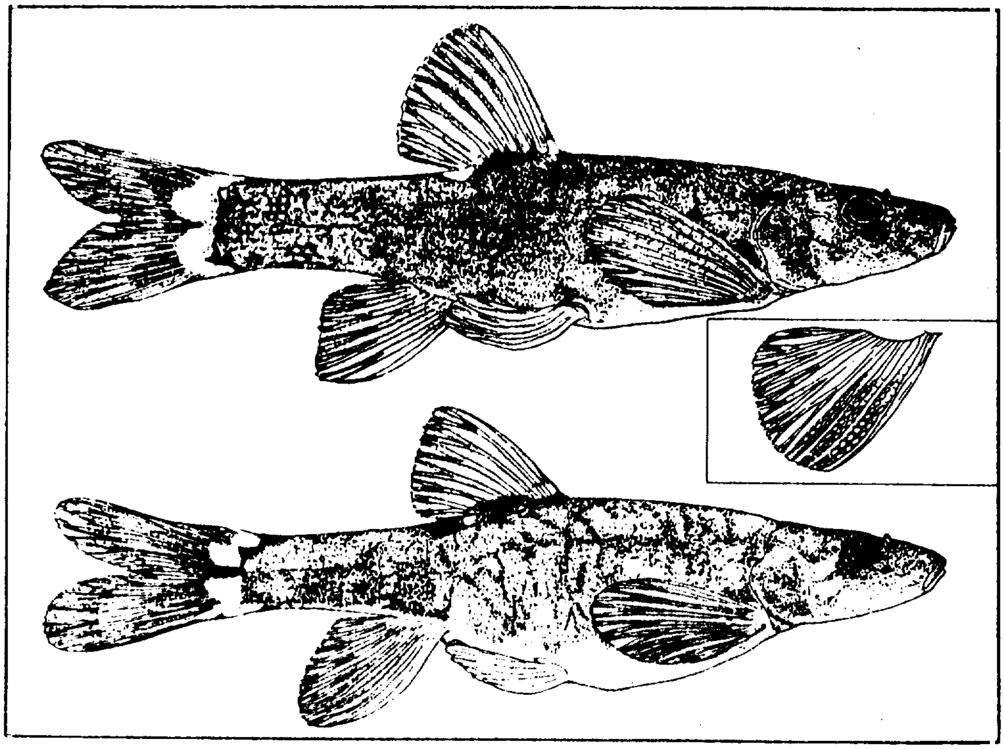
Region 2

U.S. Fish and Wildlife Service

Albuquerque, New Mexico

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

Date: 9/30/91



Loach minnow, Tiaroga cobitis.

Upper: male, 45 mm standard length (SL), and detail of pectoral fin (inset); lower, female, 43 mm SL. Scalation omitted. From Minckley (1965).

Frontispiece

DISCLAIMER

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Loach Minnow Recovery Plan. Albuquerque, New Mexico.
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Fish and Wildlife Reference Service
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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 loach minnow 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, San Francisco, and Tularosa rivers and Dry Blue Creek in New Mexico, and in Aravaipa and Campbell Blue creeks and the White, San Francisco, and Blue rivers in Arizona. All existing populations are under threat.

Habitat Requirements and Limiting Factors: This fish is a bottom dwelling species which inhabits turbulent waters over gravel-cobble bottoms in fast-flowing streams. Major threats include dams, water diversion, watershed deterioration, 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 loach minnow 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 loach minnow and non-native fishes.
4. Quantification of habitat and effects of habitat modification.
5. Enhancement of habitats of depleted populations.
6. Reintroduction of loach minnow 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 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.

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I. INTRODUCTION

The loach minnow, Tiaroga cobitis Girard, is a small, secretive fish endemic to the Gila River basin of Arizona and New Mexico, USA, and Sonora, Mexico. Although this unique, monotypic genus has been known to science for more than a century, relatively little is understood of its basic ecology. The loach minnow was apparently not considered imperiled by Miller (1961) and later by Minckley (1973). It once was locally abundant in suitable habitats in the Gila River system upstream of Phoenix, Arizona, but today is restricted to scattered tributary populations in Arizona and New Mexico. Present and historic distributions of the species are figured for Arizona by Minckley (1973, 1985) and for New Mexico by Propst et al. (1988) and for both in Figure 1, below.

The loach minnow 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 bases of diminution of its range and numbers due to habitat destruction, impoundment, channel downcutting, substrate sedimentation, water diversion, groundwater pumping, and the spread of exotic predatory and competitive fishes, and because of continued threats posed by proposed or ongoing dam construction, water loss, habitat perturbations, and exotic species (FWS 1985). Critical habitat was initially proposed (FWS 1985, Appendix A), but legal designation was deferred until 18 June 1987 (FWS 1986). Although that date expired with no action, proposed critical habitat is still in force, providing limited habitat protection. Final designation of critical habitat is currently under administrative review.

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

Description

The loach minnow (Frontispiece) is a small, stream-dwelling member of the minnow family (Cyprinidae); it's description below is summarized from Girard (1857) and Minckley (1973):

> The body is elongated, little compressed, and flattened ventrally. There are eight rays in the dorsal fin and seven in the anal fin. The lateral line has about 65 scales. The mouth is small, terminal, and highly oblique; there are no barbels. The upper lip is non-protractile, attached to the snout by a broad fold of tissue (the frenum). Openings to the gills are restricted. Pharyngeal teeth are in two rows, with formula 1,4-4,1.
>
> Coloration of the body is an olivaceous background, highly blotched with darker pigment. Whitish (depigmented) spots are present at origin and

insertion of the dorsal fin and dorsal and ventral portions of the caudal fin base. A black, basicaudal spot usually is present. Breeding males have bright red-orange coloration at the bases of the paired fins and on the adjacent body, on the base of the caudal lobe, about the mouth, near the upper portion of the gill opening, and often on the abdomen. Females in breeding become yellowish on the fins and lower body.

Distribution and Abundance

Historical. Loach minnow is endemic to the Gila River basin of Arizona and New Mexico, USA, and Sonora, Mexico (Figure 1). The species was recorded in Mexico only in Rio San Pedro, in extreme northern Sonora (Miller and Winn 1951). Distribution in Arizona included the Salt River mainstream near and above Phoenix, White River, East Fork White River, Verde River, Gila River, San Pedro River, Aravaipa Creek, San Francisco River, Blue River, and Eagle Creek, plus major tributaries of larger streams (Minckley 1973, 1980; University of Michigan Museum of Zoology, unpublished records). Populations transplanted from Aravaipa Creek into Sonoita Creek (Santa Cruz County, Arizona) in 1968 and Seven-Springs Wash (Maricopa County, Arizona) in 1970 have since been extirpated (Minckley and Brooks 1985). Distribution in New Mexico included the Gila River (including East, Middle, and West forks), San Francisco River, Tularosa River, and Dry Blue Creek; there have been no recorded transplants of loach minnow in New Mexico or Sonora.

There are substantial gaps in time and space among data upon which to base estimates of historical abundance of loach minnow, but it is unlikely (because of its highly specialized nature) that the species was ever abundant other than locally. However, the historical record indicates that suitable, presumably occupied habitat was widespread throughout the region. Like most western cyprinids, distribution and abundance of loach minnow undoubtedly varied greatly in response to natural changes in environmental conditions (Minckley and Meffe 1987).

Present. Loach minnow is believed extirpated from Mexico, although the Gila River drainage in that Country still lacks adequate surveys. The species persists in Arizona only in limited reaches in White River (Gila County), North and East forks of the White River (Navajo County), Aravaipa Creek (Graham and Pinal counties), San Francisco and Blue rivers and Campbell Blue Creek (Greenlee County) (Figure 1). Loach minnow is rare to uncommon in Arizona, except in Aravaipa Creek and the Blue River drainage (Minckley 1981, Montgomery 1985, Propst et al. 1985, Propst and Bestgen 1991). Known populations once present in other rivers and streams of the state have been eliminated. Unknown populations of the species may still occur in places not surveyed or incompletely inventoried, especially in Mexico and within the expansive San Carlos Apache and Fort Apache Indian reservations, or on National Forest lands in the United States.

In New Mexico, the species still may be found in the upper Gila River, including the East, Middle, and West forks (Grant and Catron counties), San Francisco and Tularosa rivers (Catron County), lowermost Whitewater Creek (Catron County), and lowermost Dry Blue Creek (Catron County). In 1982-1985, the species was locally abundant in scattered reaches of these streams; populations were small in Whitewater and Dry Blue Creeks (Propst et al. 1988, Sublette et al. 1990, Propst and Bestgen 1991). Existing

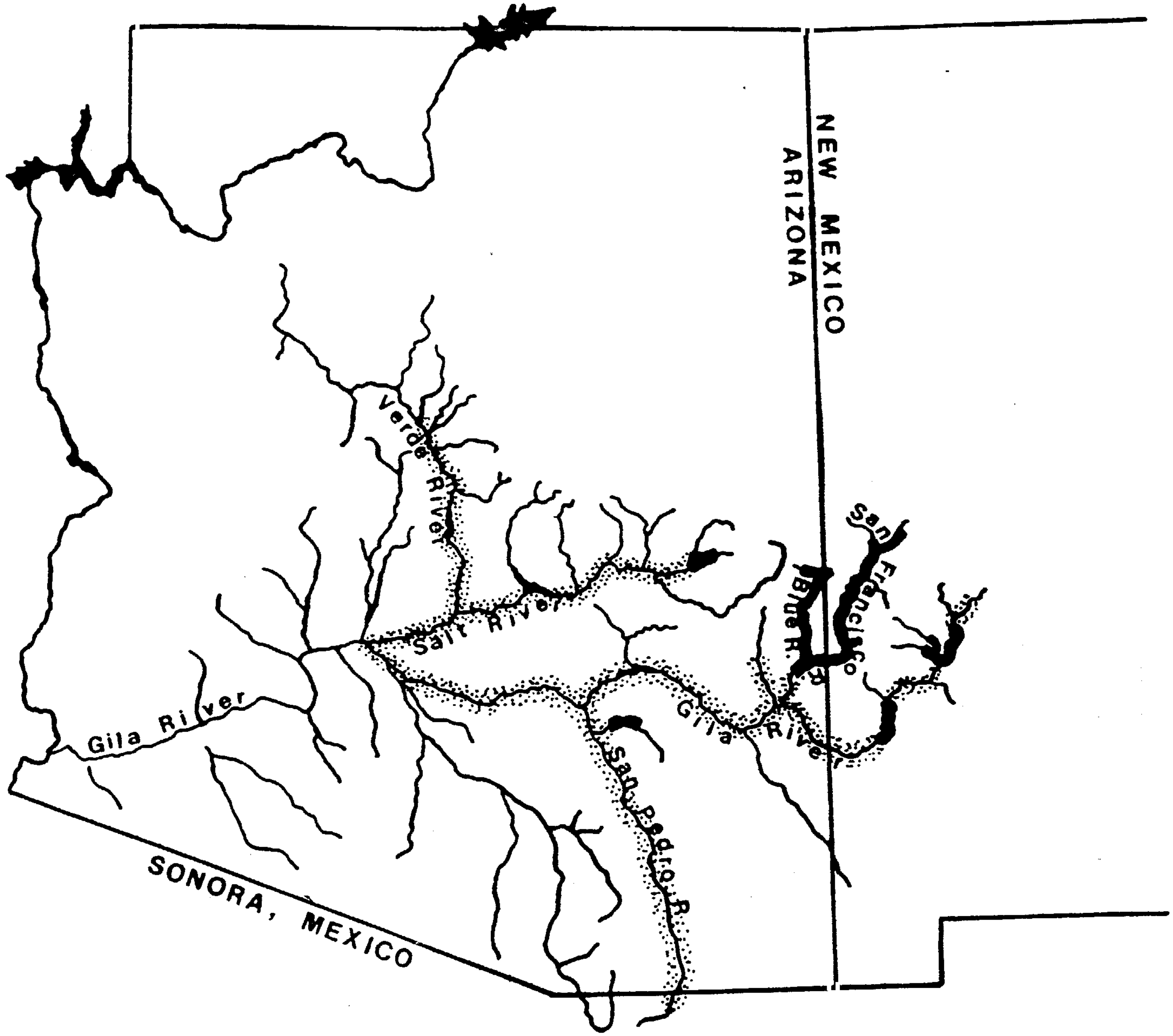

FIGURE 1. HISTORIC AND PRESENT DISTRIBUTION OF LOACH MINNOW
(Historic distribution is represented by stippled areas; present distribution is represented by solid black)

populations of loach minnow are presumably reproducing and recruiting, but their potential for long-term stability is unknown.

Both the distribution and abundance of loach minnow have become dramatically reduced in the last century (Minckley 1973, Propst et al. 1988). It is probably extirpated from Mexico. Major stream reaches in Arizona, including downstream reaches of Gila, Salt and Verde rivers, that once supported locally abundant populations are no longer occupied by the species, and its distribution in New Mexico is fragmented. Similar changes in abundance and range likely occurred in the past in response to temporal and spatial variations in the environment, but indications are that its current imperiled status is a direct or indirect result of activities of man.

Life History

Loach minnow has been intensively studied at only a few locations, resulting in an incomplete understanding of the species' ecology throughout its range. Arizona populations have received attention only in Aravaipa Creek (Barber and Minckley 1966, Minckley 1965, 1973, 1981; Schreiber and Minckley 1981, Turner and Tafanelli 1983, Rinne 1985, 1989), largely because that stream contained the only accessible sizeable population in the State. Britt (1982) examined populations in the Gila and San Francisco rivers in New Mexico, and Propst et al. (1988) concentrated investigations on the mainstem Gila River in the Cliff-Gila Valley and Tularosa River, New Mexico. Results and observations presented in this literature are summarized below; detailed information on individual populations is available in original source materials. Most other work on loach minnow has been survey-type monitoring to assess status of local populations or fish communities (e.g., Jester et al. 1968, Anderson and Turner 1977, Ecology Audits 1979, Montgomery 1985, Papoulias et al. 1989, Propst et al. 1985); these do not contribute significant new life history information.

Habitat. The loach minnow inhabits turbulent, rocky riffles of mainstream rivers and tributaries up to about 2200 meters (m) elevation. Because the species has a reduced gas bladder, it is restricted almost exclusively to a bottom-dwelling habit, swimming in swift water is only for brief moments as the fish darts from place to place. Most habitat occupied by loach minnow is relatively shallow, has moderate to swift current velocity and gravel-to-cobble dominated substrate (Barber and Minckley 1966, Minckley 1973, Propst et al. 1988, Rinne 1989, Propst and Bestgen 1991). Loach minnow at some times and places (e.g., Aravaipa Creek, Arizona) is associated with dense growths of filamentous green algae (Barber and Minckley 1966), while in other places this association has not been observed. In the upper Gila River, New Mexico, depth, velocity, and substrate of occupied habitats vary ontogenetically, seasonally, and geographically (Propst et al. 1988); the same is to be expected elsewhere.

Reproduction. Loach minnow first spawn at age I in late winter-early spring in Aravaipa Creek (Minckley 1973) and from late March into early June in New Mexico (Britt 1982, Propst et al. 1988). Spawning is in the same riffles occupied by adults during the non-reproductive season, where sex ratios appear approximately equal. Adhesive eggs are deposited on the underside of flattened rocks; cavities usually are open on the downstream side while the upstream portion of the rock is embedded in the substrate. Number of eggs per rock ranges from fewer than 5 to more than 250, with means among populations of 52 to 63. Fecundity of individual females ranges from about 150 to 250 mature ova, and generally increases with increasing size. Mature ova are about 1.5 millimeters (mm) in mean diameter, but greater (1.55-1.67 vs. 1.44-1.56 mm) among females more than 60 mm long (presumably age II), than among smaller, age I fish (Britt 1982). Embryos retrieved from beneath spawning rocks and incubated at 18 to 20° C hatched yolk-sac larvae in 5 to 6 days.

Growth. Loach minnow larvae are approximately 5 mm long at hatching. Growth rate varies with location and environmental conditions, and among year classes (Britt 1982, Propst et al. 1988). Growth is most rapid during the first summer, with age 0 fish in New Mexico usually attaining 30 to more than 40 mm standard length (SL)[1] by mid-summer and slightly more than 50 mm SL by end of the calendar year. Growth rate subsequently slows, with age I fish averaging near 55 mm SL by end of their second growing season. Winter growth is negligible. Age II fish attain maximum lengths of about 68 mm SL, although such size is infrequent. Longevity of most fish is probably 15 to 24 months, although exceptional individuals may survive 36 months. There is no evidence that male and female growth rates differ substantially, although males appear to have higher survivorship than females (Propst et al. 1988).

Foods. Loach minnow are opportunistic, benthic insectivores, largely deriving their food supplies from among riffle-dwelling, larval ephemeropterans and simuliid and chironomid dipterans; larvae of other aquatic insect groups, such as plecopterans, trichopterans, and occasionally pupae or emerging adults, may be seasonally important (Britt 1982, Propst et al. 1988, Propst and Bestgen 1991). Chironomids are relatively more important among the few food items utilized by larval and juvenile fishes; diversity of food types increases as fish become larger, but the array of foods eaten is usually small compared with other stream fishes (Schreiber and Minckley 1981, but see Abarca 1987). Because loach minnow are not known to swim in turbulent riffles other than for brief periods, it appears that they actively seek their food among bottom substrates, rather than pursuing animals entrained in the drift. Feeding habits therefore parallel seasonal changes in relative abundance, and thus availability, of riffle-inhabiting invertebrates.

Co-occurring fishes. Riffles that characterize habitats occupied by adult loach minnow are shared with few other species. Native speckled dace, *Rhinichthys osculus*, often occupies riffles with loach minnow, but the dace is a strong-swimming, mid-water-column fish that likely has little interaction with the benthic loach minnow. Native suckers, especially desert sucker, *Pantosteus clarki*, frequent riffle habitats where they graze on attached algae and its associated microfauna. Among non-native (introduced) fishes that co-occur in places with adult loach minnow, only ictalurid catfishes are likely to interact strongly with the native. Channel catfish, *Ictalurus punctatus*, of all sizes move onto riffles to feed, often on the same animals most important in diets of loach minnow. Juvenile flathead catfish, *Pylodictis olivaris*, also feed in riffles in darkness. Channel catfish tend to be benthic omnivores, but flathead catfish are notoriously piscivorous, even when small. Thus, potential for direct interaction (i.e., predation) between loach minnow and non-native catfishes is enhanced by motive (acquisition of food) and spatial overlap in riffles.

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[1]Standard and total lengths (TL) of loach minnow are convertible by the expression $SL = 0.84TL + 0.56$ ($r^2 = 0.99$, $n = 100$) (unpublished data).

Larval and juvenile loach minnow, which occupy shallower and slower habitats along riffle margins than adults (Propst et al. 1988), may encounter a suite of other fishes. However, when collected they often are the only species in samples. Among natives, larval suckers (both desert sucker and Sonoran sucker, Catostomus insignis) and larval and adult cyprinids (especially the ubiquitous longfin dace, Agosia chrysogaster) are most likely to interact with small loach minnow. These species have co-occurred for millennia.

Red shiner, Cyprinella lutrensis, is the non-native fish most likely to be found along stream margins in places occupied by small loach minnow. Red shiner now occurs in all places known to be formerly occupied by loach minnow, but the shiner is absent or rare in places where the native loach minnow persists. Although no mechanism(s) of interaction has been identified, red shiner has repeatedly been implicated in declines of loach minnow and other native fishes (Minckley and Carufel 1967, Minckley and Deacon 1968, FWS 1985, 1986), and stream reaches where loach minnow have declined or disappeared are suspiciously complementary with range expansions of the shiner. However, Marsh et al. (1989) found that habitat occupied by loach minnow was so different from that of the red shiner that interaction between the two species was unlikely to cause shifts in habitat use by loach minnow, and Bestgen and Propst (1986) suggest that red shiner moves into voids left when native fishes are extirpated in the area by habitat degradation. Exotic mosquitofish, Gambusia affinis, also occupies lateral habitats used by smaller loach minnow, and although potential mosquitofish/loach minnow interactions have yet to be examined, mosquitofish has been demonstrated to be detrimental to native topminnow, Poeciliopsis occidentalis, in both field and laboratory settings (Meffe 1983, 1985).

Reasons for Decline

Changes in distribution and abundance of loach minnow are directly or indirectly tied to man's uses of rivers, streams and landscapes, which have been variously modified by past and present activities (Hastings and Turner 1965, Hendrickson and Minckley 1985). Direct impacts have resulted from stream habitat alterations accompanying a suite of land and water use practices; most often cited are dewatering, impoundment, and livestock grazing. Certain introduced and established non-native fishes may interact negatively with native kinds, and independently or in concert with habitat alteration, result in their extirpation.

Dewatering of stream reaches may accompany groundwater pumping, stream channelization, water diversion, or damming. Absence of water obviously destroys fishes, and there can be no reestablishment of aquatic populations until flow is restored. Much historic loach minnow habitat is now dry (for example, reaches of the Gila, Salt, and San Pedro rivers in Arizona).

Impoundment results in creation of lentic habitat, which eliminates and excludes the swift-water loach minnow. Downstream effects of dams may include dewatering (above), alteration in flow regime, amelioration of natural flood events, changes in thermal and chemical character of the stream, elimination of organic drift typical of flowing waters, and other impacts, which may have a variety of lethal and sublethal effects on fishes. Natural flooding of desert streams may play a significant role in life history of native fishes because it rejuvenates habitats (Propst et al. 1988), 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). Major reaches of the Gila and Salt rivers are influenced by dams and their reservoirs and tailwaters; loach minnow no longer occur in these affected waters (e.g., Minckley 1973, unpublished data).

Livestock grazing that results in widespread removal of covering grasses and shrubs from the watershed, or denuding of riparian vegetation, may induce dramatic changes in precipitation runoff, suspended sediment, and bedload that increase stream turbidity, clog interstitial spaces of coarse substrates, and enhance erosion of stream channels and banks. Similar effects may be realized through poor timber harvest practices, mining operations (that may also contribute acute or chronically toxic levels of contaminants such as heavy metals), agriculture (that may also deliver toxic pesticides or herbicides, or enriching fertilizers), and development for industrial, commercial, or residential purposes. For example, wastewater discharges from the Cananea Mine, Sonora, Mexico, into the San Pedro River in 1977-1979 killed aquatic life, including all fishes, in a 100-km reach downstream (Eberhardt 1981). Fishes that require unperturbed, natural habitats free of environmental contaminants may not maintain viable populations when faced with such modifications, or, where impacts are tolerated, such perturbations may weaken populations of native fishes so that invading predatory and competing non-natives effectively displace them.

It is clear that habitats supplied with water of sufficient quality and quantity, and which conform with other, specific environmental characteristics, are necessary for survival of loach minnow and other native fishes. Maintenance of stream flows uninterrupted by impoundments may be especially important for loach minnow, whose populations are often naturally small and disjunct.

Habitat alteration and interaction with non-native fishes are both undoubtedly important in declines of loach minnow. However, it may not be possible to separate effects of these phenomena because in most places both occurred during approximately the same period of time. The scientific and management communities have not yet developed capabilities to examine an area from which a species has been extirpated, or in most cases of southwestern fishes even a habitat from which natives are in active decline, and determine with certainty which factor(s) is responsible.

Habitats unimpacted by man's activities, which still support populations of loach minnow, do not exist. Even Aravaipa Creek, which supports a thriving community of seven native fishes including loach minnow, has been subjected to perturbations due to grazing and water management. Reaches of the Gila River and its major tributaries in New Mexico, which have been altered only by grazing, timber harvest, and/or mining, also are occupied by viable native populations, and support few or no exotic fishes. Both Aravaipa Creek and the Gila River presently support few exotic fishes. Similar conditions characterize most streams and rivers that are still occupied by loach minnow: habitat alterations are relatively moderate and exotic fishes are few. On the other hand stream reaches from which loach minnow have been known to be extirpated are characterized by past or present moderate to severe habitat alterations and by relatively large populations of exotic fishes. Thus, unlike dewatering or severe habitat destruction, moderate habitat alteration alone does not appear sufficient to eliminate loach minnow. It is only when populations of non-native forms invade or are introduced and become established that the native taxa are severely depleted or eliminated. However, habitat alteration appears to be a major factor in invasion and establishment of exotic fish in the southwest.

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 loach minnow and their habitats, and to ensure the species' non-endangered, self-sustenance in perpetuity. Realization of this objective will constitute justification for delisting the loach minnow. 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 loach minnow. This plan recognizes the need to deal with both impacts in order to achieve the recovery objective stated above.

Stepdown Outline

1. Protect existing populations of loach minnow.
    - 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 loach minnow.
        - 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 use of live bait and seining in streams occupied by loach minnow.
    - 1.8 Examine efficacy of barrier construction to protect existing populations from 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 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 monitoring locations and sampling techniques (see 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 or the community).
  - 3.2.1 Field investigations and experimental manipulations.
  - 3.2.2 Laboratory studies.

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

- 4.1 Substrate (siltation, armoring).
- 4.2 Velocity and depth.
- 4.3 Water temperature.
- 4.4 Water chemistry.
- 4.5 Watershed characteristics.
- 4.6 Interactions among 4.1-4.4.

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 reintroductions.
  - 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 loach minnow 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. Consider contingency planning and preliminary investigations for 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 loach minnow.

Remaining populations of loach minnow continue to be threatened by destruction or modification of habitat, predation by non-native fishes, inadequacy of existing regulations, and continued introduction and dispersal of non-native fishes. Recovery of the species cannot be effected without first protecting remaining loach minnow populations.

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

Undiscovered populations of loach minnow 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 to the extent practicable. General areas which should be thoroughly sampled to determine potential occurrence of loach minnow include the Gila River drainage in Sonora, Mexico and lands in the United States owned or controlled by the U.S. Forest Service and the San Carlos and White Mountain Apache 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 loach minnow that presently occupy relatively unperturbed 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 and/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), and supported by Propst et al. (1988). FWS (1986) deferred designation until 18 June 1987, a date which has expired. 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), additional stream reaches may be appropriate for future consideration for designation as critical habitat. Much of the land adjacent to streams presently occupied by loach minnow is under full or partial jurisdiction and/or presumed protection by U.S. Bureau of Land Management (Aravaipa Creek); The Nature Conservancy (Aravaipa Creek, Gila River, New Mexico); New Mexico Museum of Natural History (East Fork Gila River); New Mexico Department of Game and Fish (West Fork and Middle Fork Gila rivers); New Mexico State Land Office (Gila River); National Park Service (West Fork Gila River, lands administered by U.S. Forest Service); U.S. Forest Service (Gila River in Gila Wilderness Area, Lower Gila Bird Management Area, and

Gila River Research Natural Area, and Gila and Apache-Sitgreaves National Forest; Blue River in Apache-Sitgreaves National Forest and Blue Range Primitive Area); and Fort Apache Indian Reservation (White River and East Fork of the White River). However, protection of loach minnow on federal and other lands can be fully realized only when critical habitat is designated, and compliance with the Endangered Species Act is implemented. Other reaches flow through private lands, and with exception of certain portions controlled by conservation organizations, may receive only minimal protection.

1.4 Enforce existing laws and regulations affecting loach minnow.

Failure of any entity to recognize and comply with laws and regulations that protect loach minnow and its habitat may contribute to 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 the laws protecting listed species and their habitats and the appropriate roles each agency should 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 loach minnow or adversely affect its proposed critical habitat.

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 loach minnow should be discouraged in all places. Information and education should be provided that will enable users to be aware of detrimental practices.

1.6 Insure perennial flows with natural hydrographs.

Loach minnow cannot exist in dewatered places, and populations may be expected to decline or disappear from stream reaches which are intermittent or ephemeral. Permanence of flows must be assured to maintain integrity of loach minnow 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 that substantially alter natural flow regimes, such as damming or diversion, should 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.**

State, Federal, or private stocking programs for non-native sport or other species must consider potential impacts of such plantings on imperiled fishes, and limit activities to waters so as to preclude possibility for negative interactions. Where they do not already exist, appropriate regulations should be promulgated that discourage transport and stocking of non-native fishes into habitats from which they have access to stream reaches occupied by loach minnow. State, Federal, or other management agencies and private entities should discontinue stockings of non-native, warmwater sport, forage, or bait fishes into or upstream from streams occupied by loach minnow, and upstream from the first absolute barrier to upstream fish movement into loach minnow 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 be required to ensure that escapement to waters occupied by loach minnow is precluded.

1.7.1 **Discourage use of live bait and seining in streams occupied by loach minnow.**

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 loach minnow are known to co-occur, responsible resource agencies should discourage or disallow use of live bait. Furthermore, baitfish seining should not be allowed to occur in stream reaches occupied by loach minnow, which could unknowingly be taken and unnecessarily destroyed.

1.8 **Examine efficacy of barrier construction to protect existing populations from invasion by non-native fishes.**

Construction of fish barriers should be considered as a preventive measure for protection of existing populations of loach minnow from contamination by non-native fishes. For example, a cooperative effort has determined that placement of such a barrier on Aravaipa Creek, Arizona, would protect upstream populations of native fishes, including loach minnow, from invasion by red shiner. Other streams occupied by loach minnow 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 habitats occupied by loach minnow already receive at least some degree of protection from State, Federal, or private entities, other lands through which potentially important stream reaches pass have no benefit of protection. Unwise land or water use practices in and adjacent to occupied reaches could have detrimental impacts upon loach minnow residing in the same drainage. Also, because fishes require water to survive, provision must be made for acquisition of water rights to insure sufficient quantities for the species to perpetuate. The U.S. Fish and Wildlife Service should designate the appropriate agencies to identify these areas and 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 and water rights may be acquired by State, Federal, or private entities inclined to do so in behalf of protecting loach minnow and their habitat. Acquisition of these lands and water rights will add to assurance that existing populations of the species and their habitats are secure.

1.11 Protect acquired lands.

Once important lands and stream reaches are in appropriate ownership, they must be administered and managed in ways consistent with perpetuation of loach minnow habitats and populations.

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, with advice of 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 standard monitoring locations for extant populations.

Stream and river reaches representing typical habitats actually or potentially occupied by loach minnow populations in Arizona and New Mexico should be selected for routine monitoring. Only when data are obtained from standard monitoring 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 habitat and loach minnow population status should be consistent spatially, temporally, and among investigators. Standard monitoring techniques should be developed and implemented to ensure that results are comparable among years, populations, and groups responsible for this monitoring. Techniques should be based upon biological information, plus practical constraints. In some instances, use of specific techniques may be restricted, for example, use of motorized equipment in wilderness areas, and such constraints should be considered in selection of methodologies.

2.3 Establish and maintain a computerized database.

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 containing all available historic information on distribution and abundance of the loach minnow 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 becomes available.

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

Populations of loach minnow vary both spatially and temporally as a result of differing dynamic characteristics exhibited by individual populations and in response to natural changes in their environment. Changes in status of any given loach minnow population 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. Changes which occur under these last conditions are reasonably interpreted as due to natural phenomena, and provide a template against which to assess change due to man's activities. Population status is most readily assessed by knowing absolute abundance of individuals in the population, and the distribution of individuals among age classes (cohorts).

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. A standard technique should be selected on a basis of biological considerations, plus practical constraints.

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 most-useful information as regards status of loach minnow. Spring sampling allows assessment of reproductive condition of the population, while autumn sampling provides opportunity to evaluate recruitment derived from springtime spawning. Both are necessary to adequately determine population status and characterize cyclic aspects of population dynamics.

2.5 **Monitor community composition.**

Populations of loach minnow 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 loach minnow 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 loach minnow, and any information that will enhance that capability may enable management decisions before potential negative impacts are realized.

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

Techniques for assessing status of the fish community should be compatible with those specifically selected for loach minnow monitoring, and should be standardized as regards place and method.

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 reliably assessed unless an indication of the range of normal variation experienced by stable 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 loach minnow populations should be gathered to elucidate relationships among populations and to provide guidance in 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 loach minnow 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 other non-natives spatially displace native fishes (e.g., Minckley and Deacon 1968, Marsh et al. 1989). These kinds of interaction thus appear most fruitful for investigation in the case of loach minnow. Other potential mechanisms of interaction, such as competition for environmental resources, 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 loach minnow and potentially detrimental non-native fishes co-occur in several places, these habitats and communities could 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 and specific experimental designs should be determined by consensus among knowledgeable individuals.

3.1.2 Laboratory studies.

Some aspects of direct interaction among loach minnow 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 loach minnow may not be caused by direct interaction, but rather indirectly by the effect of non-native fishes impacting other members of the fish community. Regardless, prudent management of loach minnow populations cannot be implemented until the nature and significance of both are 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 loach minnow and non-native fishes (see 3.1.1).

3.2.2 Laboratory studies.

Studies of loach minnow, 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, loach minnow habitat needs and the effects of physical habitat modification on life cycle completion.

Localized depletion or extirpation of loach minnow 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 loach minnow 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 loach minnow habitat needs and usage. Research must consider all life history stages as well as variations in seasonal and diurnal use.

4.1 Substrate (siltation, armoring).

Erosion and siltation which result in filling of interstitial spaces of gravel-rubble riffles occupied by loach minnow may interfere with successful egg deposition and incubation, and thus impact recruitment, population abundance, and age-class structure (Propst et al. 1988). Substrate armoring which renders egg deposition sites unavailable to loach minnow 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 loach minnow, which have demonstrated specializations for these factors (Turner and Tafanelli 1983, Propst and Bestgen 1991). Available data should be reviewed and augmented so that preferenda can be determined, and tolerance limits established. This information will enable refinement of management strategy design and implementation.

4.3 Water temperature.

Water and land use practices may influence thermal regimes in habitats occupied by loach minnow. Relationships between loach minnow life history and temperature are poorly known, and should 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 loach minnow. Preferenda and tolerance limits of loach minnow 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 Watershed characteristics.

It has been speculated that loach minnow may be limited to occupation of streams with a certain minimum watershed size and/or water volume (Propst, pers. comm.), based on their absence from small tributary streams even when 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. Flood frequency and volume is a major watershed characteristic and is frequently modified in southwestern streams during the course of water development. Flooding has been shown to be a major factor in the relationship of native to non-native fishes (Meffe and Minckley 1987, Propst et al. 1986). Relationships between watershed characteristics and loach minnow 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.

4.6. Interactions among 4.1-4.4.

Water and land use practices may affect one or several environmental parameters important to successful loach minnow 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.

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 loach minnow populations have been depleted. Such management provides opportunity for continued study of relationships between loach minnow 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 loach minnow, 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 conditions.

5.2 Determine necessary habitat and landscape improvements.

Habitat improvements can be effected only when physical characteristics necessary for loach minnow 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.; removal or other control of non-native fishes, where problematic, may also be necessary (6.2.3-6.2.5).

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.

6. Reintroduce populations to selected streams within historic range.

One of the most critical goals to be achieved toward loach minnow 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 that management strategies were effective enough that attainment of full recovery is probable.

6.1 Identify stocks amenable to use for reintroduction.

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., upper Gila River for Eagle Creek, Aravaipa Creek for San Pedro). Results of a genetic survey (2.6 above) will be used as guidance in selecting appropriate donor stock. If it is determined that existing populations do not have capability to supply sufficient individuals for reintroductions, hatchery-produced fish may be used (8 below).

6.2 Identify river or stream systems for reintroductions.

Among streams from which loach minnow have been extirpated, Eagle Creek and San Pedro River, Arizona, represent those most amenable to reestablishment of the species. Loach minnow occurred in Eagle Creek at least in 1950, when R. R. Miller collected 13 individuals (University of Michigan Museum of Zoology, unpublished record). Although the stream contains relatively large areas of apparently suitable habitat and supports a largely native fauna (Minckley 1973, Propst et al. 1985, unpublished data) loach minnow apparently no longer occur there; reason(s) for its apparent extirpation are unknown. San Pedro River is the type locality for loach minnow (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 (Minckley 1987). Not only the mainstream San Pedro may be readily amenable to restoration for loach minnow; certain perennial reaches of major tributaries (e.g., Redfield Canyon, Babocomari River) also have potential for reestablishment of the species. Aravaipa Creek, which is home to the largest remaining loach minnow population in Arizona, is tributary to the San Pedro River. Bonita Creek (tributary to the Gila River in Arizona), plus other, yet to be identified locations, should also be evaluated as potential recipients of reintroduced populations.

6.2.1 **Determine suitability of habitat.**

Eagle Creek and San Pedro River systems, plus others when identified, should be evaluated as regards suitability to provide loach minnow habitat. Specific reaches that fulfill known requirements, plus areas amenable to restoration, should be identified. Causes and sources of former and continuing habitat degradation and of the original extirpation need to be evaluated and rectified if necessary.

6.2.2 **Enhance habitat as necessary (4, 5.3).**

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 **Assess status of non-native fishes in the watershed.**

Non-native fishes pose potential threats to reestablishment of loach minnow. 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 loach minnow 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 loach minnow.

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

Non-native species in places from which they could invade loach minnow 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 pesticide application, while other waters, such as cattle tanks, could be reclaimed by either drainage or pumping, pesticide treatment or a combination thereof.

6.3 **Reintroduce loach minnow to selected reaches.**

Loach minnow should be collected, transported, and reintroduced into selected stream reaches after habitat restoration and non-native species removals have been accomplished. Stockings should be of sufficient numbers of individuals to assure maintenance of reasonable genetic heterogeneity of the reintroduced population (Echelle 1988, 2.6 and 6.1, above).

6.4 Monitor success/failure of reintroductions.

Reintroduced loach minnow populations should be periodically monitored; location, time of year, and methods should be standardized so data are comparable with previous information for other populations and can be used to assess changes in status (2, above). Preliminary evaluation of success should be made five years after reintroductions, and periodically thereafter until criteria for success have been fulfilled.

6.5 Determine reasons for success/failure.

Success of reintroductions will be indicated by establishment of reproducing, self-sustaining populations of loach minnow 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 and 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 causes 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 causes of initial failure are identified and removed. In some instances, repeated sequences of reintroduction, monitoring, assessment, and refinement may be necessary before local management goals are satisfied.

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

Recovery goals call for protecting existing populations, restoration of depleted stocks, and reestablishment of loach minnow in places from which the species has been extirpated, and insurance that the animal has opportunity for self-sustenance in perpetuity. Fulfillment of these goals will constitute justification for delisting of the species. 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 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 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 provides valuable information, and usually can be assessed expediently. However, such data are not generally useful for evaluating change in population 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 "average" 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 likely indicates substantial pressure on the population, and may require rapid remedial action.

7.1.3 Reproduction.

Populations can perpetuate themselves only if reproduction replaces individuals lost to natural (or other) sources of mortality. Loach minnow reproduction should be assessed by determining 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 adult 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 of the stock, even though (diminished) reproduction and recruitment occur up to the time of extirpation. While it is probably impractical to attempt to quantify minimum stock size for all present and future populations of loach minnow, some consensus should be achieved among knowledgeable individuals as to what represents reasonable minimum stock size for loach minnow in various habitats. Depletion of a population below that minimum should be taken as indication that one or more environmental factors is negatively impacting the population. Further investigation to determine and rectify the cause would be necessary. A self-sustaining population should not dwindle below a previously determined minimum stock size.

7.3 Environmental variables.

Self-sustenance in perpetuity requires that habitat at all times meet the minimum requirements for life cycle completion by the species. Some habitats may support loach minnow populations for a period of time, then fail to do so. 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 the tolerance range acceptable to loach minnow.

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 or toxicity among loach minnow, or otherwise interfere with life cycle completion.

7.3.3 Biological community.

Maintenance of loach minnow populations in perpetuity requires that the composition and integrity of the biological community of which it is a member also be maintained in a natural state. Loach minnow 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 the status of loach minnow. Invasion of the community by exotic forms, especially non-native fishes, may have severe impacts upon loach minnow 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 loach minnow.

8. Consider contingency planning and preliminary investigations for 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 loach minnow. This is because the species continues to occupy, in substantial numbers, several 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.

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 context of existing wild populations (Echelle 1988).

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

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

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

Standardized techniques and facilities should be developed by which loach minnow 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 induction of gamete maturation and expression, fertilization, and incubation. 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.**

Loach minnow propagated and reared in a hatchery can serve many purposes. Fish can be transported to selected sites for reestablishment of extirpated populations, keeping in mind the genetic considerations outlined in 6.1, above. Research programs to answer basic questions of loach minnow 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 loach minnow in particular and endangered species in general. In each instance where hatchery fish were used, wild donor populations would be preserved against any potential damage which could result from removal of individuals.

9. **Information and education.**

Free exchange of information and ideas among individuals representing both private concerns and the public sector including citizen's groups should be recognized as essential support 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 <u>Public sector.</u>

Loach minnow 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 the desires of the public, it is essential that they be offered every opportunity to be informed and to participate in all aspects of loach minnow recovery. Public support has capability to greatly enhance and thereby assure success of loach minnow recovery; such support is derived from informed people.

9.1.1 <u>Local media and target campaigns.</u>

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

9.1.2 <u>States of Arizona and New Mexico.</u>

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

9.1.3 <u>National exposure.</u>

Federal laws that protect threatened and endangered plants and wildlife are of interest to all residents of the Nation. It thus is appropriate 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 <u>Assist appropriate Mexican agencies and organizations in information and education.</u>

A significant portion of the San Pedro River is in Mexico, and stream reaches within that Country may be occupied by undiscovered populations of loach minnow. Moreover, health of aquatic biota including possible reintroduced populations of loach minnow 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 appraised 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 loach minnow 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 loach minnow recovery. Ideas must be exchanged freely so that optimal strategies can 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 loach minnow 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 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 can have opportunity to comment on and thereby potentially enhance recovery of loach minnow.

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

Participants in studies of loach minnow 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

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

Other - **O**

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

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	RESPONSIBLE AGENCY FWS PROGRAM	RESPONSIBLE AGENCY 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	PROGRAM	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

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
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 to 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

IV. APPENDIX A: PROPOSED CRITICAL HABITAT

Proposed critical habitat for loach minnow, *Tiaroga cobitis*, in Arizona and New Mexico, as originally proposed by FWS (1985). Legal descriptions (township, range, and section) are not included herein. All stream reaches are figured in FWS (1985). Additional stream reaches occupied by yet undiscovered populations of loach minnow may be considered for future addition 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, approximately 24 kilometers (km) of stream.

2. Greenlee County:
   a. Blue River, approximately 78 km of river extending from the confluence with the San Francisco River upstream to the confluence of Campbell Blue Creek and Dry Blue Creeks in Catron County, New Mexico.
   b. Campbell Blue Creek, approximately 14 km of stream extending from the confluence with the Blue River upstream to the confluence with Coleman Creek (approximately 0.8 km of this reach are located in Catron County, New Mexico).
   c. San Francisco River, approximately 6 km of river, extending from the confluence with Hickey Canyon upstream to the confluence with Blue River.

New Mexico:

1. Catron County:
   a. Dry Blue Creek, approximately 3 km of stream, extending from the confluence with the Blue River upstream.
   b. San Francisco River, approximately 15 km of stream, extending upstream from the U.S. Highway 180 bridge.
   c. Tularosa River, approximately 24 km of stream, extending from the confluence with Negrito Creek upstream to the town of Cruzville.

2. Grant and Catron Counties:
   a. East Fork Gila River, approximately 26 km of river, extending from the confluence with the West Fork upstream.
   b. West Fork Gila River, approximately 12 km of river, extending from the confluence with the East Fork upstream.
   c. Middle Fork Gila River, approximately 18 km of river, extending from the confluence of the West Fork upstream to the confluence with Brothers West Canyon.

3. Grant County: Gila River, approximately 37 km of river, extending from the confluence with Mogollon Creek downstream.

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.