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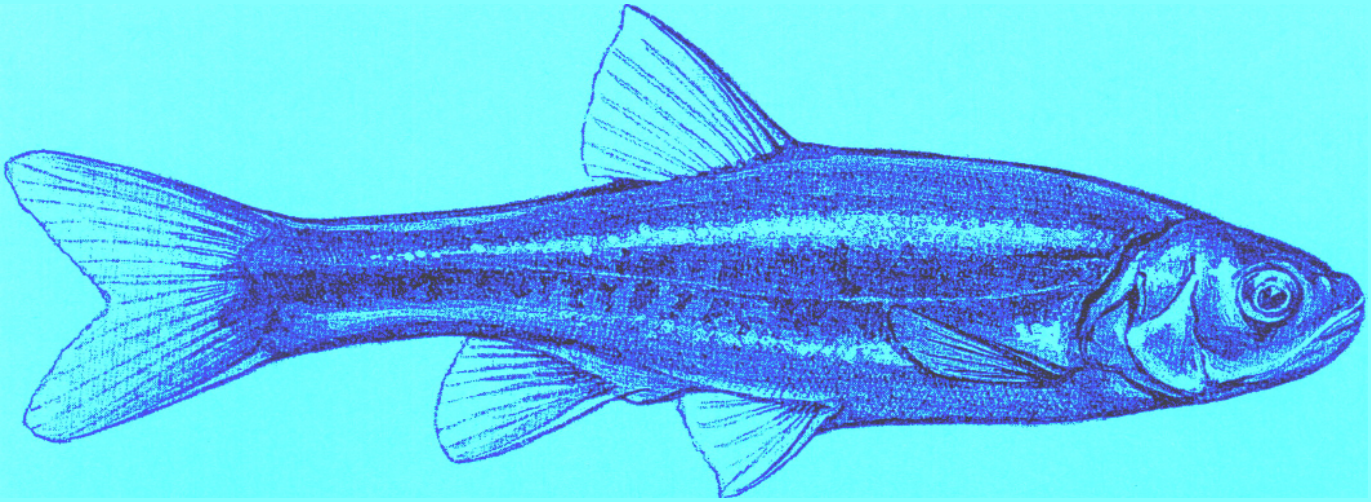

Little Colorado River Spinedace Recovery Plan

Little Colorado River Spinedace
Lepidomeda vittata
Recovery Plan

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Parker Fishery Resource Office,
Parker, Arizona 85344

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for

U.S. Fish and Wildlife Service,
Albuquerque, New Mexico

Approved: Nancy M. Kaufman
Regional Director

Date: JAN 09 1998

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LITERATURE CITATION

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EXECUTIVE SUMMARY

Current Species Status: Listed as threatened throughout its range. Restricted to north-flowing tributaries of the Little Colorado River in Apache, Navajo and Coconino counties, Arizona.

Habitat Requirements and Limiting Factors: Springs, streams and rivers with perennial flow. Tends to prefer pools, but occurs sporadically throughout the habitat. Has a tolerance for wide temperature fluctuations and habitat types. Species survival threatened by habitat loss, habitat modification, competition and predation from non-native fish and introduced parasites.

Recovery Objectives: Delist species.

Recovery Criteria: Secure and maintain all extant populations. Establish refugia in the most natural, identifiable habitats within the probable historic range. Reintroduced populations will not be considered established until they have persisted for a minimum of five years.

Actions Needed:

1. Secure natural populations and their habitats.
2. Reestablish populations
3. Monitor all populations.
4. Define habitat requirements of the species.
5. Develop genetic information and pedigree
6. Inform the public.

Costs - (Dollars X 1000):

Year	Priority 1 Tasks	Priority 2 Tasks	Priority 3 Tasks	Total
1998	126.0	271.0	12.0	409.0
1999	131.0	368.0	12.0	511.0
2000	123.0	373.5	12.0	508.5
2001	18.5	394.5	12.0	425.0
2002	19.0	284.5	12.0	315.5
2003	1.0	41.0	12.0	54.0
2004	1.0	43.0	12.0	56.0
2005	1.0	28.0	12.0	41.0
2006	1.0	28.0	12.0	41.0
2007	1.0	31.5	12.0	44.5
Total	422.5	1,863.0	120.0	2,405.0

Date of Delisting: Expected to occur in 2007 if delisting criteria are met ($2,405.00).

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Figure 1. Map with tributaries of the Little Colorado River drainage in Arizona where *Lepidomeda vittata* have been collected. Map from Blinn et al. (1996) 1

Part I

INTRODUCTION

The Little Colorado River spinedace (spinedace), *Lepidomeda vittata*, is currently restricted to north flowing tributaries of the Little Colorado River in Apache, Coconino and Navajo counties of eastern Arizona (Figure 1). The species was described by Cope (1874) from specimens collected during 1871-1874 by the Wheeler expedition (Wheeler 1889). The spinedace is a member of the tribe Plagopterini and is represented by three other species (one extinct) as well as by two monotypic genera (*Meda* and *Plagopterus*). All members of the Plagopterini are already listed as either threatened or endangered or are in the process of being listed. The other species of spinedace occur in extreme northwest Arizona (*L. mollispinis*) and in Nevada and Utah (*L. albivallis* and *L. altivelis*, Miller and Hubbs 1960; Minckley 1973; LaRivers 1962).

The spinedace was included in the U.S. Fish and Wildlife Service's (USFWS) "Review of Vertebrate Wildlife for Listing as Endangered or Threatened Species" (USFWS 1982). At that time, the species was considered a category one species, indicating that the USFWS had substantial information on hand to support a proposal to list the species as endangered or threatened. On 12 April 1983, the USFWS was petitioned by the Desert Fishes Council to list the spinedace. This petition was found to contain substantial scientific or commercial information and a notice of the finding was published on 14 June 1983 (USFWS 1983). After review and evaluation of the petition's merits, the USFWS found the petitioned action warranted. A notice of finding was published on 13 July 1984 and the species was proposed for listing on 22 May 1985 (USFWS 1984, 1985). The spinedace was listed as threatened in 1987 (USFWS 1987). Areas designated as Critical Habitat includes 31 miles of East Clear Creek, Coconino County, from its confluence with Leonard Canyon upstream to Blue Ridge Reservoir and from the upper end of Blue Ridge Reservoir to Potato Lake; eight miles of Chevelon Creek, Navajo County, from the confluence with the Little Colorado River upstream to the confluence of Bell Cow Canyon; and five miles of Nutrioso Creek, Apache County, from the Apache-Sitgreaves National Forests boundary upstream to Nelson Reservoir Dam (USFWS 1987).

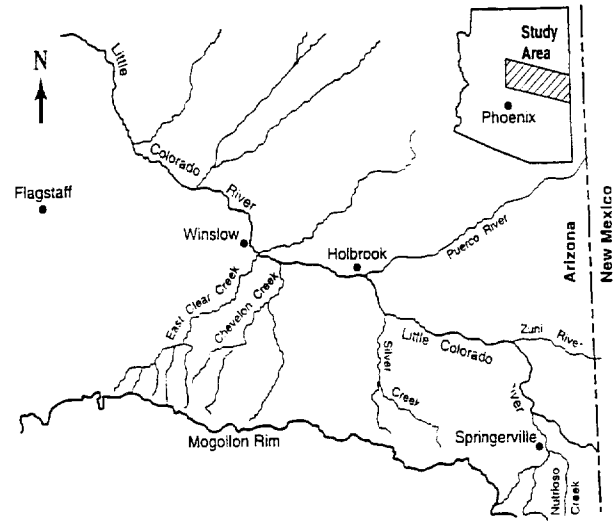

Figure 1. Map with tributaries of the Little Colorado River drainage in Arizona where *Lepidomeda vittata* have been collected. Map adapted from Blinn et al. (1996).

DESCRIPTION

The following description of the spinedace was summarized from Cope (1874), Miller and Hubbs (1960) and Minckley (1973). Mouth moderately oblique; second "spine" of dorsal fin strong; Dorsal fin moderately high, and acute, its depressed length 2.0 to 2.3 in predorsal length; anal fin-rays eight (rarely nine); scales in lateral line usually

more than 90, generally embedded and difficult to count; pharyngeal teeth in two rows, 1 or 2, 4-4, 1 or 2. Vertebrae number 41 to 43. The species is generally less than 100 mm in total length (Miller 1963).

Sexual dimorphism is minimal, with males and females reaching generally the same length. Pectoral fin of males consistently extends beyond insertion of the pelvic fin; in females pectoral fin is shorter, generally not reaching the insertion point. There are a few differences in breeding colors between sexes. The bases of paired fins in males have been described as turning an intense reddish-orange (Miller 1963) or a wash of weak yellow or orange (Minckley and Carufel 1967). Females also reported to develop a watery yellowish or reddish-orange at the bases of the paired fins (Miller 1963). Tubercles on the bodies of males have been reported (Minckley and Carufel 1967).

Life colors described by Miller (1963) were as follows: "... nearly vertical dark lines (that extends dorsally from the midside) shine like polished silver and the venter is white. The upper sides are olivaceous, and the back is olivaceous, bluish or lead grey. Except for pigmentation along the fin rays and on the interradial membranes near the bases of the fins, both paired and unpaired fins are largely clear. Irregularly distributed, fine, black puncticulations (giving a pepper-like effect) overlie the silvery sides from the bases of the dark vertical lines to about halfway between the lateral line and the midline of the abdomen... When the live fish are viewed from directly above, a conspicuous, cream-colored spot is seen at both the origin of the dorsal fin and near the bases of the terminal rays of this fin." Parts of the belly are watery-yellow; fins otherwise clear. Scales show light bluish to greenish-brass reflections.

DISTRIBUTION

Historical.

The original collections of spinedace were from "The Little Colorado River somewhere between the mouth of the Zuni River and Sierra Blanca (White Mountain)." (Miller and Hubbs 1960). The species may have also occurred in New Mexico in the Zuni watershed south of Gallup but there are no records to that effect (Miller 1961, Minckley and Carufel 1967, Sublette et al 1990). Prior to 1939, four collection records for this species were available, although Miller (1961) stated "... there is no reason to doubt that *L. vittata* was once abundant in the main stem part of the upper Little Colorado River and in its several cool tributaries (Silver Creek, Show Low Creek, Chevelon Creek, and Clear Creek) that rise on the northern slopes of the White Mountains and the Mogollon Rim."

Extensive collecting in 1960 suggested the spinedace had been extirpated throughout its known range, but a single specimen was taken from Clear Creek (Miller 1961, 1963). Surveys conducted in 1961 found a large population in East Clear Creek to which the species was thought to be restricted (Miller 1963). Because of the apparent decline in abundance and distribution, the species was described as endangered in 1961 (Anonymous 1966, Bransen 1966; Miller 1963, 1964; Miller and Lowe 1964; Minckley 1965). Between 1963 and 1966, however, the spinedace appeared in most north flowing tributaries of the Little Colorado River and its headwaters (Minckley and Carufel 1967). Populations then again declined, until it was again considered endangered (Minckley 1973). A new population discovered in lower Chevelon Creek demonstrated that the fish still persisted in the watershed in 1977 but its status remained precarious (Blinn et al 1977).

Present.

Distributional surveys made in 1983 throughout the species known historic range confirmed that five populations were still present (Minckley 1984). Spinedace were taken at 11 localities, nine previously reported and two which had not. Previously reported localities were in the Little Colorado River mainstem, East Clear, and Chevelon creeks. Two new localities were in Nutrioso Creek, Apache County. Collections in the 1990s continued to find spinedace in the Little Colorado River, East Clear and Chevelon creeks, two more new localities in Nutrioso Creek, Apache County, and a new population in Rudd Creek, a tributary of Nutrioso Creek (AGFD 1988, Blinn and Runck 1990; Marsh and Young 1989). Population levels of spinedace in East Clear Creek has continued to decline markedly since the 1983 collections; spinedace are again considered rare in that system (Denova and Abarca 1992).

HABITAT

Miller and Hubbs (1960) described localities where spinedace were taken as "...[water] yellowish, brownish-white, and murky; current slight to swift; bottom, thick mud, sand, clay, gravel, and rock; depth of capture, 1 to 3 feet; and vegetation, white water buttercups (rather thick in patches), *Chara*, some rushes and algae." In East Clear Creek they generally found the fish in permanent flowing stream sections and occasionally in stagnating pools. Miller (1963) reported the fish occurred in flowing stream sections where substrates consisted of sand, gravel, rocks, boulders, some silt and bedrock. Water color varied from greenish brown to clear. Stream width averaged 15 meters (m) with fish being taken in water up to two m deep (Miller 1963).

Spinedace occupies mid water portions of clear flowing pools of medium depth, with fine gravel bottoms (Miller 1963, Minckley and Carufel 1967). The species avoided the deepest heavily shaded pools and relatively shallow open areas; spinedace were predominately in open pools with undercut banks and/or boulders for cover. During periods of high discharge the species became more widely distributed throughout East Clear Creek with adults occurring at the upper ends of pools and the shallow lower ends of riffles. During spate conditions, spinedace occurred in eddies lateral to the current (Minckley and Carufel 1967). Minckley (1984) found spinedace in pools with slow to moderate current adjacent to riffles. Water depths varied from 16-88 cm over a variety of substrates including bedrock, sand, gravel, cobble and mud. More recent studies have reported similar patterns of habitat preferences and furthermore documented a wide tolerance of the species for a variety of physico-chemical factors (Blinn and Runck 1990, Denova and Abarca 1992, Nisselson and Blinn 1991).

LIFE HISTORY

Reproduction.

Early observations of spinedace spawning activities are limited. However, C. Hubbs (Miller 1963) observed fish he presumed to be males following apparent females and nibbling them about the vent. Eggs are presumably randomly deposited over the stream bottom or on aquatic vegetation or other debris (Minckley 1973). Minckley (1973) and Minckley and Carufel (1967) suggested spinedace spawn from early summer to early autumn. Miller (1961) suggested that spawning occurred in both May and July of 1961 based on the collection of young-of-the-year fish. Based on length-frequency distributions, spinedace spawned in June-July in 1983 (Minckley 1984). Blinn and Runck (1990) presumed that spawning occurred during late spring or early summer as females with mature eggs were collected during May only. Fish

taken in June and July lacked eggs. Blinn (1993) reported spinedace averaging 87 mm total length present in the Arboretum refugia were in reproductive condition on 10 May 1993. By 24 May, several hundred juvenile fish were observed.

More recent observations at The Arboretum illustrated that spinedace spawned in slow current over cobbles with several (4-8) males attending each female. Spawning activity was observed throughout May of 1994 (D. W. Blinn pers. obs.).

High proportions of females with mature ovaries were found in both May and October, suggesting that females may spawn more than once a year (Minckley and Carufel 1967). The same study reported three size classes of eggs, with fecundity estimates ranging from 650-1000 total eggs per female. Blinn and Runck (1990) determined that spinedace egg diameter ranged from 20-50 microns at the first discernable egg stage to 1.0-1.28 mm for mature eggs. Fish <50 mm total length lacked mature eggs, which generally were found in fish >64 mm total length. The percentage of mature eggs continued to increase with size of fish but varied with season and location. When gonadalsomatic values approached 20%, >90% of the eggs were mature, while <60% of the eggs were mature in fish with a gonadalsomatic indices of <10%. Detailed descriptions of larval spinedace are presented in Miller (1963).

GROWTH AND SURVIVAL.

Preliminary data indicates that spine-dace are 6-8 mm in total length when they hatch and reach 25 mm in one month. After 10 weeks fish are 50-60 mm, reaching 75-80 mm by the end of the first year. Collection of the original transplants placed in the Arboretum pond indicates they live at least three years (Dean Blinn, pers. comm.).

GENETICS.

Patterns of genetic variation within and among remaining populations of spinedace were recently described by Tibbets, et al. (1994). Results from mitochondrial DNA and allozyme surveys indicate considerable population structure, with most variation found among samples. Distributions of variation suggest that there are three distinct populations within the Little Colorado River drainage. All of these populations should be maintained to conserve genetic variation in this species (Tibbets et al. 1994).

FOOD HABITS.

Stomach analysis of fish collected from Nutrioso and Chevelon creeks indicated spinedace are predacious. In May, aquatic insects, primarily chironomid larvae and ephemeropteran nymphs, were the most common foods in stomachs. In July, stomach contents commonly included cladocerans and detritus; Heteroptera, Coleoptera and filamentous green algae were abundant and terrestrial invertebrates, (Formicidae, Diptera, Thysanoptera and Crustacea) were present. Studies of spinedace collected from Chevelon Creek revealed similar information. Stomachs contents from fish collected in June contained chironomids and ephemeropterans, filamentous green algae and vascular aquatic plants fragments were more common, than in July and terrestrial insects and filamentous green algae were also present. Smaller fish contained a higher percentage of small aquatic insects, ephemopterans and chironomids (Blinn and Runck 1990).

Stomachs from spinedace collected in October contained terrestrial insects, chironomid larvae, corixidae and elmidae. Adult dipterans were major components of stomach contents of spinedace collected in January; chironomid larvae, plecopteran nymphs and corixidae were common (Blinn and Runck 1992). No terrestrial insects were identified in January (Blinn and Runck 1992).

CO-OCCURRING FISHES

Native fishes associated with spinedace include speckled dace (*Rhinichthys osculus*); bluehead sucker, (*Pantosteus discobolus*); Little Colorado river sucker (*Catostomus* sp.). Roundtail chub (*Gila robusta*), (now rare in the Little Colorado River basin) and Apache Trout (*Onchorhynchus apache*). Historically, prior to the introduction of nonnative species and habitat modification, it is presumed an equilibrium existed among native fishes thereby permitting the native fauna to coexist through time.

Introduced species which now occur with spinedace include carp (*Cyprinus carpio*), fathead minnow, (*Pimephales promelas*), red shiner, (*Cyprinella lutrensis*), golden shiner, (*Notemigonus crysoleucus*), bluegill, (*Lepomis macrochirus*), green sunfish,(*L. cyanellus*), largemouth bass, (*Micropterus salmoides*), cutthroat trout, (*Onchorhynchus clarki*), rainbow trout, (*O. mykiss*), brown trout; (*Salmo trutta*), brook trout, (*Salvelinus fontinalis*), channel catfish (*Ictalurus punctatus*) and plains killifish, (*Fundulus zebrinus*). All are potential predators on spinedace, eggs, larvae and adults.

REASONS FOR DECLINE

Threats to the survival of spinedace include changes in stream flow patterns, decline in water quality and quantity, modifications of watersheds (logging, dams, road construction), manipulation of fish populations (use of chemicals and others) and interactions with introduced fishes.

Documenting spinedace decline is complicated by their distributional patterns. Populations fluctuate dramatically, being very abundant at times and essentially absent or difficult to find at other times. Such fluctuations have been observed between years, months, and, in some cases days, (Miller 1963, Minckley and Carufel 1967). Changes between years may be attributed to climatic conditions such as drought or increased rainfall. Population variations over shorter durations remain unexplained and are one of the unique characteristics of this species. This characteristic may have been historically beneficial in allowing spinedace to exploit or evacuate habitats quickly, but the human-related changes to habitat conditions may have interfered with the fishe's effectiveness in utilizing habitats on a short-term basis.

Although generally undocumented, spinedace populations are believed to be impacted by: 1) reduction in stream discharge because of dam construction on the Little Colorado River, 2) alteration in patterns of flow, and 3) changes in sedimentation, movement and deposition. Dams have been constructed on Chevelon, Willow, East Clear and Silver creeks, and numerous lakes and diversions have been constructed throughout the watershed (Anon. 1981). The most obvious impact of these structures is reduction of stream flows and direct loss of habitat.

Increased deposition of sediment in spinedace habitat is believed detrimental to long term spinedace survival. Although current logging operations are designed to prevent such deposition prior practices may have caused extensive habitat loss and/or degradation. Logging procedures, road building, and overgrazing by ungulates on the watershed all tend to increase deposition of sediments. Increased sedimentation rates, modifications of existing channels, and habitat loss resulting from increased runoff caused by such practices have adverse impacts on spinedace. Because this fish historically occupied permanent flowing streams that contained diverse substrates (Miller 1963) increased sedimentation rates may have reduced substrate diversity believed necessary for spinedace survival.

The use of piscides in the Little Colorado River basin during the mid 1900's may have adversely impacted spinedace populations (Hemphill 1954; Minckley and Carufel 1967). However, manipulation of

fish populations by chemical means is no longer widely practiced.

The impact of introduced fishes on native fish can be subtle (e.g., displacement from preferred habitats) indirect (e.g., competition) or direct (e.g., predation). To date, little information is available to quantify the exact impacts of most introduced fishes on native forms; however, both competition and predation are strongly suspected as reasons for the decline or disappearance of numerous native fish populations. This is the case with the red shiner, which has been implicated in the decline of two other Plagopterines, the woundfin (*Plagopterus argentissimus*) and spikedace (*Meda fulgida*). Recently, Douglas et al. (1994) and USFWS (1991) presented various theories to explain the relationship between red shiners and spikedace to include invasions of: 1) previously unoccupied niches; 2) vacant niches left by other native minnows extirpated because of habitat alteration; and, 3) areas occupied by spikedace and the consequent displacement of spikedace through competition and/or predation. These theories are shared by Minckley (1973), Minckley and Carufel (1967), Minckley and Deacon (1968), Propst et al. (1985, 1986), Bestgen and Propst (1986), Marsh et al (1989). In the Gila River the invasion of unoccupied niches by red shiner was thought to present the most likely reason for the loss of spikedace (Probst et al. 1986, Bestgen and Propst 1986). A recent laboratory study and *in situ* found shifts in habitat use by spikedace in the presence of red shiners (Marsh et al. 1989). Spinedace may be impacted in much the same way as the spikedace.

Historically, native fish populations in the Little Colorado River consisted of two cyprinids and two catostomids and Apache trout which maintained equilibrium populations. Under historic conditions, fish populations undoubtedly varied with changes in climatic conditions but an ample habitat was available to maintain populations through time. With development of the basin and resultant habitat modifications, native fish populations were impacted adversely. In concert with these habitat modifications, non-indigenous salmonids were introduced and maintained to sustain a recreational fishery. Predation on spinedace and competition for food and habitat is believed to have contributed to the decline of spinedace within the Little Colorado River system.

Minckley and Deacon (1991), Meffe (1983, 1985) and Rinne and Minckley (1991) have proposed that predation plays a major role in the overall decline of native southwestern fishes. This hypothesis was recently examined in a study which investigated the significance of rainbow trout predation on distribution and behavior of spinedace (Blinn and Runck 1992, Blinn et al. 1993). Laboratory and *in situ* experiments illustrated high predation rates on spinedace even in the presence of natural cover and abundant macroinvertebrate prey. Spinedace showed little predator avoidance in the presence of rainbow trout, suggesting limited interaction with large nonnative piscivores during the evolutionary history of the species. These results suggest that rainbow trout may have a significant influence on the distribution and behavior of spinedace, and may contribute to the disjunct distribution of this native species. Habitats with high turbidity appear to be among the few places where this fish can co-occur with rainbow trout in southwestern lotic ecosystems. However, preliminary case experiments in lower Nutrioso Creek suggest that even in presence of elevated turbidity the impact of trout predation appears significant (J.N. Rinne, pers. comm.). The influence of introduced salmonids is further exacerbated by brown trout and brook trout now found in drainages historically occupied by spinedace.

Green sunfish also impact spinedace, but presumably to a lesser degree (Blinn and Runck 1990). Although some centrachid species do occur sympatrically with a few spinedace populations their impact is

generally believed to limit rather than increase spinedace abundance. Centrachids and have been strongly implicated in the failure of razorback sucker recruitment in Lake Mohave (Minckley et al. 1991). Crayfish can also have detrimental impacts on spinedace (White 1995). In additional to predation, suspected impacts from introduced fishes include competition for food and stress or disease caused by parasites introduced with nonnative fish. The exotic Asian tapeworm is established in Virgin River fishes and no effective barrier exists to prevent its invasion of the upper Little Colorado river and its tributaries. The impact of the Asian tapeworm on spinedace is unknown but presumed to be negative since it impacts other native fish populations negatively (Heckman et al 1986).

Part II

RECOVERY

The goals of this recovery plan are to identify steps and mechanisms considered necessary to: 1) protect existing spinedace populations, 2) restore depleted and extirpated spinedace populations, 3) protect and enhance existing habitats, and 4) ensure that spinedace continues to exist in the future. When these goals are achieved, it will be possible to delist this species. This plan may require revision of objectives and tasks when new data becomes available; delisting criteria will be modified as appropriate. Both the combined and separate impacts of habitat modification, dewatering and interactions with non-native fishes are considered major reasons for the decline and threatened extirpation of spinedace. Recovery cannot be achieved until these factors are successfully alleviated.

Step Down Outline

1.0 Protect existing populations of spinedace.

1.1 Prioritize existing and new populations as to need for protection.

1.2 Develop secure refugia for the four extant populations of spinedace within their historic drainages.

1.2.1 Establish/maintain refugia in the East Clear Creek drainage.

1.2.1.1 Above Blue Ridge reservoir.

1.2.1.2 Below Blue Ridge reservoir.

1.2.2 Establish/maintain refugia in the Silver Creek drainage.

1.2.3 Establish/maintain refugia in the Rudd-Nutrioso Creek drainage.

1.2.4 Establish/maintain refugia in upper and lower Chevelon Creek.

1.2.5 Maintain refugia at The Arboretum in Flagstaff.

1.2.6 Establish and maintain refugia at the Wenima Wildlife Area.

1.3 Acquire and protect lands and water rights where required to conserve spinedace.

1.4 Enforce existing laws and regulations affecting spinedace.

1.4.1 Inform appropriate agencies/ individuals of applicable manage ment/enforcement responsibilities and opportunities.

1.4.2 Insure compliance with Section 7 and Section 9, of the Endangered Species Act.

1.5 Discontinue introduction of non-native fishes into areas deemed necessary for spinedace recovery.

1.5.1 Ensure fish stocking plans are consistent with the goals and objectives of this recovery plan.

2.0 Improve or restore habitats occupied by spinedace populations.

2.1 Identify habitats for restoration/ maintenance.

2.2 Determine steps necessary for restoration and implementation.

2.2.1 Remove introduced fishes in areas where their presence threatens continued spinedace existence.

2.2.2 Install barriers or other struc tures to prevent reestablishment of non-native fish.

2.3 Manage the ecosystem for native organisms to maintain, enhance or redevelop the native biodiversity which was present historically.

3.0 Reintroduce spinedace to selected habitats within historic range.

3.1 Identify areas for reintroduction

3.1.1 Enhance habitat as necessary

3.1.2 Remove nonnative fish and cray fish from habitats essential for spinedace recovery.
3.1.3 Prevent introduced fish from re-invading renovated habitat.
3.1.4 Reintroduce spinedace into available habitats.
3.1.5 Monitor reintroduction(s)
3.1.6 Determine success/failure of reintroductions
3.2 Determine genetic composition of extant populations.
3.2.1 Use such information to determine stocks for introductions.
3.2.1.1 Develop a genetic pedigree for spinedace.
3.2.1.2 Maintain maximum genetic heterozygosity in existing and reintroduced populations.

4.0 Monitor status of existing populations.
4.1 Establish and implement standard monitoring locations for extant populations.
4.2 Establish and implement standard sampling procedures and techniques.
4.3 Establish and maintain adatabase for monitoring and reintroduction information.
4.4 Determine variation in spinedace abundance population structure, and movement.
4.4.1 Develop standard methods for quantifying abundance.

5.0 Identify type and importance of interactions with both native and nonnative fish.
5.1 Direct and Indirect interaction.
5.1.1 Examine direct interactions experimentally under laboratory and field conditions with: Apache, rainbow, brown and brook trouts, red shiners, fathead minnows, green sunfish, speckled dace, crayfish, salamanders, other species of fish and invertebrates as appropriate.
5.1.2 Examine indirect interactions experimentally under laboratory and field conditions with: Apache, rainbow, brown and brook trouts, red speckled dace, crayfish, salamanders, other species of fish and invertebrates, as appropriate.

6.0 Determine quantitative criteria for describing a self-sustaining population.
6.1 Determine levels of natural variation.
6.1.1 Absolute numbers.
6.1.2 Population structure.
6.1.3 Reproduction.
6.1.3.1 Describe spawning characteristics
6.1.3.1.1 Describe substrates, water velocity, and temperature.
6.1.4 Recruitment.
6.1.5 Minimum population size.
6.1.6 Environmental characteristics.
6.1.6.1 Physical characteristics.
6.1.6.2 Chemical characteristics.
6.1.6.3 Biological characteristics of community.

7.0 Develop captive breeding program.
7.1 Develop procedures for propagat ing, holding and maintaining spinedace.
7.2 Supply fish for reintroduction, education and research.

8.0 Information and education.
8.1 Public I/E
8.1.1 State outreach efforts
8.1.2 National exposure.
8.1.3 Local media and specific campaigns.
8.1.4 Develop communication between State, Federal agencies and local residents.
8.2 Professional information.
8.2.1 Publication in peer-reviewed, open literature.
8.2.2 Information exchange at meetings.
8.2.3 Presentations at professional, scientific meetings.

NARRATIVE

1.0 Protect existing populations of spinedace.

Spinedace populations are known to remain in the Little Colorado River, Rudd, Nutrioso, Chevelon, Silver and East Clear creeks as well as other possible locations, threatened by ongoing habitat modification or destruction. Stream alteration, watershed modification and introduction of and dispersal of non-native fishes into the Little Colorado River drainage poses an increasing threat to remaining spinedace populations. Loss of any of these populations significantly increases risk of extinction by decreasing the likelihood of species survival. Loss of one or more of these populations may be grounds to consider reclassifying spinedace as endangered rather than threatened. It is imperative that existing populations and their habitats be protected to ensure survival of and effect recovery of this species.

1.1 Prioritize existing and new populations as to need for protection.

Within the possible range of the spinedace, every effort should be made to determine status of known populations and locate additional populations, by surveying areas throughout their historic range. All populations should be identified so that range and distribution of this species is known. Areas where surveys are lacking include parts of the Chevelon and East Clear Creek drainages on the Apache-Sitgreaves and Coconino National Forests. These streams should also be surveyed north of the forest boundary. New populations should be characterized according to protection currently provided. All populations should be ranked according to importance in conserving the species. Spinedace which occupies relatively undisturbed habitat and are protected by governmental or private agencies will be considered in less danger than those occupying habitats which are heavily modified, contain non-native fish or are not protected. By ranking the various populations, according to their importance to achieving recovery focused actions can be taken to enhance recovery. Populations which appear in imminent danger should be given highest priority to ensure their continued survival and movement toward recovery of the species. Tentatively, known populations would be ranked as the Silver Creek population in most imminent danger (possibly extinct); followed by East Clear, Chevelon, Rudd and Nutrioso Creeks and the Little Colorado river.

1.2 Develop secure refugia for four extant populations of spinedace within their historic drainages.

Refugia within the drainages of extant populations should be developed to provide a source of fish to expand populations within the respective drainages. The refugia may be represented by stream systems containing natural or man-made barriers or isolated springs.

1.2.1 Establish/maintain refugia in the East Clear Creek drainage.

1.2.1.1 Above Blue Ridge Reservoir. Potato Lake downstream is one possibility and is within current Critical Habitat.

1.2.1.2 Below Blue Ridge Reservoir.

1.2.2 Establish/maintain refugia in the Silver Creek drainage.
The main spring at Silver Creek State Fish Hatchery could

provide a refugia for spinedace. Access is controlled by the State of Arizona and the spring/spring run could be renovated. The spring is ca 2 m deep and 30 m in diameter, thus providing adequate habitat for spinedace and is a likely candidate for a wild refugia.

1.2.3 Establish/maintain refugia in the Rudd-Nutrioso Creek drainage.
Both systems are currently being considered for refugia, particularly Rudd Creek where property and water rights have recently been acquired by the Arizona Game and Fish Department.

1.2.4 Establish/maintain refugia in upper and lower Chevelon Creek.
The lower reach is within designated Critical Habitat but is on State and private land. Spinedace existence currently depends on the lack of development in the area and the protection of Indian pictographs by a private landowner. Areas above Chevelon Lake should be examined for possible refugia sites also.

1.2.5 Maintain refugia at The Arboretum in Flagstaff.
Potential sites include the Arboretum in Flagstaff as well as the Pinetop Hatchery pond. The Arboretum is a private organization which is dedicated to maintaining endangered species and has developed a strong information and education program for listed species.

1.2.6 Establish and maintain refugia at the Wenima Wildlife area.
This area, located on the Little Colorado River is owned and managed by Arizona Game and Fish Department and is a candidate for a refugium.

1.3 Acquire and protect lands and water rights where required to conserve spinedace.

Much of the habitat occupied by spinedace occurs within the Apache-Sitgreaves or Coconino National Forests. These areas are protected by the Forest Service and specific stream reaches are designated Critical Habitat. Property and water rights have recently been acquired on the Little Colorado River (Wenima and Slade properties) and on Rudd Creek by the State of Arizona. Additional landsand water rights should be acquired as they become available to maintain perennial flow that mimics the natural hydrograph. Obtaining such lands and water rights will help insure that existing spinedace populations and habitats are secure.

1.4 Enforce existing laws and regulations affecting spinedace.

Failure by individuals or organizations to recognize and follow laws and regulations that protect spinedace and their habitat may further imperil the species and result in population declines that compromise survival and impedespecies recovery.

1.4.1 Inform appropriate agencies/individuals of applicable management/enforcement responsibilitie and opportunities. All agencies and personnel should be made aware of their responsibilities under the existing laws to protect listed species and their habitats, and actions each agency should take to effectively ensure spinedace protection.

1.4.2 Ensure compliance with Section 7 and Section 9 of the Endangered Species Act.
All Federal agencies share responsibility for the conservation of federally listed species. Private and public organizations are subject to Section 9 prohibitions and implementing regulations regarding take of Federally listed endangered or threatened species.

1.5 Discontinue introduction of non-native fishes into areas deemed necessary for spinedace recovery.

Recovery habitat is defined as stream or stream reaches essential and dedicated to spinedace recovery. Production and introductions of non-nativefishes by Federal hatcheries and federally funded management actions within watersheds containing spinedace should be evaluated through the Section 7 consultation process. Future construction of Federal and federally funded hatcheries should be determined on the presence or absence of listed species in the watershed to which they drain and the likelihood of an escapement of reared fish not native to the watershed. Construction of such facilities should not occur until the probability of an escapement of fish into a spinedace habitat is nil.
Non-federally funded state activities and privately owned hatcheries should be made aware of the presence of listed species and of possible threats presented by their activities such as: inadvertent introductions of fish or disease organisms into the watershed. Every attempt should be made to cooperatively prevent any adverse action(s) to spinedace before they occur and to prevent Section 9 violations.

1.5.1 Ensure fish stocking plans are consistent with the goals and objectives of this recovery plan.
Review stocking plans to prevent the introduction of non-native fish into spinedace habitats where such introductions would pose a threat to spinedace recovery.

2.0 Improve or restore habitats occupied by spinedace populations.

Occupied and recovery habitats should be improved or restored where possible to enhance spinedace populations. Development of management plans that eliminate negative impacts of non-native fish introductions should be pursued.

2.1 Identify habitats for restoration/ maintenance.

Unoccupied habitats within the historical range of spinedace should be examined as possible reintroduction sites. Areas which now contain spinedace and exhibit marginal habitat conditions should be enhanced.

2.2 Determine steps necessary for restoration and implementation.

Procedures for restoration of declining or extirpated spinedace populations should be adopted. In many cases such action will require the removal of the conditions which resulted in habitat degradation. Overgrazing the watershed, destruction of the riparian corridor and removal of non-native fishes are examples of actions needing alteration(s). Additionally, further changes in forest or land management practices should be actively pursued to benefit the spinedace and the ecosystem upon which they depend.

2.2.1 Remove introduced fishes in areas where their presence threatens continued spinedace existence.
If it is determined that non-native fishes are negatively

impacting spinedace recovery they should be removed as effectively as possible. Additionally, in conjunction with renovation, every effort should be made to prevent reestablishment of non-native fish populations.

2.2.2 Install barriers or other structures to prevent reestablishment of non-native fish. Permanent structures should be put in place to prevent re-invasion of non-native fish. Such structures would vary for the different streams and could involve both up and down stream structures above the barrier as well as cessation of stocking in the watershed upstream of the barrier where downstream move ment of stocked fish would pose a treat to spinedace recovery.

2.3 Manage the ecosystem for native organisms to maintain, enhance or redevelop the native biodiversity which was present historically.

System management of the ecosystem in which the spinedace evolved is imperative. In using this multi-species approach to recovery, natural biodiversity can be maintained to benefit all native organisms.

3.0 Reintroduce spinedace to selected streams within historic range.

A major step toward recovery will be the reintroduction of spinedace back into historic habitats. Habitats should be examined and modified as appropriate and realistic prior to spinedace reintroduction.

3.1 Identify areas for reintroduction.

3.1.1 Enhance habitat as necessary. There are many ways to enhance habitat depending on what impacts are occurring. Reduction or cessatation of cattle grazing and removal of non-native fish, are among options that should be considered.

3.1.2 Remove non-native fish and crayfish from habitats essential for spinedace recovery. The impact of various non-native fish species and crayfish upon spinedace populations is strongly suspected (White 1995) and recently documented for rainbow trout (Blinn and Runck 1992). Spinedace populations must be provided every opportunity to increase their population size and status. Providing habitat devoid of non-native fishes may be critical to the spinedace recovery.

3.1.3 Prevent introduced fish from re-invading renovated habitat. Watersheds designated as possible reintroduction sites must be isolated as much as possible from the threat of non-native fishes. Construction of barrier dams or other applicable structures to insure downstream populations of non-native fishes do not access the areas above the barrier will reduce the threat greatly.

3.1.4 Reintroduce spinedace into available habitats. The reintroduction of spinedace into a habitat properly documented as a suitable for reintroduction is essential for the recovery of this fish. Once a habitat is certified as suitable, fish should be introduced as multiple stockings over the course of one or more years following the initial reintroduction.

3.1.5 Monitor reintroduction(s).
All reintroduced populations should be monitored annually to determine their success.

3.1.6 Determine success/failure of reintroductions.
The success/failure of reintroductions should be tracked through time and documented. Where failures occur, efforts should be made to correct the cause before additional fish are stocked. Data pertaining to successes and failures should be incorporated into future reintroduction attempts to increase later stocking success.

3.2 Determine genetic composition of extant populations.

The genetic composition of current populations should be determined by chemical analysis of mTDna and allozymes prior to any reintroduction.

3.2.1 Use such information to determine stocks for introduc tions. Information developed by chemical analysis of extant populations has determined significant differences occur between extant populations. Currently, stocking should be limited to the sub-basin containing the parent stock.

3.2.1.1 Develop a genetic pedigree for spindace.
A genetic pedigree should be developed for the spinedace. The resulting pedigree would be implemented based on recommendations of the recovery team to prevent lessening of the genetic variability of various populations.

3.2.1.2 Maintain maximum genetic heterozygoxity in existing and reintroduced populations.
The highest genetic diversity available must be maintained in existing brood and reintroduced populations.

4.0 Monitor status of existing populations.

All populations must be monitored annually to determine their status. Such action will enhance identification of long term trends and aid in management of all spinedace populations.

4.1 Establish and implement standard monitoring locations for extant populations.

Standard monitoring locations to be determined by historical and recent collections. Monitoring should be done subsequent to anticipated spawning periods and for current year to determine the spawning success of last year's population.

4.2 Establish and implement standard sampling procedures and techniques.

Standard procedures and techniques should be used when sampling for spinedace. These procedures and techniques should be used by all entities collecting spinedace and be consistent through time and among investigators. Every attempt should be made to ensure that all data collected by researchers are comparable. Once established, procedures and techniques should not change unless better methods, agreed upon by the affected parties, become available. Change should be evaluated carefully prior to their implementation.

4.3 Establish and maintain a database for monitoring and reintroduction information.

A central database should be developed for all information collected on spinedace. It should be at an accessible location and available to all stakeholders and interested persons.

4.4 Determine variation in spinedace abundance, population structure, and movement.

Variation in abundance, population structure and movements through time is necessary to maintain and manage spinedace populations. Currently, this species is characterized by wide population fluctuations which remain unexplained. Long-term data sets should help determine the cause of fluctuations and aid in spinedace management.

4.4.1 Develop standard methods for quantifying abundance. Techniques such as spray marking, mark and recapture and depletion sampling are available to determine spindace abundance. These methods may need modification for spinedace. If necessary other methods may need to be developed, if appropriate. Techniques used should be based on good judgement, and used consistently.

5.0 Identify type and importance of interactions with both native and non-native fish.

5.1 Direct and indirect interactions.

5.1.1 Examine direct interaction experimentally under laboratory and field conditions with: Apache, rainbow, brown, and brook trouts; red shiners, fathead minnows, green sunfish, speckled dace, crayfish, salamanders, other species of fish and invertebrates as appropriate.

5.1.2 Examine indirect interactions experimentally under laboratory and field conditions with: Apache, rainbow, brown and brook trouts; red shiners, fathead minnows, speckled dace, green sunfish, crayfish, salamanders, other species of fish andinvertebrates as appropriate.

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

Quantitative data describing parameters believed necessary to assist in maintaining a self-sustaining population should be established. This data can be provided by determining the relationships between various types of habitat modifications and spinedace biology. Such data should be made available to all stakeholders and members of the scientific community responsible for effecting recovery of the species.

6.1 Determine levels of natural variation.

Spinedace populations fluctuate tremendously among years, months and days. The causes of these fluctuations must be understood to effectively manage the species.

6.1.1 Absolute numbers. Population estimates can be determined by a variety of mark and recapture techniques. Once the preferred method has been determined for spinedace, it should be refined and standardized so that data collected between populations can be compared. As a long-term data set develops, acceptable variation in population size, numbers in size classes and perhaps recruitment to the adult population will be better understood.

6.1.2 Population structure.
Spinedace cannot be effectively managed until information is available on the structure of extant populations. Such data can be gathered by taking measurements of individuals sampled during population estimates. Normal distribution of various age classes would be expected in a healthy population. Conversely, the lack of a year class could indicate less than suitable conditions for that population and might call for remedial action(s).

6.1.3 Reproduction.
Reproduction in the various spinedace populations is presumed to be occurring annually, but recruitment varies considerably. In order to better manage this species several aspects of reproduction must be understood.

6.1.3.1 Describe spawning characteristics.
More detailed information on spawning in spinedace is required to effectively manage the species.

6.1.3.1.1 Describe substrate, water velocities and temperature.
The type of substrate, water velocities and temperatures used during spawning by spinedace must be better characterized to manage this fish.

6.1.4 Recruitment.
The level of recruitment in the various spinedace populations needs to be determined. Information, used in concert with other biological information and habitat measurements can be used to determine what are optimal, good and poor habitats. Habitats can then be managed more effectively.

6.1.5 Minimum population size.
There is a minimum size for each spinedace population; below this level, the population will not sustain itself through time. Species experts should attempt to define minimum stock population size for the various spinedace populations. When a population falls near or below that minimum it should be taken as an indication that environmental factor(s) are negatively impacting the population. Investigation to determine and rectify the cause of this depletion would then be necessary. Populations which are self-sustaining should not be permitted to fall below the minimum population level.

6.1.6 Environmental characteristics.

6.1.6.1 Physical characteristics.
Physical characteristics of the habitat need to be determined. Such parameters include temperature, current velocity, substrate; still others have yet to be determined. Knowledge of these parameters is necessary to better identify optimal or sub-optimal habitats for the spinedace management.

6.1.6.2 Chemical characteristics.
The chemical characteristics of streams include dissolved oxygen and carbon dioxide content, alkalinity, pH, etc. Knowledge of these parameters is necessary to better identify optimal or sub-optimal habitats for spinedace management.

6.1.6.3 Biological characteristics of the community.
In order to maintain and perpetuate spinedace populations, the natural biodiversity of the community must be maintained. Fish depend on many aspects of the aquatic and surrounding community, from the oxygen content of water, types of predators, and prey items to places of refuge. Each community should be characterized to better effectively manage spinedace.

7.0 Develop captive breeding program.

The development of a captive rearing program will insure survival of this species. When developed properly captive production and subsequent reintroduction will maintain the natural heterozygosity of wild populations.

7.1 Develop procedures for propagating, holding and maintaining spinedace.

Technology exists for development of these procedures at Dexter National Fish Hatchery and Technology Center. Such procedures should be developed now, rather then waiting until population numbers are so low that the development of such a program might jeopardize the species' continued existence.

7.2 Supply fish for reintroduction, education, and research.

Once the technology exists to reliably produce spinedace in quantity (7.1), stocks can be made available for reintroduction.

8.0 Information and education.

8.1 Public information and education.

Exchange of information and ideas between individuals representing scientific, managerial, and private citizens or groups are essential for a successful recovery program. All aspects of this recovery plan should be made available to any interested party. The public particularly should be informed of recovery actions that will be implemented to recovery spinedace.

8.1.1 State outreach efforts.
Media with statewide distribution should be targeted to provide information pertaining to recovery of this fish. Such exposure could be done periodically to ensure continued public interest/awareness, thus aiding spinedace recovery.

8.1.2 National exposure.
Federally listed plants and wildlife are of interest to all residents of the United States. When possible information should be made available to the general public.

8.1.3 Local media and specific campaigns.
It is important to keep local media, and residents that could be affected, apprised of decisions being made that directly, and perhaps immediately impact them. Specific programs should be identified to better inform specific groups/communities as appropriate.

8.1.4 Develop communications between State, Federal agencies and local residents. Dialogue between State, Federal and private organizations must be maintained to keep all entities informed.

8.2 Professional information.

All scientific information, trip reports, published reports, raw data, results of field and laboratory research must be available to all professionals working on spinedace. Free exchange of information and ideas is essential to their recovery. All information should be placed at a recognized institution which has the capability to provide information to agencies and persons interested in spinedace.

8.2.1 Publication in peer-reviewed, open literature.
Persons studying the Spinedace should be encouraged to publish their findings as soon as it is appropriate. Scientific publications undergo peer review by other professionals enhancing the quality of the research and credibility of the researcher. Such publications also have had benefit of critical review and thus meet the standards of excellence to which professionals strive.

8.2.2 Information exchange at meetings.
Periodic meeting with species experts and the public would provide a source of communication to deal with special circumstances. Such action allows discussion of ideas and resolve difficulties.

8.2.3 Presentations at professional scientific meetings.
Research results should be presented at local, regional and national scientific-gatherings to allow professionals the opportunities to comment on and enhance the spinedace recovery.

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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 populations 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 - 0

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:

AGFD - Arizona Game and Fish Department
ES - Ecological Services
FWS - USDI Fish and Wildlife Service
FR - Fisheries Resources
FS - USDA Forest Service
LE - Law Enforcement

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK NO	PRIORITY NUMBER	TASK DURATION	RESPONSIBLE AGENCY			FISCAL YEAR COSTS (ESTIMATE)			COMMENTS
					FWS REGION	PROGRAM	OTHER	FY1	FY2	FY3	
I-1	Prioritize populations for protection needed	1.1	1	1 year	2	ES/FR	AZGF FS	1,000			
M-3	Develop refugium above Blue Ridge Reservoir	1.2.1.1	2	2 years	2	ES/FR	AZGF FS		50,000	50,000	
M-3	Develop refugium below Blue Ridge Reservoir	1.2.2	2	2 years	2	ES/FR	AZGF FS	50,000	50,000		
M-3	Develop refugium in Silver Creek Drainage	1.2.2	2	2 years		ES/FR	AZGF		50,000	50,000	
M-3	Develop refugium in Rudd -Nutrioso Creek drainage	1.2.3	2	2 years		AZGF	AZGF FS			50,000	FY4 = 50,000
M-3	Develop refugia in Chevelon Creek	1.2.4	2	2 years		AZGF	AZGF FS PRIVATE				FY4 = 75,000 FY5 = 75,000
M-3	Maintain refugium at Flagstaff Arboretum	1.2.5	2	10 years	2	FR		10,000	10,000	10,000	FY4-10 = 70,000
M-3	Develop refugium in Little Colorado River	1.2.6	2	2 years	2	ES/FR	AZGF FS				FY4 = 50,000 FY5 = 50,000
A-3	Acquire and protect land and water rights	1.3	1	ongoing	AZGF			10,000	10,000	10,000	In addition to funds required under task 1.2
O-1	Inform agencies/ individuals of responsibilities/opportunities	1.4.1	1	ongoing	2	LE/ES/FR	AZGF FS				Ongoing and within budget
O-2	Ensure compliance with Section 7 & 9 of the Endangered Species Act	1.4.2	1	ongoing	2	LE/ES/FR	AZGF FS				Ongoing and within budget
O-3	Ensure fish stocking plans are consistent with recovery plan goals and objectives	1.5.1	1	ongoing	2	ES/FR	AZGF FS				Ongoing and within budget
I-3	Identify habitats	2.1	2	3 years	2	FR	AZGF FS	5,000	5,000	5,000	
M-4	Remove non-native fish in areas where continued spinedace survival is threatened	2.2.1	1	5 years	2	FR	FS AZGF	2,000	2,000	2,000	FY4 = 2,500 FY5 = 3,000
M-4	Install barriers to prevent introduction of non-native species	2.2.2	1	5 years	2	FR/ES	FS	5,000	10,000	10,000	FY4-5 = 30,000
M-3	Manage ecosystems to enhance biodiversity of native species	2.3	2	10 years	2	FR/ES	AZGF FS	AZGF 10,000	10,000	10,000	FY4-10 = 52,500
M-3	Identify areas for reintroduction	3.1.1	2	3 years	2	FR	AZGF FS	1,000	1,000	1,000	
M-4	Remove non-native competitors/predators	3.1.2	2	5 years	2	FR	AZGF FS	2,000	2,000	2,000	FY4 = 2,000 FY5 = 2,500
M-4	Prevent reentry of non-native competitors/predators	3.1.3	2	8 years	2	FR	AZGF FS			2,500	FY4-10 = 17,500
M-2	Reintroduce Spinedace	3.1.4	2	5 years	2	FR	AZGF FS			3,000	FY4-7 = 12,000
M-7	Monitor success of reintroduction	3.1.5	2	7 years	2	FR	AZGF FS				FY4-7 = 14,000
M-7	Determine status of reintroduction	3.1.6	2	3 years	2	FR	AZGF FS				FY4 = 15,000 FY7 = 2,000 FY10 = 2,500
I-5	Develop genetic pedigree	3.2.1.1	1	2 years	2	FR			7,000	8,000	

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK NO	PRIORITY NUMBER	TASK DURATION	RESPONSIBLE AGENCY			FISCAL YEAR COSTS (ESTIMATE)			COMMENTS
					FWS REGION	PROGRAM	OTHER	FY1	FY2	FY3	
I-5	Maintain maximum genetic variability	3.2.1.2	1	10 years	2	FR	AZGF FS	1,000	1,000	1,000	FY4-10 = 7,000
I-1	Establish and implement monitoring for extant location	4.1	2	3 years	2	FR	AZGF FS	1,000			FY4 = 1,000 FY10 = 1,000
I-1	Establish and implement standard sampling procedures and techniques	4.2	2	10 years	2	FR	AZGF FS	5,000	4,000	4,000	FY4-10 = 35,000
I-4	Develop methods to quantify abundance	4.4.1	2	1 year	2	FR		1,000			
R-9.10	Examine direct interactions with other species	5.1.1	1	3 years	2	FR	AZGF FS	50,000	50,000	50,000	
R-9.10	Examine indirect interaction with other species	5.1.2	1	3 years	2	FR	AZGF FS	50,000	50,000	50,000	
R-1	Determine self-sustaining population numbers	6.1.1	2	5 years	2	FR	AZGF FS	25,000	25,000	25,000	FY4-5 = 50,000
R-1	Determine self-sustaining population structure	6.1.2	2	5 years	2	FR	AZGF FS	25,000	25,000	25,000	FY4-5 = 50,000
R-3	Determine physical characteristics for spawning	6.1.3.1.1	2	4 years	2	FR	AZGF FS	20,000	20,000	20,000	FY4-5 = 20,000
R-1	Determine recruitment numbers required for self-sustaining populations	6.1.4	2	5 years	2	FR	AZGF FS	20,000	20,000	20,000	FY4-5 = 40,000
R-1	Determine minimum population size required to maintain self-sustaining populations	6.1.5	2	5 years	2	FR	AZGF FS	20,000	20,000	20,000	FY4 -5 = 40,000
R-3	Determine physical characteristics required to maintaining self-sustaining populations	6.1.6.1	2	4 years	2	FR	AZGF FS	20,000	20,000	20,000	FY4 = 20,000
R-12	Determine chemical characteristics required to maintain self-sustaining populations	6.1.6.2	2	4 years	2	FR	AZGF FS	20,000	20,000	20,000	FY4 = 20,000
R-1	Determine biological characteristics required to maintain self-sustaining populations	6.1.6.3	2	5 years	2	FR	AZGF FS	25,000	25,000	25,000	FY4-5 = 50,000
M-1	Rear and supply fish for recovery purposes	7.2	2	7 years	2	FR					FY4-10 = 70,000
O-1	Outreach efforts with Arizona	8.1.1	3	10 years	2	FR	AZGF FS	5,000	5,000	5,000	FY4-10 = 35,000
O-1	Outreach efforts nationally	8.1.2	3	10 years	2	FR/PA	FS	1,000	1,000	1,000	FY4-10 = 7,000
O-4	Outreach efforts in local communities where spinedace occurs	8.1.3	3	10 years	2	FR/PA	AZGF FS	1,000	1,000	1,000	FY4-10 = 7,000
O-4	Coordinate communications among federal, state, and local community efforts	8.1.4	3	10 years	2	FR/PA	AZGF FS	1,000	1,000	1,000	FY4-10 = 7,000
O-1	Inform scientific community through outreach efforts	8.2.1	3	10 years	2	FR/PA	AZGF FS	1,000	1,000	1,000	FY4-10 = 7,000
O-1	Inform professional community at meetings	8.2.2	3	10 years	2	FR/ES	AZGF FS	1,000	1,000	1,000	FY4-10 = 7,000
O-1	Inform by giving presentations at meetings	8.2.3	3	10 years	2	FR/ES	AZGF FS	1,000	1,000	1,000	FY4 -10 = 7,000
O-4	Publish research findings in professional journals	8.2.4	3	10 years	2	FR/ES	AZGF FS	1,000	1,000	1,000	FY4-10 = 7,000

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