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Single versus multiple species management: native fishes in Arizona

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Abstract

The question of single vs. multiple species management of threatened and endangered fishes is discussed using examples from Arizona, where efforts to conserve native fishes have largely taken a single species, 'real' approach. Such a strategy has been dictated by multiple factors including: (1) the interaction between climate and topography – interaction that legislates regional hydrology, (2) marked alteration of historic hydrology by dams, diversion, and groundwater mining, and (3) introduction of non-native species of fishes. However, opportunities for multiple and perhaps 'ideal' species management must be continually embraced, despite the increased complexity of the task. In either case, conservation of native fish communities is inseparable from conservation of habitats and will require sustaining the few remaining un-dammed, free-flowing rivers in the State and managing rivers or drainage basins to incorporate (1) sustainable riparian-stream habitats and security of habitats, (2) an ecosystem, watershed or river basin approach, and (3) a cooperative (i.e. interagency), long-term, and vigilant approach.

1. Introduction

Increased emphasis on conserving and managing species was initiated with passage of the Endangered Species Act in 1973. Whereas, listing and protection were inherent within the Act, Johnson and Rinne (1982) suggested that a third, and perhaps the most important objective of the Act, recovery, was the key to sustaining threatened and endangered fishes. Since 1973, almost 1100 species have been listed as threatened or endangered in the (United States U.S. Fish and Wildlife Service, 1994). Unfortunately, few species have been de-listed as a result of recovery and management activities (Williams et al., 1989). This suggests a need to evaluate the approach to recovery activities.

We examine one facet of the approach to management and conservation of threatened and endangered species, "Do we manage on a species-by-species basis or attempt to address groups of species or communities?" In other words, which approach, single or multiple species management, is most effective and feasible? We address native fishes from the southwestern United States, specifically within Arizona. In doing so, we will (1) address factors influencing which approach to follow, (2) discuss examples of single and multiple species management and their relative success or the lack of in sustaining species or communities of native fishes, and (3) suggest which approach is most likely to sustain native fishes in Arizona, and perhaps throughout the West.

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2. Factors influencing the choice

2.1. Climate, topography, and hydrology

Many aquatic habitats are disjunct in Arizona and the Southwest. Such fragmentation results, in part, from interactions of climate, topography, and hydrology (Green and Sellers, 1964; Nations and Stump, 1981; Rinne, 1995a; Rinne et al., in press). Arizona is drained primarily by the Colorado River and its tributaries (Fig. 1). Historically, most of this system, except during periods of extreme drought, was continuous from headwater cienegas and montane creeks through degrading, canyon-bound streams at intermediate elevations to generally aggrading, large low elevation rivers.

Within the wide range of topography (almost sea level to 3000 m) and stream size (from <0.1 to >5000 $m^3 s^{-1}$), aquatic habitat conditions varied greatly. Prior to damming, the mainstream rivers were turbid and swift during spring runoff and floods, clear during times of base flow, and intermittent in lower desert reaches during drought. In addition, isolated perennial springs existed across the landscape (Rinne and Minckley, 1991). Attendant to such variability in hydrology, a highly specialized fish fauna developed (Miller, 1961; Branson, 1973; Minckley, 1973; Rinne and Minckley, 1991).

Floods and droughts were a normal part of the hydrograph and influenced the distribution and abundance of native fishes. In particular, large floods apparently rejuvenated the systems and either stimulated spawning or enhanced recruitment (Minckley and Meffe, 1987; Stefferud and Rinne, 1995; Rinne and Stefferud, 1996). Natural, episodic droughts also had a major influence on native fishes when massive mortalities in lower reaches of desert rivers occurred and fish were constricted to refuge areas. However, connectivity of stream systems and refuges provided for recolonization of desiccated reaches when precipitation returned flows to the streams (Minckley, 1973; Rinne et al., in press).

In concert with floods and droughts, wildfires impacted forested watersheds containing cool or cold-water species. Uncontrolled wildfires could alter hydrological patterns and extirpate local populations of fishes (Rinne, 1996; Rinne and Neary, 1996; Propst et al., 1992), which would be reestablished by connecting with downstream reaches.

2.2. Alteration of historic hydrology

Damming and diversion of southwestern rivers during the first half of the 20th century destroyed connectivity of river systems, overwhelmingly influenced the distribution of riverine aquatic habitats, and caused localized extirpation of many native species (Rinne, 1991, 1994). Most of the natural drainage courses of the Southwest (Miller, 1961; Minckley and Deacon, 1968; Deacon and Minckley, 1974) and Arizona (Rinne, 1991, 1994) are now greatly modified, largely through damming. Commencing with the 1902 Reclamation Act, impoundment of streams and rivers has restricted naturally-flowing waters primarily to upstream, upper elevation (>760 m) landscapes (Fig. 1). Once free-flowing reaches of the lower Salt, Gila, Verde, and Colorado rivers are now relegated to modified, stabilized, or completely-dried river beds. Additionally, ground water mining has caused water tables to drop and springs to cease flowing.

In summary, the combination and cumulative effects of climate, topography, and hydrology (natural and altered) have resulted in isolated, disjunct populations of many of the native species in Arizona and the Southwest. Accordingly, conservation and management of these species in a singular fashion has occurred as a matter of expediency and necessity to sustain respective species in these remote, isolated, often refugia habitats.

2.3. Introduction of non-native fishes

Low species diversity and physical modification of aquatic habitats were compounded by extensive and intensive introduction of non-native fishes (Deacon et al., 1964; Minckley, 1973; Rinne, 1991, 1994, 1995c). Almost 100 species of fishes were introduced into Arizona during the past century; almost half are established (Rinne, 1995c). Competition for space and resources (Rinne et al., 1980) and direct predation (Schoenherr, 1981; Meffe et al., 1983; Minckley, 1983; Meffe, 1985; Blinn et al., 1993; Rinne, 1995d; Rinne and Alexander, 1995) have resulted in marked reduction in range and numbers of many native species.

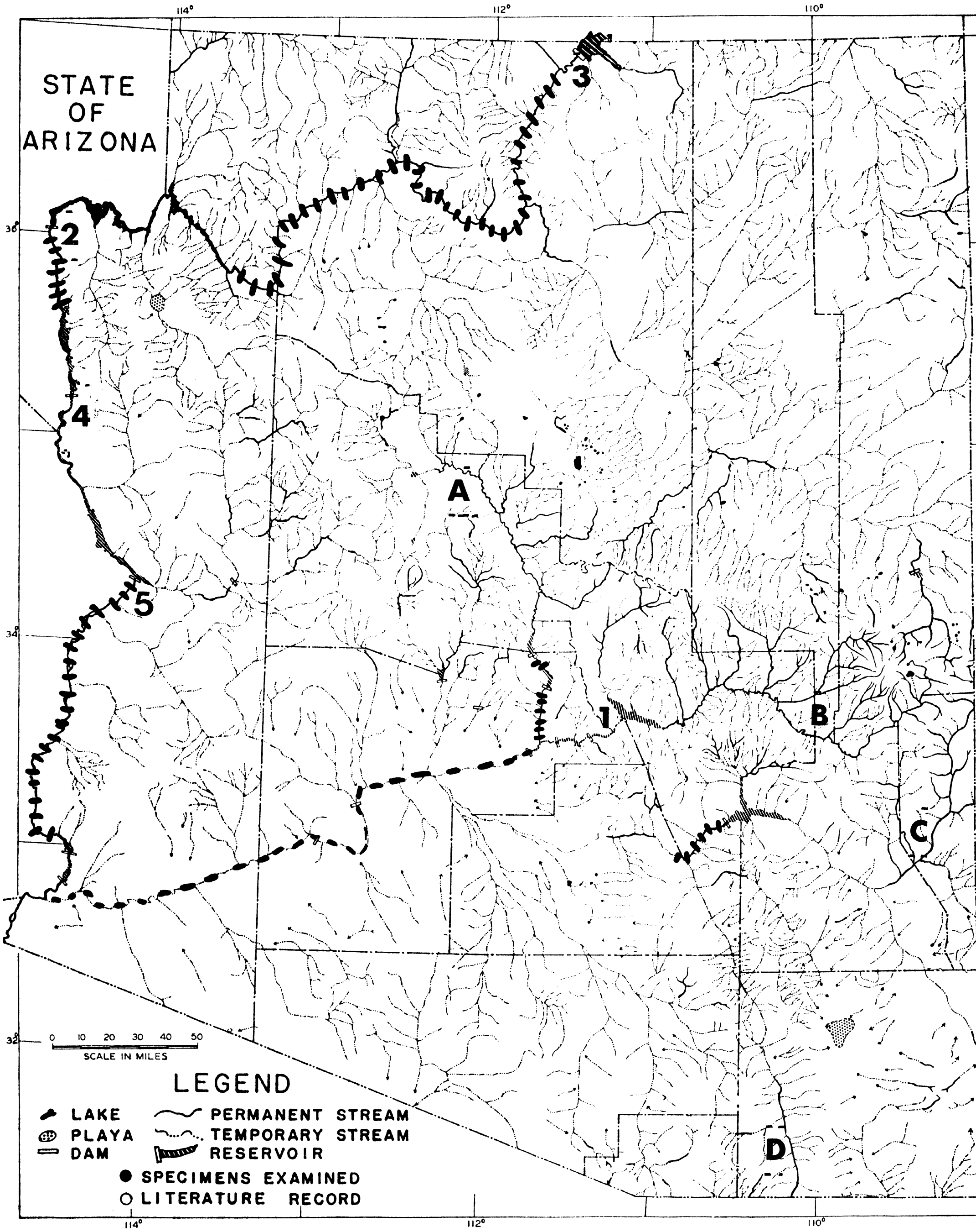

Fig. 1. Hydrological map of Arizona indicating the marked alteration of natural drainage patterns by damming. Control of the Verde and Salt rivers commenced with Roosevelt Dam in 1911 and was followed by a series of dams on these two large river systems (1). Modification of the Colorado River began in 1935 with completion of Boulder Dam (2), and was followed by lakes Powell, Mohave, and Havasu (3–5, respectively). Cross hatching on rivers indicates modified flows as a result of dams, dashed lines show intermittent and dried reaches of mainstream rivers. Only the upper Verde (A), Salt (B), Gila (C), and San Pedro (D) sustain free-flowing river habitats, with native species present, thereby providing opportunity for multiple species management of native fishes.

3. Diversity of fauna and historic vs. current distributions

The native fish fauna of Arizona evolved in a framework of highly variable conditions of water quantity and quality, and is comprised primarily of cyprinids and catostomids, with other groups (salmonids, cyprinodontids, poeciliids, and ictalurids) represented by only a few or a single species. The fauna is depauperate compared to that of drainages of the eastern United State; about three dozen native fish species, including three marine representatives, have been recorded from Arizona (Minckley, 1973). By comparison, 30–40 species may inhabit a single creek or riffle in drainages in more mesic areas (Larimore et al., 1952; Jenkins and Freeman, 1972; Evans and Noble, 1979; Fuselier and Edds, 1996).

Alterations of the hydrologic regime of most waters in Arizona by diversions, damming, and groundwater mining, plus introductions of non-native fishes, have combined to reduce the abundance and range of most native fishes. Nineteen species are listed as threatened or endangered under the Endangered Species Act, and an additional eight are considered species of special concern (U.S. Fish and Wildlife Service, 1994; Arizona Game and Fish Department, 1996).

In summary, aquatic habitats and their respective piscine inhabitants have been greatly altered over the past century. Water, the medium basic to management and sustainability of the native fish fauna of Arizona and the Southwest (Rinne, 1995b), strongly dictates conservation strategies for this un-diverse and largely-listed fauna. The few reaches of streams that still include assemblages of native fishes are un-dammed. These free-flowing reaches are essential for managing a native fish community, especially if non-native species of fishes are present (Rinne and Stefferud, 1996). Accordingly, conservation and management of native fishes in Arizona must parallel availability and security of extant riverine aquatic habitats and potential occupation of those habitats by fishes.

4. Single species management

To date, most recovery efforts for Arizona fishes have involved single species management; their success, for many reasons, has been variable. More important than the question of success, are two others: (1) can species be restored on an individual basis, even in small isolated habitats dispersed across the landscape (Minckley et al., 1991a, b)? and (2) should species be managed as single entities when they (like all species) evolved over millennia with other species?

4.1. Gila topminnow (Poeciliopsis occidentalis occidentalis) (endangered)

Prior to 1940, Gila topminnow was the most common fish in the lower Colorado River basin (Hubbs and Miller, 1941). Historically, except for mountain streams, it occupied the entire Gila River basin (Minckley, 1973). By the time it was listed as endangered in 1967 (U.S. Fish and Wildlife Service, 1994), it was reduced to naturally occurring in less than 12 isolated springs and streams in southern Arizona (Minckley et al., 1977; Meffe et al., 1983). Between 1970 and 1982, intensified survey efforts found several new populations (Johnson and Kobetich, 1970; McNatt, 1979; Rinne et al., 1980; Meffe et al., 1982). But at present, less than 12 natural populations in Arizona exist. Most, either have been lost or are in jeopardy because of the introduction of western mosquitofish (*Gambusia affinis affinis*), ground water mining, or desiccation by livestock operations (Minckley et al., 1991a).

Initial recovery efforts were made by concerned individuals prior to listing of the species (Minckley, 1969), and in 1981, cooperative, intensified efforts of several Federal and State agencies were initiated to sustain a focused, extensive recovery effort for the species (Johnson and Rinne, 1982; Minckley et al., 1991a). More than 200 localities were stocked with this diminutive livebearer, some multiple times, however, less than 10% of the sites were successful for longer than a few years (Minckley and Brooks, 1985; Minckley et al., 1991a; Weedman and Young, 1995, 1996). Simons et al. (1989) suggested that the recovery effort was successful, albeit with a low rate (Hendrickson and Brooks, 1991). However, the frequent loss of populations, some even after a decade of existence (Collins et al., 1981), questions whether such an assessment is valid, especially when viewed in terms of overall efforts expended per population established. Gila topminnow naturally occupied harsh meta-environments where rapid expansion and contraction of available habitats was common. The low rate of long-term reintroduction success may reflect the history of the species, and probably should not be used as a criticism of the recovery effort.

Although Gila topminnow occurred along with up to a dozen other native species in the margins of large river systems (Hubbs and Miller, 1941; Minckley and Deacon, 1968), these habitats are either no longer available or are occupied by introduced predatory species. By and large, the physiography, climate, and hydrology of Arizona, combined with loss of habitat and introduction of non-native species, have dictated the rules for recovery of this rare species. Recovery of Gila topminnow in its native habitat is no longer possible, but continued survival of isolated populations using long-term reintroduction programs and vigilant conservation of habitats, can prevent extinction.

4.2. Gila trout (Oncorhynchus gilae) (endangered) and Apache trout (O. apache) (threatened)

The two trouts native to Arizona also have been managed as single species. As with topminnow, this approach was dictated largely by a distribution controlled by both natural and man-induced factors (Rinne et al., in press). Although once occupying a much greater range, both species now occur in disjunct headwater tributaries, where occasionally speckled dace (*Rhinichthys osculus*), desert sucker (*Catostomus clarki*, and sonora sucker (*C. insignis*) are present. Although extensive efforts have been expended to recover these two fishes (Rinne and Turner, 1991; Propst et al., 1992; Turner, 1996), both have remained in the same listing status for over two decades, illustrating the difficulty of recovery.

The original five native populations of Gila trout had been expanded into five additional streams and the species was proposed for down-listing when a wildfire in 1989 destroyed the largest population (and type locality). Since 1989, wildfires have destroyed two more populations and threatened several others (Turner, 1996), and a few populations have become hybridized with non-native trouts. Gila trout is now extant in eleven streams and may soon be re-proposed for down-listing.

Through a long-term, cooperative re-introduction effort, *Apache trout* is near the designated number of 30 streams required for de-listing. However, recent studies revealed that genetic contamination by rainbow trout (*O. mykiss*) (Carmichael et al., 1993; Carmichael et al., 1995), and invasion by brown trout (*Salmo trutta*) into many Apache trout streams have slowed progress toward that goal.

Unlike Gila topminnow, habitats for the two trouts are available, or can be made available by removing non-native trouts. Recovery and down- or de-listing is a reasonable presumption for management, and can be achieved by cooperative, long-term, and vigilant management. Management must accommodate loss of populations by unpredictable, catastrophic events such as wildfire (Rinne and Medina, 1995; Turner, 1996). As with Gila topminnow, recovery efforts for the two trouts have achieved success by sustaining species where they may previously have been extirpated. However, ultimate success of self-sustaining populations of native trout across a sizeable portion of landscape and accompanied by native *cypriniform* species remains an unrealized goal in Arizona.

5. River basin, multiple species efforts

With one exception, there have been no government-sponsored efforts, *sensu stricto*, to manage a native fish community within a river basin or drainage in Arizona. Recovery teams (i.e. Desert Fishes, Colorado Fishes) represent organized attempts to address groups of species. The former was organized to address disjunct populations of native, low desert species such as Gila topminnow, desert pupfish (*Cyprinodon macularius*), loach minnow (*Rhinichthys cobitis*), and spikedace (*Meda fulgida*), as opposed to conserving a native fish community in one drainage basin. In other words, it was an 'amalgamation of species' effort, wherein each species was the focus of the recovery effort.

The Colorado Fishes Recovery team was formed in 1975 as the 'Colorado Squawfish Recovery Team' before changing names and emphases a year later (Wydoski and Hamill, 1991). This cooperative effort has been critical to sustaining Colorado squawfish (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), and bonytail (*Gila elegans*) from the mid 1970s till date. Wydoski and Hamill (1991) suggested that the recovery effort for the mainstream Colorado River fishes is probably the most complex conservation effort for native fishes in the West over the past two decades. Yet, it addresses only the listed native species of the upper Colorado River. Since two disjunct populations of razorback sucker and bonytail exist in the upper and lower Colorado Basin with no extant squawfish population in the lower basin, recovery activities for these species paralleled their current distributions (Minckley et al., 1991b; Tyus, 1991; Wydoski and Hamill, 1991). Recovery efforts for razorback sucker, bonytail, and Colorado squawfish in Arizona have consisted primarily of intensive hatchery rearing programs and re-introduction into historic range (Johnson, 1985; Rinne et al., 1986; Johnson and Jensen, 1991).

The San Bernardino and Leslie Canyon National wildlife refuges in southeastern Arizona were established to conserve four listed fishes (beautiful shiner (*Cyprinella formosa*), Yaqui chub (*Gila purpurea*), Yaqui catfish (*Ictalurus pricei*), Yaqui topminnow (*P. o. sonoriensis*)), and four additional non-listed indigenous fishes in the Rio Yaqui (U.S. Fish and Wildlife Service, 1995). Aquatic habitats and fish populations have been restored and stabilized on the refuge. However, achievement of the larger goal of conserving Rio Yaqui fishes is problematic because little of the Rio Yaqui watershed is within the refuge in the United States and groundwater mining in Mexico is ongoing.

Dam building in the Southwest has resulted in modification of stream hydrographs (stabilized flows, loss of perennial surface flow), with the result that few large river systems retain their native fish fauna (Fig. 1). Even in reaches with a predominantly native fauna, such as the upper Verde River, the diversity of native species has been reduced by up to one-half, and non-native species are present (Stefferud and Rinne, 1995; Rinne and Stefferud, 1996). Arizona Game and Fish Department, the primary manager of native fishes in the State, recognizes the need for multi-species management, and is considering designation of river basins or drainages for native fish management (Rinne and Janish, 1995). However, a river or drainage basin, multiple-species approach to recovery of native fishes in Arizona has yet to be realized.

6. Discussion and conclusions

Conservation of native fishes in Arizona during the past 25 years has primarily involved a single species management approach. These efforts have been critical to survival of the native fish fauna not only of Arizona but throughout the West (Deacon and Minckley, 1991). Initial efforts commenced in the mid 1960s because of the initiative of concerned and dedicated professionals, not management agencies. With passage of the 1973 Endangered Species Act, conservation and recovery efforts were intensified and institutionalized. Unfortunately, by that time, most of the mainstream river channels had been altered by damming (Minckley, 1973; Rinne, 1991, 1994; Rinne and Minckley, 1991), and almost a hundred non-native fishes had been introduced into the waters of Arizona (Rinne, 1995c). Populations of large river species and formerly-abundant smaller species, such as Gila topminnow and desert pupfish, were maintained in isolated refuge habitats, in some cases those created by damming (Minckley, 1973). The combination of listing of individual species and their existence in disjunct, un-connected aquatic habitats, resulted in the single species (often ad hoc) approach for their recovery. These efforts were critical for the very survival of some species; nevertheless, some taxa became extinct (Miller et al., 1989). In retrospect, distribution, necessity, interest, and opportunity defined recovery efforts which have largely followed a species-by-species approach. Without these efforts, additional populations, and perhaps species may have been lost.

We suggest that single species management not only has been beneficial to the native fishes of Arizona, but will continue to be so. However, we suggest that despite probable increased complexity of the task, future conservation efforts should look for opportunities to manage communities of native fishes. In doing so, riparian areas and streams should be managed to sustain the integrity of aquatic habitats. Management of native fishes must be approached on a river basin, watershed, or ecosystem basis. Suitable habitats are obviously prerequisite to survival of the native fish communities–habitats and species or communities are inseparable. That is, without habitat, conservation of species (single or multiple approach) becomes a moot point. The more viable and secure these habitats are for native fish recovery, the higher the probability that species can be sustained. Preserves (Moyle and Sato, 1991) may be crucial as refuge areas from which dispersal into adjacent portions of the range may occur. Smaller, less diverse, more isolated communities are both easier to preserve and will likely contain a single species of native fish. The larger the area needed for a preserve or special conservation area, the lower the probability it will be established because of political, socioeconomic, physical and biological factors that dramatically increase the complexity of the task.

Water in the arid West is a highly valued economic and political resource. Relegation of large quantities of it for native species will always have to withstand the force of its value for economic development. Political and economic practice involving ownership and management in the Southwest will probably continue to render single species management the most workable option for sustaining native fishes. In essence, multiple species management in larger systems is 'the ideal;' and a single species, small systems approach is 'the real.' Whether a real or ideal approach is adopted, there is no substitute for the most fundamental requirement for conservation of native fishes: vigilance. That is, we must not adopt the mind set that we have fully secured a species and walk away. In contrast, monitoring, management and adaptive management of species will be a continuing process.

If a North American desert fish species is not currently listed as endangered, it will not be long before it reaches that point (Pister, 1990). Presently, single species management provides the best means of delaying, and perhaps precluding this dire prediction. By comparison, a multiple species management approach has inherent temporal and spatial problems that render this approach unfeasible because of its insensitivity to preclude potential listing or, ultimately, loss of a single species within a community.

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