Forest and Fishes: Effects of Flows and Foreigners on Southwestern Native Fishes

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Abstract

Habitat alteration in physical (stream channel characteristics), chemical (nutrients, temperature), or biological (introduced species) form can have dramatic effects on native southwestern USA fishes. Southwestern flow regimes, their alterations, and introduction of alien species have had a dramatic, negative impact on native southwestern fishes. The cumulative and interactive impacts may result in various responses by native fish assemblages. Managers should not expect the same result when one or more factors are in operation that may affect an aquatic ecosystem in the southwestern USA. Ultimately, consideration of temporal-spatial influences, natural factors, interactions of factors, and sound monitoring or research activities will determine which factors most influence southwestern fish assemblages in respective situations.

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Introduction

Native fishes of the southwestern United States (Minckley 1973, Rinne 2003a) have declined dramatically in range and numbers in the last century (Rinne 1994, Mueller and Marsh 2002). Multiple, cumulative factors such as dams, diversions, introductions of non-indigenous species, and varying land uses have been implicated as factors causing their demise. The question can be asked, "What are the relative impacts of hydrology, introduced fishes and other organisms, and land uses such as timber harvest and livestock grazing on native fishes occupying southwestern riparian ecosystems?" The primary objective of this paper is to briefly introduce and delineate factors that have impacted historically and will potentially continue to negatively impact the native, largely threatened and endangered fish fauna of the American Southwest (Rinne and Minckley 1991, Rinne 2003a, 2003b). Each factor that individually, and ultimately, cumulatively impacts native fish assemblages will be introduced and evidence presented documenting the degree of impact on native fish assemblages in the southwestern U. S.

Cumulative, impacting factors

Hydrological and physical habitat alteration and introduction of nonnative fishes (Miller 1961, Rinne 1994, 2003b) are the two factors most commonly associated with the marked decline in range and numbers of most native fish species in the Southwest. As a result, the majority of the southwestern fish species have been officially listed as threatened or endangered (Rinne 2003a). Recently, land uses such as domestic livestock, grazing of forest landscapes and their riparian corridors (Rinne 2000) have been implicated as a negative impact on native fish assemblages. Studies of changes in fish assemblages on the upper Verde River, Arizona over the past decade (Figure 2) and literature on the topic over the past few decades will be used to demonstrate and document the relative impact of flows or stream hydrographs on fishes and the removal of livestock grazing and associated habitat changes.

Natural and human-altered hydrology

Where natural flow regimes persist, rivers change dramatically and abruptly temporally and spatially from flood to drought across the arid, more xeric regions of the interior West (Hubbs and Miller 1948). Similarly, the natural hydrology of southwestern desert rivers and streams is highly variable and episodic (Minckley and Meffe 1987, Rinne and Stefferud 1997) (Figure 1). In absence of any human-imposed factors, native fishes appear to be adapted to survive and sustain themselves under these conditions. Natural flow regimes have generally been considered optimum for sustaining native fishes (Poff et al. 1997).

The Southwest has sustained extensive and recently intensive human immigration. Accompanying this influx of Europeans was the ever-increasing demand for water that has resulted in dramatic alteration of the historic hydrology of the Southwest (Rinne 2002). The 1902 Bureau of Reclamation Act instituted these dramatic changes. The first Reclamation dam, Roosevelt, was completed on the Salt River in 1911 and the hydrology of the Salt River downstream was irreversibly changed. This dam and others retained peak flows that originated from upper elevation, forested areas in the Central Arizona Mountains.

In 1932, completion of Hoover Dam on the Colorado River and additional dams such as Glen Canyon Dam impounding Lake Powell imposed a dramatic and lasting change in the hydrologic regime of the Colorado River mainstem. Periodic natural and often quite dramatic flood flows (Mueller and Marsh 2002) were forever lost to the system. Rinne (1994) calculated that over 75% of the large mainstream river habitats in Arizona were either lost or altered between 1911 and 1970. Diversions such as Imperial Dam on the lower Colorado River and groundwater pumping imposed additional alterations to natural flow regimes. Coolidge Dam and the Ashurst-Hayden Diversion on the Gila River, both completed in 1928, effectively dried the Gila River to its confluence with the Salt River. Other major tributaries to the Gila from the south, the San Pedro, San Simon and Santa Cruz Rivers have been dried primarily as a result of groundwater pumping.

Fish response to altered hydrology

The Gila topminnow, *Poecilliopsis occidentalis*, was once (1940s) the commonest native species in the lower Colorado River (Minckley 1973, Hubbs and Miller 1941). It now persists naturally in fewer than a dozen, isolated diminutive spring heads or spring runs in southern Arizona (Meffe et al. 1983). The large Colorado pike minnow (*Ptyocheilus lucius*), historically referred to as the "Colorado salmon" by locals because of large spawning runs, is now extirpated in the lower Colorado River and might be only locally present as a result of restoration-repatriation programs. Similarly,

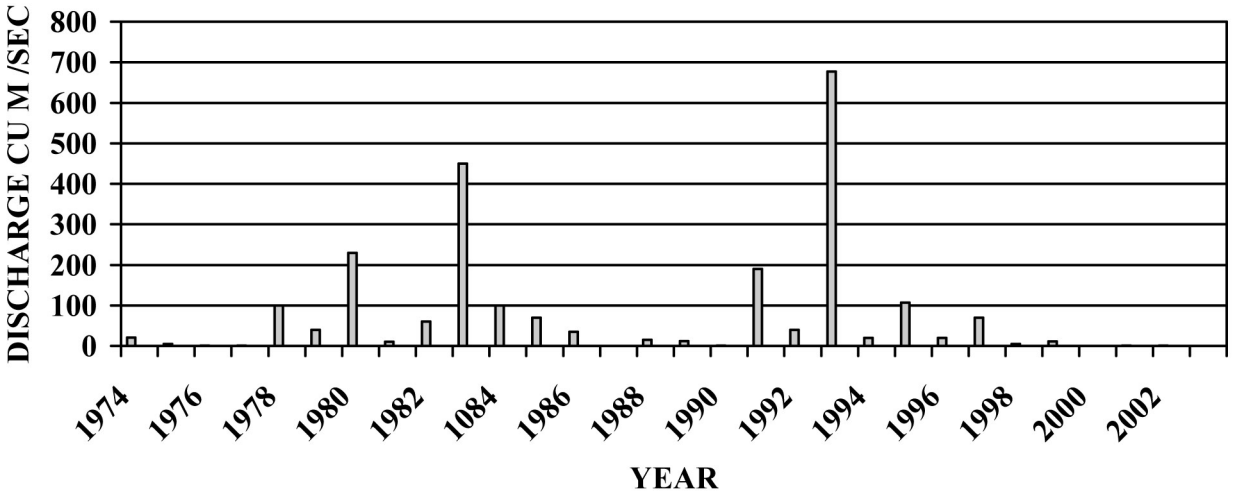

Figure 1. Instantaneous peak discharges in the Verde River, 1974-2002.

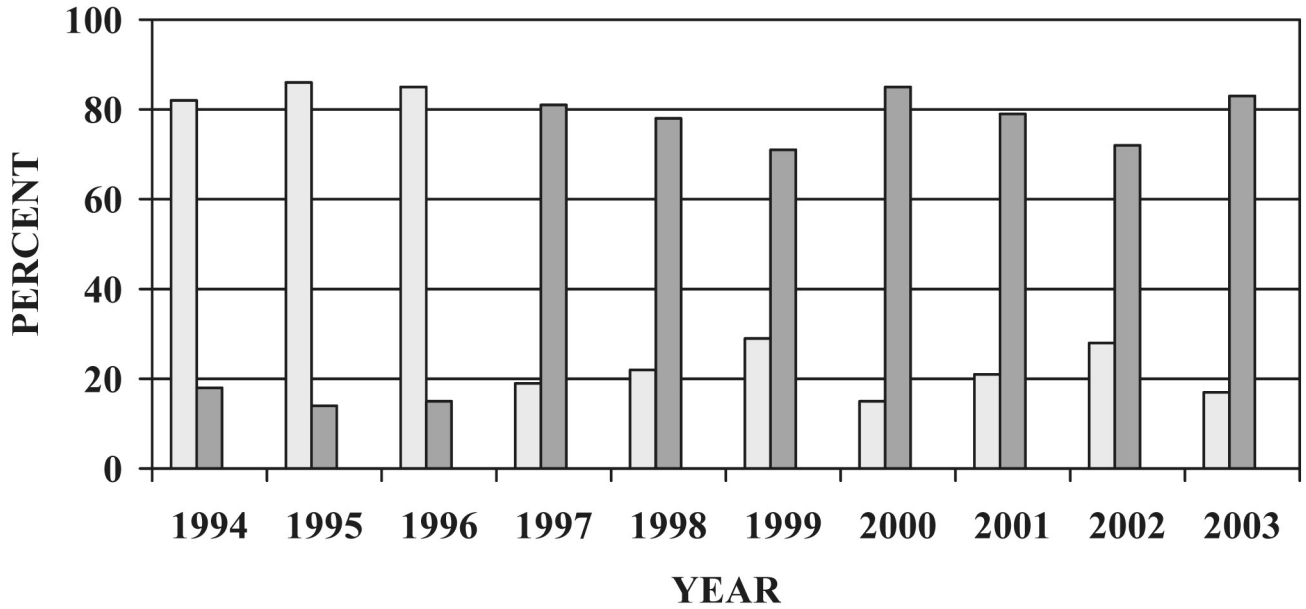

Figure 2. Change in relative proportions of natives (light bars) and nonnative (dark bars) in samples in the upper Verde River, 1994-2003, a period of low, drought flows (see Figure 1).

the razorback sucker (*Xyrauchen texanus)* was once so abundant in the river that it was pitch forked from canal systems in the Phoenix area and used as fertilizer. The bonytail chub (*Gila elegans)* along with razorback sucker occurs only in Colorado River reservoirs either as scenescent populations that correlate well with dam closures or as repatriated individuals. All these species are now officially listed as endangered. Others, such as spikedace (*Meda Fulgida)* and loach minnow (*Rhinichthys cobitis*) are threatened species. In the upper Verde River peak flows (Figure 1) have been demonstrated, in the short term, to be positively related to native fish populations (Figure 2; Rinne 2002).

Foreigners

Changes in fish assemblages

The native fish fauna of the Southwest is low in diversity and high in uniqueness and specialization (Miller 1961, Minckley 1973, Rinne and Minckley 1991). Fewer than 50 species of fishes naturally occurred in the waters of the Southwest and only two dozen were historic inhabitants in the waters of Arizona (Minckley 1973, Rinne and Minckley 1991). By comparison, over 100 species of fishes have been introduced into Arizona alone (Rinne 1994) and half have become established (Rinne 2003a) as self-sustaining populations. Most of the introductions were for sport fishing, which naturally

followed the massive increase in reservoir surface water acres and habitat (Rinne 2003a). Rinne and Janisch (1995) reported the extensive coldwater introductions, and Rinne et al. (1998) the warmwater introductions in Arizona streams and lakes.

Nonnative, or non-indigenous fish introductions into foreign waters have generally been shown to have a negative, often dramatic impact (Courtenay and Stauffer 1984). In the Southwest, increased presence and abundance of these species is negatively correlated with native species. In the upper Verde River, in 1994, nonnative fishes comprised less than 10% of fishes captured (Figure 2). Only a decade later, in 2003, 90% of the fishes captured were nonnative species. In the Gila River, Colorado (Mueller and Marsh 2002) and Rio Grande rivers similar patterns of increase in non-native fishes is paralleled by an often, dramatic decrease in native species. Native trout species have declined dramatically with the introduction on nonnative trout. Rinne and Minckley (1985) documented the inverse distributions of the native Apache trout (*Oncorhynchus apache*) and introduced rainbow (*O. mykiss*) and brown (*Salmo trutta*) trout. Gila topminnow populations decrease in presence of the introduced mosquitofish (*Gambusia affinis)* (Meffe et al. 1983). Replacement can come by way of competition, hybridization or direct predation (Minckley 1983, Rinne 2003a). In summary, native southwestern fishes and non-native, predatory or competitory fishes generally cannot co-exist (Rinne et al. in press) in the same reaches of stream. Hydrological and geomorphological influences and interactions can alter this statement (Rinne 2002).

Other foreign species

In addition, other foreign aquatic species also have been introduced into the waters of the West and Southwest. Two principal species are a vertebrate, bullfrog (*Rana catesbiena*) and an invertebrate, crayfish (*Procambarus sp)*. Data, albeit mostly observational, indicate the dramatic impact of these two foreign aquatic species. White (1999) documented the impact of crayfish on the native Colorado spinedace (*Lepidomeda vittata)* through predation on eggs of this native, threatened fish species. However, in general data are lacking on the potential or real impact of these two species.

Domestic Livestock

Grazing of domestic livestock on upper elevation forested landscapes and riparian areas is generally thought to have an effect on fish habitats and fish species. However, most of the information pertain to salmonid species (Rinne 2000) and would apply only to the three native species of southwestern trouts (Gila (*Oncorhynchus gilae*), Apache (*O. apache*), and Rio Grande (*O. clarki virginalis*) cutthroat). Data on the upper Verde River, a warm water aquatic ecosystem in Arizona, do not corroborate the contention that livestock have a significant or even a demonstrable effect on native fishes (Figure 2). Removal of livestock on the upper Verde River in 1997 has resulted in markedly improved riparian conditions in form of increased vegetation and stream bank and channel alterations (Rinne and Miller in press). However, most native species, including the threatened spikedace, have declined in abundance and distribution in the upper Verde River. Most of the information addressing livestock grazing effects on fishes is 1) largely opinionated and conjecture, 2) based on qualitative, short term, non-replicated data, 3) primarily for salmonids, and 4) not based on sound science. Further, complicating and confounding factors make it difficult to produce definitive answers. The negative effect of grazing on native, cypriniform species for such variables as stream banks (Rinne and Neary 1997) and sediment levels (Rinne 2001) are not demonstrable. At present, there is no evidence, based on sound science, that grazing by domestic livestock has an obvious and well-documented negative effect on native fish species.

Cumulative, inter-active factors

The above factors that potentially negatively impact native southwestern fishes obviously do not act independently. That is, several factors operating simultaneously may produce a different result on fish assemblages in southwestern rivers. For example, flood flows on the upper Verde River in 1993 immediately favored the native fishes (Rinne and Stefferud 1997). Subsequently, low or drought flows (Figure 1) were paralleled by an increase in non-native species. Removal of livestock grazing on the river corridor was then superimposed. Although this management action improved riparian vegetation and is generally considered a favorable restorative action for "fish habitat," it has not resulted in an increase in native fishes (Figure 2). Indeed, the opposite appears to be true. The increase in cover and change in water depths have favored introduced, "cover seeking," more lentic species such as smallmouth bass (*Micropterus dolomieus*) and green

sunfish (*Lepomis cyanellus*) (Pflieger 1975), yellow bullhead (*Ameiurus natalis*), mosquito fish (*Gambusia affinis*) and red shiner (*Cyprinella lutrensis*). The question becomes "Which of the two factors, flows (natural and altered) or foreigners in the form of nonnative fishes and domestic livestock has the greatest influence on native fishes?" Further, "Do livestock and non-native fishes have a greater influence on fish assemblages than does the hydrograph?"

In the upper Gila River, New Mexico, natural, historic flow regimes are extant in the Gila-Cliff Valley (Rinne 2002). Grazing occurs in most reaches of the river, however, livestock have been removed from the Gila Bird Area for a time period similar to that of the upper Verde River. The same native fish assemblage that occurs in the upper Verde consistently has comprised greater than 90% of the total numbers of fishes captured in these reaches over the past six years (Rinne and Miller in press). Native fishes also are predominant in contiguous grazed reaches. These data suggest that a natural, more variable hydrograph characterized by frequent flood events may override or more strongly influence fish assemblages than does domestic livestock grazing (Rinne 2002).

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