FISHES OF THE RIO FUERTE DRAINAGE

Peces de la Cuenca del Río Fuerte

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ABSTRACT. The Rio Fuerte drains 33,835 km^2.of the Sierra Madre Occidental of the Mexican states of Chihuahua, Sinaloa, Durango, and Sonora. Its tributaries pass through of Barranca del Cobre (Copper Canyon) as they drop from headwaters as high as 2,808 m above sea level to the Mar de Cortés (Gulf of California). Its headwaters interdigitate closely with east-flowing tributaries of the Rio Conchos, an important tributary of the Rio Bravo (Grande), and interior drainages of Chihuahua and Durango, such as the Rio Nazas. The Fuerte shares its fish fauna with these neighboring drainages, and has no endemics. Northernmost tributaries are relatively arid, but southern tributaries drain sub-tropical areas with much higher rainfall. Dams and diversions now block movements of many marine fish species that used to move far upstream, and more are in construction or planned. Large river fish habitats at lower elevations have been converted almost entirely into canals and the natural mainstream channel now carries only minimal or highly modified discharges, often contaminated by agricultural runoff. At higher elevations, fish habitats have been severely impacted by logging and grazing. Logging development continues, recently expanding from traditional conifers to lower-elevation oaks. Exotic fishes have had, or

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surely will have, broad impacts on the native fauna through predation, competition and hybridization. Tilapias from Africa are widely established now, as are several centrarchids that will undoubtedly impact on the native cichlid (*Cichlasoma beani*), cyprinids, catostomids, poeciliids, and others. While not well studied taxonomically, the basin's native catfish, closely related to *Ictalurus pricei*, is now broadly hybridizing with introduced channel catfish (*I. punctatus*). At higher elevations, the beautiful native Mexican golden trout is very likely to hybridize with rainbow trout being widely introduced for fish culture.

Key words: Fishes, Rio Fuerte.

RESUMEN. El Río Fuerte drena 33,835 km^2 de la Sierra Madre Occidental en los estados de Chihuahua, Sinaloa, Durango y Sonora. Sus tributarios fluyen a través de la Barranca del Cobre (Copper Canyon) y caen desde las cabeceras de 2,808 m sobre el nivel del mar hacia el Mar de Cortés (Gulf of California). Sus cabeceras interdigitan cercanamente con los tributarios de flujo este del Río Conchos, un importante tributario del Río Bravo (Grande) y drenajes interiores de Chihuahua y Durango como el Río Nazas. El Fuerte comparte su fauna de peces con estos drenajes vecinos y no presenta endémicos. Los tributarios norteños son relativamente áridos, pero los tributarios sureños drenan áreas subtropicales con mayor régimen de lluvias. Las presas y canales, que bloquean ahora el movimiento de muchas especies de peces marinos que lo usaban para remontar el río, siguen en construcción y planeación. Los hábitats de peces de ríos grandes en bajas elevaciones han sido convertidos en canales y el canal principal natural ahora mantiene descargas mínimas o altamente modificadas, frecuentemente contaminadas por desechos de la agricultura. A grandes elevaciones, los hábitat de los peces han sido impactados severamente por la tala y el pastoreo. Los desarrollo madereros continúan y recientemente se han expandido de las tradicionales coníferas a los encinos de mas baja elevación. Los peces exóticos tienen o seguramente tendrán grandes impactos sobre los peces nativos a través de la depredación, competencia e hibridación. Las tilapias de Africa están ahora ampliamente establecidas al igual que varios centrárquidos, que indudablemente impactan sobre el cíclido nativo (*Cichlasona beani*), ciprínidos, catostómidos, pecílidos y otros. Aunque no está bien estudiado taxonomicamente, el bagre nativo de la cuenca, cercanamente relacionado a *Ictalurus pricei*, está ahora hibridizándose ampliamente con el bagre de canal introducido. A grandes elevaciones, la hermosa trucha dorada Mexicana nativa, es muy posible que hibridice con la trucha arcoiris, que ha sido ampliamente introducida como pez de cultivo.

Palabras clave: Peces, Río Fuerte.

INTRODUCTION

THE RIO FUERTE is a study in diversity from nearly all perspectives. It originates as small streams in high elevations (2800 m) of the Sierra Madre Occidental in northwestern México, in montane coniferous forests and meadows flanking the continental divide in the states of Chihuahua and Durango. These tributaries join to form large rivers which fall rapidly along boulder-strewn beds through Madrean Evergreen pine and oak woodlands into Sinaloan Thornscrub and Sinaloan Deciduous Forests (Brown 1982). All pass through extremely rugged, nearly uninhabited and highly inaccessible canyonlands, including North America's largest canyon, the Barranca del Cobre. Riparian communities include the unique Sinaloan Riparian Evergreen Forest and Woodland. On its way through Sinaloa it passes across a rich alluvial coastal plain of economically very important, intensively developed and well-populated agricultural lands, often referred to as the "breadbasket of México", before entering its estuary and the Gulf of California (Mar de Cortéz).

Not surprisingly the fish fauna is also diverse, reflecting this ecological diversity, as well as biogeographic history. The area lies in a mixing zone of neotropical and nearctic faunas, so has representatives of both. Furthermore, parts of the basin appear to have had prehistoric hydrographic connections with drainages of the eastern flanks of the continental divide, which, when captured by headwater erosion, brought fishes from the Río Grandean (Río Bravo del Norte) fauna into this tributary of the Pacific (Hendrickson et al. 1980; Minckley et al. 1986; Smith and Miller 1986). Finally, the Río Fuerte's substantial discharge, broad coastal plain and estuary provided easy access to marine fishes capable of utilizing freshwaters, so it has a diverse secondary freshwater fauna. Recently, introductions of exotics have increased diversity (perhaps only temporarily), and impacts of these on the native fauna are starting to be seen.

The tendency toward diversity also applies to the published literature on the fishes of this basin. While Río Fuerte forms of *Poeciliopsis* (see species accounts below) likely have had more published about them than have any other Mexican freshwater fishes, the majority of the fauna remains very poorly known. Reflecting a general paucity of collections data throughout the region, most recent studies which include Río Fuerte fishes in reviews of biogeography and species relationships or distributions (Burr 1976; Hendrickson et al. 1980; Hendrickson 1983, 1987; Miller 1986; Minckley et al. 1986; Siebert and Minckley 1986) provide no more resolution for distributions than presence or absence in the group of drainages referred to as "Sinaloan Coastal Rivers", or similar groupings which include many rivers far south of the Río Fuerte. Due mostly to geographic isolation and inaccessibility, the relatively few ichthyological collections that have been made have been from more accessible, peripheral regions (Figure 1), and were made primarily for taxonomic and biogeographic studies (Hubbs and Miller 1954; Needham and Gard 1959; Miller 1960; Rosen and Bailey 1963; Needham and Gard 1964; Moore et al. 1970). Ecological observations have typically been ancillary to those objectives.

We attempt here to provide accounts of what is currently known about distribution and abundance of the fishes of the basin, their evolutionary histories and ecology, and current conservation status. To do so we rely on our own fieldwork, literature, and data provided by others, or obtained from fish collection databases (but we have not verified all data from collections by personal inspection of specimens). It is not our intent to give comprehensive accounts for all species, but rather to provide brief abstracts for selected species which we deem to be interesting or informative with regards to evolutionary history, ecology, conservation status or general scientific or economic interest. As previous reviews of the regional fish fauna have consistently treated the fauna of all rivers between the Río Yaqui and the Río Grande de Santiago (Lerma) in a single category, despite interbasin faunal differences,we provide here the first published checklist of the ichthyofauna of this single basin (Table 1).

We hope that our compilation will provide baseline data useful for future studies, conservation actions, and assessment of future alterations. Finally, by attempting to cite most of the relevant publications of which we are aware, or review papers, we hope also to provide a springboard into the literature for readers interested in further studies of this interesting and endangered fauna.

WATERSHED OF THE RIO FUERTE

Fourteen major sub-basins of the Río Fuerte are indicated in Figure 1. Headwaters originating at elevations as high as 2,808 m above sea level in the Sierra Madre Occidental in Chihuahua and Durango include the Rivers Verde, Turuachi, Los Loera, San Miguel, Urique and Oteros (=Chinipas). Some of these interdigitate closely with eastward-draining Río Conchos and Río Nazas tributaries, as well as westward draining streams of the Rivers Sinaloa and Culiacán, and have probably historically exchanged tributaries with those basins via headwater captures. Principal tributaries of lower elevations include the Rivers Oteros (=Chinipas), Urique, San Miguel, Batopilas and Verde in Chihuahua, the Choix and San Miguel in Sinaloa, and the Alamos/Cuchujaqui system in Sonora. The total area drained is 3,383,585 ha., and average annual discharge is 5,102 x 10^6 m^3 (INEGI 1995). Two large dams (Presa Miguel Hidalgo and Presa Luis Donaldo Colosio) now impound the mainstream in northernmost Sinaloa. Below Presa Miguel Hidalgo, discharge is largely diverted into extensive networks of irrigation canals which provide water to agricultural production on the coastal plain.

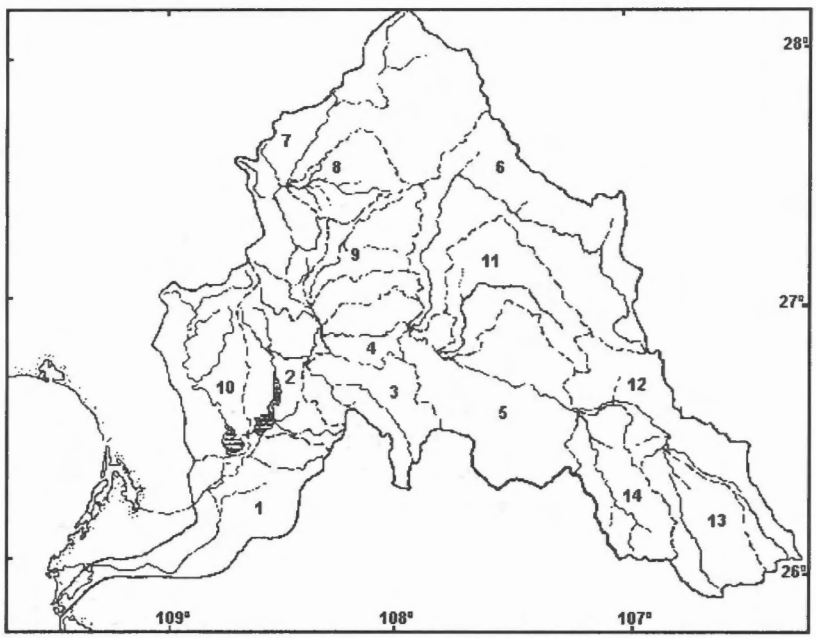

Fig. 1. Map of the Rio Fuerte basin illustrating major sub-basins 1) Rio Fuerte-San Miguel; 2) Rio Fuerte-Presa Miguel Hidalgo; 3) Rio Choix; 4) Río Reforma; 5) Rio San Miguel; 6) Rio Urique; 7) Rio Oteros (Chinipas); 8) Rio Tepochique; 9) Rio Septentrión; 10) Arroyo Alamos; 11) Rio Batopilas; 12) Rio Verde; 13) Rio Turuachi; 14) Rio Los Loera.

The Río Cuchujaqui and Arroyo Alamos flow from the Sierra San Ignacio and Sierra de Alamos to join near Alamos and form the only significant (118×10^6 m^3 annual discharge) (INEGI 1995) Sonoran tributary of the Río Fuerte. Its discharge is now wholly diverted from the Fuerte system, passing through canals and agricultural applications to the Sea of Cortéz through Laguna de Agiabampo, Sinaloa, north of the mouth of the Río Fuerte.

Adjacent and nearby major independent drainages are the Ríos Mayo and Yaqui to the North, Río Conchos, a principal tributary of the Río Grande (Río Bravo del Norte) to the East, along with its former tributary, the now endorheic Río Nazas, and the Ríos Sinaloa, Mocorito and Culiacán, to the west and southwest. Reviews of fish faunas of these rivers are available elsewhere (Hendrickson et al. 1980; Miller 1986; Minckley et al. 1986; Smith and Miller 1986).

AQUATIC HABITATS

Habitats of the basin include estuaries, controlled and uncontrolled large rivers, reservoirs, canals, and a diversity of small and large arroyos with intermittent and perennial flows. Some marshlands occur at both extremes of the drainage, in alpine meadows and the estuary. These aquatic systems pass through surrounding terrestrial biomes as varied as mountain meadows, desert canyons, and rich, irrigated coastal plains (see other chapters; also Ramamoorty 1992). Many streams and rivers flow turbulently through deep canyons, including the famous Barranca del Cobre of Chihuahua. Strong, seasonal flashflooding is common.

Even though much of the region is remote, and sparsely populated, truly pristine aquatic habitats are no longer found. In headwater and mid-elevation basins, logging and grazing have had diffuse impacts on factors such as erosion, discharge, sedimentation, general water quality, and temperatures. Major expansion of the logging industry in the basin has been recently proposed (Lowerre and English 1990). Introductions of exotic fishes, predominantly to reservoirs from which at least some have spread far upstream and downstream, have had broad impacts on the native fauna through predation, competition and hybridization. At lower elevations, natural big-river habitats disappeared from the coastal plain of the Río Fuerte over a decade ago as a result of damming and agricultural diversions which altered hydrographs, sediment and nutrient relationships, temperatures and fish movements. For much of the year, the majority of the river's discharge is routed into canals while very little remains in the natural channel. Additional dams are planned (including one on the Río Choix), and the PLHINO project proposes to connect the Ríos Mayo and Fuerte in the foothills region. In lower reaches, evidence of impacts of agricultural chemicals has become common.

ACCOUNTS OF SELECTED FISHES OF THE RÍO FUERTE BASIN:

Family Clupeidae

Dorosoma smithi Hubbs and Miller
Sardinita del Pacífico, Pacific gizzard shad

This is the only wholly freshwater shad native to Pacific drainages (Hubbs and Miller 1941; Whitehead 1985), ranging from Nayarit to the lower Río Yaqui (Branson et al. 1960; Alvarez del Villar

1970; Hendrickson et al. 1980). Since it is known from the mouth of the Rio Yaqui and its large upstream reservoirs, it is likely that its distribution in the Río Fuerte is similar. Though thorough analyses of geographic variation have not been done, Rio Yaqui populations are known to differ slightly from others (Branson et al. 1960; Alvarez del Villar 1970) in having a smaller head and eye, and shorter interorbital and dorsal fin base measurements (Minckley et al. 1979).

This species, a plankton filter feeder, often forms large schools in lentic habitats and may be an important food of other species (Hendrickson et al. 1980). Since threadfin shad, *Dorosoma petenense*, has been widely introduced to reservoirs of the western United States, and recently was discovered in the nearby lower Río Yaqui in Sonora (Varela-Romero 1988), it can be expected to appear also in the Rio Fuerte, where it will almost certainly interact in some way with this native shad, likely to its detriment.

Lile stolifera (Jordan and Gilbert)
Sardinita listada

This fish ranges from Perú to the Gulf of California, where it extends as far north as the mouth of the Río Yaqui, often penetrating far into freshwater (Castro-Aguirre 1978; Hendrickson et al. 1980). It is usually found in schools or individually in lentic and lotic habitats of low current velocity over mud to sand bottoms in salinities of 0 to 35 ppt. It appears to feed, as do many of its congeners, either by filtration of zooplankton or by predation (Castro-Aguirre and Vivero 1990).

Little is known of this species, but Castro-Aguirre (1978) mentions that it should definitely be considered euryhaline since both adults and juveniles are known from freshwater sites far inland, as well as from marine habitats. A congener has established an isolated, landlocked freshwater population in a reservoir in Michoacán (Castro-Aguirre and Vivero 1990). If migratory between marine and freshwater habitats, this species can be expected to have been impacted by dams and water management in the lower basin.

Family Cyprinidae

Campostoma ornatum Jordan
Rodapiedras Mexicano, Mexican stoneroller

This species occurs on both sides of the Sierra Madre Occidental in Sonora, Chihuahua, Durango and Zacatecas, and in small, restricted adjoining areas in the extreme southern parts of both Arizona and Texas in the United States (Burr 1976). In Pacific drainages, the Río Fuerte appears to be its southern limit (Hendrickson 1983). Although highly variable throughout its range, and with some significant differences among basins, Burr (1976) considered much of the variation to be due to ecological factors, and thus did not revise the single-species taxonomy.

This is a small fish, rarely attaining more than about 10 cm Standard Length (SL, distance from tip of snout to caudal fin base). It is often extremely abundant in small to medium-size streams of both high and middle elevations, preferring clear waters with gravel and rock substrates, such as Arroyo Cuchujaqui. The top of the skull of adult males develops striking, strong tuberculation during the breeding season, which appears to peak during March to June in Sonora and Chihuahua (Burr 1976), though it may extend well beyond that period (McNatt 1973). Foods are predominantly algae, diatoms, and bacteria, as in its more-studied congener, *Campostoma anomolum* (Power et al. 1985; Matthews et al. 1987). It is obviously an important food for piscine predators like trout (McNatt 1973). Several

parasites were reported from specimens taken in the RioSahuaripa in the Rio Yaqui system (Campoy-Favela et al. 1989).

Gila pulchra (Girard)
Charalito Conchos; Conchos chub

Though taxonomy and evolutionary relationships in this genus remain uncertain, this species is currently considered to be a member of the subgenus *Temeculina*, which may be the sister group of the present genus *Algansea* (Barbour and Miller 1978), the distribution of which is centered on the Mesa Central of Mexico, to the south and east of the Rio Fuerte. Specimens which have been referred to this or undescribed, closely related taxa, have come from headwaters of the rivers Yaqui, Mayo, Fuerte and Conchos and some adjacent endorheic basins, formerly part of the Río Grande system (Minckley et al. 1986; Smith and Miller 1986). Other species of the subgenus *Temeculina* are known from Sonoran Rivers and southern and Central California (Minckley et al. 1986).

Little is known about this fish. Most collections have been from headwaters at relatively high elevations. In the Rio Yaqui, it appears to replace *Gila robusta* at higher elevations, and there is little or no distributional overlap between the two (Hendrickson et al. 1980).

Gila robusta Baird and Girard
Charal aleta redonda, roundtail chub

In México, this species ranges through all Sea of Cortéz tributaries from the Rio Culiacán north throughout the Rio Yaqui (Hendrickson 1983). It also is found in Gila River tributaries of northern Sonora and Arizona, and formerly occurred in the lower reaches of the Rio Colorado (Minckley 1973). It is widely distributed in the Colorado River system of the United States (Arizona, New Mexico, Colorado, Utah, Nevada, Wyoming) (Smith et al. 1979). A large number of forms have been described or mentioned in the literature. Three forms or subspecies of *G. robusta* of the Gila River drainage have been described (Minckley 1973; Rinne 1976), tributaries and mainstream habitats of the Colorado River support morphologically diverse forms (Suttkus and Clemmer 1977; Smith et al. 1979; Douglas et al. 1989), and more than one form may occur in the species in the Río Yaqui (Hendrickson et al. 1980). Morphological diversity has not been examined in the Rio Fuerte, but an intensive study of morphology and genetics of the *Gila robusta* complex is in progress, including specimens from throughout its range in Mexico (Dr. W. Starnes, Smithsonian Institution, pers. comm.).

Wide-ranging in the Rio Fuerte, this species has been taken from headwaters to low-elevation streams and mainstream rivers. It generally prefers pools, especially in smaller streams, but is also taken in strong currents in rivers. It is apparently the top native piscine predator in the Mexican drainages in which it occurs (Hendrickson et al. 1980), but its diet often is omnivorous and extensively insectivorous (Schreiber and Minckley 1981). It attains about 50 cm SL (Hendrickson et al. 1980).

Gila robusta is considered threatened in México (Secretaria de Desarrollo Social 1994). Principal threats are habitat destruction due to road building, logging, dams, irrigation diversions, impacts of mining and ore processing, and introductions of exotic species such as introduced bass (*Micropterus* sp.) which likely compete with it (Minckley 1973; Barrett and Maughan 1994) and prey upon smaller individuals. The degree to which Río Fuerte populations have declined from pristine levels is unknown, but it is now clearly rare or extirpated from mainstream reaches below impoundments where it almost certainly was formerly more abundant. Two congeners of the "robusta" complex endemic to the Colorado

River of the United States are critically endangered as a result of the impacts of dams and exotic species (Tyus and Karp 1989a, b; Minckley 1991), both of which will undoubtedly be increasing in the Rio Fuerte ecosystem in the future.

Rhinichthys chrysogaster Girard
Charalito aleta larga, longfin dace

Longfin dace ranges from the Bill Williams drainage of northwestern Arizona and Gila River of central Arizona and west-central New Mexico, throughout all major Gulf of California drainages in México southward to the Río Sinaloa. We follow recent revisionary studies (Coburn and Cavender 1992) which indicate that the monotypic genus *Agosia,* in which this species has long resided, is nested phylogenetically within *Rhinichthys*, and therefore should be considered part of that genus. Within this wide-ranging species, at least two, and possibly three different morphotypes have been detected (Hendrickson 1987). A northern form has its southern limit in the de la Concepción (Magdalena) of Sonora, while a southern form occupies the Willcox Playa endorheic system of southeastern Arizona, the rivers Sonora and Yaqui southward through the RioSinaloa. Within the southern form, further differentiation may exist, with specimens from the rivers Mayo, Fuerte and Sinaloa differing slightly morphologically from those of the rest of the range of the form.

One of the most abundant and widely distributed fishes in the Sonoran Desert region, it occupies mostly smaller streams, but is occasionally found in large rivers. It is typical of small, and often intermittent streams, preferring shallow pools and riffles, and generally avoiding deeper pools and rapids (Minckley and Barber 1971). Juveniles are especially adept at entering and exploiting ephemeral habitats of dynamic desert streams, with adults tending to remain in more permanent habitats. It is most abundant at low and middle elevations, but sometimes can be found quite high (2,000 m (Hendrickson 1987)). Adults rarely attain lengths greater than about 100 mm SL (Hendrickson 1987), and most commonly do not exceed about 80 mm SL. Food habits in Arizona are omnivorous to herbivorous, with algae often comprising a large part of the diet (Fisher et al. 1981; Grimm 1988). Also in Arizona, in the Gila River basin, reproduction occurs throughout the year, but with peaks in spring and summer (Minckley 1973). Males become highly tuberculate during reproduction and spawning takes place in depressions in sand bottoms. Tuberculation and nesting behavior of the southern form may differ from that of the northern form (Hendrickson 1987).

Family Catostomidae

Catostomus cf *bernardini* Girard
Matalote Yaqui, Yaqui sucker

This species is one of a clade of closely related species distributed across much of western North America (Smith 1992). It occurs throughout mid-to low-elevations of the rivers Yaqui, Mayo, Conchos (where formerly referred to as *C. conchos* (Miller 1976; Smith and Miller 1986)), Fuerte, Sinaloa, Culiacán and San Lorenzo drainages (Hendrickson 1983). *Catostomus insignis* of the Gila River basin in Sonora, Arizona and New Mexico is a close relative (Smith 1992). Specimens from the Rio Fuerte may be somewhat differentiated from those of the Rio Yaqui, Mayo and Conchos. A thorough revision of geographic variation in this group is needed.

This is a large fish, attaining 40-50 cm SL, that is common in large rivers, as well as small streams. Adults are typically found in deeper pools, often under cover, moving into shallow areas and currents

to feed, while juveniles tend to stay along the edges of pools and in riffles. Populations sometimes appear able to persist in mainstream rivers below dams if adequate flows and temperatures are available. Its diet is mostly insectivorous, but also includes some aquatic vegetation and assorted other organic material. During what appears to be an extended reproductive period (May to August), males develop strong tubercles on the anal and caudal fins. Eggs are deposited into interstices of sediments (Minckley 1973; Hendrickson et al. 1980).

Family Ictaluridae

Ictalurus pricei Rutter
Bagre Yaqui, Yaqui catfish

Generally all catfishes native to Pacific slopes of North America north of the Rio Grande de Santiago (Lerma) have been placed in this species by previous workers, but both distribution and taxonomy are very poorly known. The form in the Río Fuerte closely resembles that from Rio Yaqui, and so we, like others (Minckley et al. 1986; Smith and Miller 1986), retain it in that species pending further studies. Similar unstudied forms occur at least as far south as the Río San Lorenzo (Hendrickson 1983).

Little is known directly of the natural history and ecology of Yaqui catfish. Most have presumed it to be similar to its morphologically similar close relative, the well-studied channel catfish, *Ictalurus punctatus*, which is largely insectivorous and omnivorous to somewhat piscivorous at larger sizes. Yaqui catfish hybridize readily with channel catfish, which has been widely introduced throughout its range. As a result, in the Rio Yaqui, pure Yaqui catfish have recently become rare, and at least all mainstream river populations appear to have been converted to massive hybrid swarms (Campoy-Favela et al. 1989 and unpubl. data). Hybrids have also recently been detected in the Ríos Fuerte and Culiacán (unpubl. data) and likely exist in other nearby drainages. Recent repeated failures of fish culturists to reproduce Yaqui catfish in hatcheries using various techniques that have been used successfully with channel catfish, however, indicate that at least reproductive behavior and requirements may differ considerably from those of channel catfish (Buddy Jensen, U.S. Fish and Wildlife Service, Dexter, New Mexico, pers. comm.).

Family Salmonidae

Oncorhynchus chrysogaster (Needham and Gard)
Trucha dorada Mexicana; Mexican golden trout

The Mexican golden trout, of headwaters of the rivers Fuerte (Rio Verde sub-basin), Sinaloa and Culiacán, was described in 1964 (Needham and Gard 1964), though its existence had been rumored long before (Cope 1886; Meek 1904; Needham 1955). It is, without doubt, one of the most strikingly beautiful fishes of North America, with bright orange below the jaw and on the belly, and with brilliant golden hues along its sides (see color plate of Needham and Gard 1959). Recentphylogenetic analyses indicate it to be the basal member of the genus, which includes all rainbow and cutthroat trouts of Western North America, and all Pacific salmon (Stearley 1992; Stearley and Smith 1993). An early split from the rest of the genus is thus indicated, and if, contrary to earlier opinions (Needham and Gard 1959), rainbow-like trout from the rivers San Lorenzo and Presidio are introduced (Miller and Smith 1986), *O. chrysogaster* is the most southern, living North American salmonid (Miocene to Pleistocene fossils are known from Central Mexico (Cavender and Miller 1982; Miller and Smith 1986).

A large part of the interest of the biologists who first collected and described this fish was in obtaining genetic stock for trout production in the United States. It was hypothesized that it would likely have little migratory propensity, high temperature tolerance, and other characteristics desirable in salmonid aquaculture and management (Needham 1955). The keen interest and considerable collecting effort of 4 decades ago appear to have waned quickly, since very little has since been published on this spectacular species, other than the aforementioned phylogenetic analyses which included it, and brief mentions of it in other works. Rainbow trout, *O. mykiss*, was introduced long ago in many parts of the Sierra Madre Occidental (Meek 1904; Needham and Gard 1959; Hendrickson et al. 1980), and, though we failed to find any definite documentation, we would be surprised if it has not also been released in headwaters of the Rio Fuerte. If rainbows have been introduced to Mexican golden trout habitats, it is highly probable that hybrid swarms have resulted, as they have in other areas where native Western North American trouts have come into contact with introduced rainbows (Rinne and Minckley 1985; Loudenslager et al. 1986; Rinne 1990; Propst et al. 1992). Other threats to the species include habitat alterations associated with logging, grazing and road building. A thorough, distribution-wide survey of populations of this species is clearly in order to determine their status.

Family Poeciliidae

This much-studied (Meffe and Snelson 1989) tropical and sub-tropical family has a broad distribution in the New World, ranging from northern South America to north-central Arizona. Many are well known in the aquarium trade (guppies, mollies, swordtails, and platys). As a result of introductions for insect control, at least two members of the genus *Gambusia* now enjoy nearly global distributions. Unfortunately, their introductions have often had adverse impacts on native faunas (Courtenay and Meffe 1989). Though mostly freshwater, some euryhaline forms enter estuaries and can be found along the coast. All are small fishes which bear live young (viviparous), and have short generation times. Sperm is transferred to females by a copulatory organ derived by elongation and other elaborate structural modifications of male anal fin rays. Numerous all-female populations are known.
Two genera are native to northwestern Mexico, *Poecilia* and *Poeciliopsis*. The RioFuerte is a center of diversification in the latter, with four sexual species and an intensively studied, diverse complex of unisexual clones.

Poecilia butleri Jordan
Topote del Pacífico; Pacific molly

This species reaches its northern distributional limit in Arroyo Cuchujaqui, but extends southward to Guatemala, being found in the majority of Pacific drainages of México (Schultz and Miller 1971). It is usually found in low-gradient streams and in Sinaloa is especially common in estuaries and mouths of rivers. In Arroyo Cuchujaqui it is often abundant in association with *Poeciliopsis latidens* in open and quiet habitats with high standing crops of filamentous algae. It is less common in the mainstream habitats of the Rio Fuerte, and if present there, is restricted to margins.

In light of the extensive body of literature on its congeners (Meffe and Snelson 1989), surprisingly little has been published on this species. Its morphology and habitat preferences suggest an omnivorous or herbivorous diet, similar to that of congeners. Further south it hybridizes with *Poecilia sphenops*, which typically occurs higher in drainages (Schultz and Miller 1971).

Poeciliopsis latidens (Garman)
Guatopote de Sinaloa; lowland livebearer

The lowland livebearer is found in Pacific coastal plain rivers from Nayarit to as far north as the Rio Fuerte basin, including Arroyo Cuchujaqui and others in the area of Alamos, Sonora (Hubbs and Miller 1954). Seven to twelve dark, narrow, transverse bars and spots along the sides readily distinguish it from heterosexual congeners.

This species can be found in both fresh and brackish waters (Hubbs and Miller 1954). Schultz reported laboratory production of all male offspring when this species was bred to *P. monacha-lucida* unisexuals (Schultz 1973), yet a *P. monacha-latidens* all-female unisexual exists in nature in the Rio Fuerte, and an all female triploid (*P. monacha-lucida x latidens*) is found in the Río Mocorito (Schultz 1989). We envision no imminent threats to the conservation status of this widely distributed and abundant species, except perhaps for exotic species.

Poeciliopsis lucida (Miller)
Guatopote de Mocorito; clearfin livebearer

This sexually reproducing species is known only from the Rio Fuerte, and the next two rivers to the south, the Sinaloa and Mocorito (Miller 1960). It is similar, and closely related, to *P. occidentalis* , which occurs in the more northern rivers; Mayo, Yaqui, Matape, Sonora, de la Concepción and Gila (Vrijenhoek et al. 1985; Juárez-Romero et al. 1988; Quattro and Vrijenhoek 1989; Schultz 1989). Hybridization with congeners has produced diploid and triploid unisexual clones (see below). This species can be differentiated from sympatric, heterosexual congeners by its clear fins, for which it was named, as well as on the basis of dentition and a fine axial line of dark pigment along each side and on the midline of the caudal peduncle (Miller 1960).

Microhabitat segregation of *P. lucida* and unisexual clones in Arroyo Jaguari, a tributary of the Rio Fuerte, has been well studied (Schenck and Vrijenhoek 1989; Weeks et al. 1992). *Poeciliopsis lucida* is generally found in low current velocities and in association with abundant filamentous algae. Sex ratio generally favors females (Thibault 1974) but is also influenced by temperature (Sullivan and Schultz 1986). Young are small at birth (7 - 8.5 mm TL) (Miller 1960). Diet of this species is almost exclusively sand and detritus, but it also takes some algae and invertebrates (Schenck and Vrijenhoek 1989).

Poeciliopsis monacha (Miller)
Guatopote Mayo; headwater livebearer

This species is known only from middle to low elevation, small arroyos of the Rio Mayo, such as Cedros, Grande (Tábelo) and San Bernardo, and from similar habitats in the RioFuerte (Arroyos Cuchujaqui, Guiracoba, and Jaguari), and Río Sinaloa (Schultz 1989). It is characterized by tricuspid inner teeth, rounded dorsal and anal fins, and shorter head than sympatric congeners (Miller 1960). Hybrid crosses with this species have produced unisexual clones (Schultz 1989).

Pools and areas of slight current in small, and often intermittent, and generally rocky, canyon streams are the typical habitat of *P. monacha*. It is sometimes accompanied by congeneric sexual species and unisexual clones, but it's name is from the Greek "monachos", meaning solitary, in reference to its mostly isolated and restricted distribution (Miller 1960). Pools in which it lives often become isolated and deoxygenated in summer (Vrijenhoek 1979; Vrijenhoek et al. 1992), where food may also be scarce.

Perhaps as adaptations to low food availability, cannibalism has been noted in nature in this species (Thibault 1974), and females reabsorb embryos under starvation (Meffe and Vrijenhoek 1981). Eggs and embryos are both quite large for the genus (Schultz 1989). Sex ratio generally favors females (Thibault 1981). Diet consists of sand, detritus, algae and invertebrates (Schenck and Vrijenhoek 1989). While it is known from several sites in the Río Fuerte, its distribution in the only other major basin in which it is known to occur, the Río Mayo, is even more restricted, and recent data indicate that it might be extinct in that system (Quattro et al. 1992). A more thorough survey of remote foothill arroyos in both river basins is needed to better assess the conservation status of this species. Despite lack of appearance of this species as threatened or endangered in all previous lists (Table 1), we consider it to merit a conservation status of at least special concern until thorough inventories produce more data to allow re-appraisal of its situation.

Poeciliopsis prolifica (Miller)
Guatopote culiche; blackstripe livebearer

This species extends from the lowermost Rio Yaqui southward on the coastal plain through Sinaloa to San Blas, Nayarit (Miller 1960). In the Rio Mayo it has been taken from near the mouth and in Arroyo Los Cedros, and in the Rio Fuerte, is known from many arroyos in the area of Alamos, including the Cuchujaqui. It is easily differentiated from sympatric heterosexual congeners by its long, slender body and a conspicuous dark lateral streak set off by lighter areas above and below, as well as presence of two prominent dark blotches below the preorbital region (Miller 1960).

The typical habitat of this species is arroyos with slight currents and sandy bottoms. It occasionally penetrates saline waters in estuaries and delta areas. Though not known to have contributed to any unisexual clones in nature, it is frequently taken together with other congeners. Named for its prolific reproduction, it produces as many as 6 broods per month (Miller 1960), but broods are typically of few (average 2.9) individuals (Reznick and Miles 1989). Like *P. viriosa* (of rivers south of the Río Fuerte), nuptial colors of males are similar to females (Miller 1960), not black as in *P. lucida*, *P. monacha* and *P. occidentalis*.

There is no reason to believe that this widely distributed species is imminently threatened, but as for all poeciliids, introduction of *Gambusia affinis* could have significant adverse impacts.

UNISEXUAL CLONES IN THE GENUS

Poeciliopsis

A complex of unisexual clones, each independently derived from individual, interspecific hybridization events, occurs in the region . Four different unisexual hybrid combinations have been identified from the Rio Fuerte basin (Table 1), the apparent center of clonal diversity, but others occur in nearby basins (Schultz 1989). The standard nomenclature developed for these organisms depicts their hybrid origins. For example, *P. monacha-lucida* is a diploid form derived by hybridization between P. monacha and P. lucida, having one haploid genome of each. Poeciliopsis monacha –2 lucida is a triploid with 2 haploid genomes of P. lucida and one of P. monacha. All unisexual populations rely on sperm of parental, or related, sexual taxa for reproduction, and thus must be sympatric with them. The two diploid forms from the Rio Fuerte, P. monacha-lucida and P. monacha-latidens, reproduce by hybridogenesis, and are thus best referred to as hemiclones, since only the female half of the genome is clonally inherited. A new paternal genome from the sexual host species is incorporated in each generation, but excluded

at the time of oogenesis. The two triploid forms occurring in the Rio Fuerte (*P. monacha-2 lucida* and *P. 2 monacha-lucida*), and elsewhere, reproduce entirely clonally by gynogenesis, in which sperm of the sexual species do nothing more than activate embryonic development and inheritance is thus totally maternal with no incorporation of male genome.

Diversity in *Poeciliopsis* in the Río Fuerte goes far beyond a simple list of sexual and unisexual forms. Within each named unisexual hybrid combination, are multiple distinct clones (Vrijenhoek 1984), each traceable to an independent hybridization event, such that each named unisexual form of *Poeciliopsis* is polyphyletic. The clones are typically identifiable only through genetic analyses (protein electrophoresis or DNA techniques), or by immuno-histocompatibility tests (Eisenbrey and Moore 1981). *P. monacha-lucida*, for example, consists of at least 8 mtDNA clones. There is substantial genetic diversity not only among the named forms, but within each form among its multiple independently derived clones (Avise et al. 1992). On the basis of theoretical studies which predict that lack of recombination will result in inability of unisexual organisms to adapt to changing environments, clones have generally been thought to be short-lived in comparison to sexual species. (Avise et al. 1992). Recent evidence, however, indicates that at least one *Poeciliopsis* clone has persisted for 100,000 generations or more, and has dispersed widely from its site of origin, accumulating multiple mutations during this prolonged history (Quattro et al. 1992).

The genetic diversity among *Poeciliopsis* clones is expressed ecologically. Not only does each named unisexual form occupy different niches, distinct from parental species, but there are also detectable niche differences among clones within each unisexual form (Schenck and Vrijenhoek 1989; Weeks et al. 1992). For example one clone of *P. monacha-lucida* is predominantly insectivorous, while another of the same unisexual form is mostly detritivorous (Weeks et al. 1992). Distinct clones of *P. 2 monacha-lucida* in Arroyo Platanos in the Rio Fuerte also have different food habits and prefer different ranges of current velocities and different locations in pools (Schenck and Vrijenhoek 1989). Variation among clones, and between clones and their sexual parental species, has also been documented in susceptibility to parasites (Lively et al. 1990; Leberg and Vrijenhoek 1994), thermotolerance and heatshock (Corrado et al. 1986), and resistance to chemical induction of tumors (Schultz and Schultz 1984; Corrado et al. 1986; Schultz and Schultz 1988; Schultz et al. 1989).

Family Cichlidae

Cichlasoma beani (Jordan)
Mojarra Sinaloense, Sinaloan cichlid

This species of tropical origin ranges from northern Jalisco to lower reaches of the Rio Yaqui and its tributaries in Sonora (Alvarez del Villar 1970; Hendrickson et al. 1980). It prefers low-gradient, clear warmwater streams and pools which typically have dense algal growths or rooted submergent macrophytes or other forms of cover, such as tree roots and undercut banks, but also occurs in large rivers.

Although we know of no detailed diet studies, this species is apparently omnivorous. As in other cichlids, sexual dimorphism in coloration is obvious during spring and summer breeding when antagonistic interactions among breeding adults are commonly seen. Decreases in populations in Sonora have been noted, and these appear to be associated with increasing distribution of confamilial Old World exotics (e.g. *Oreochromis* spp.), and centrarchids (*e.g. Lepomis* and *Micropterus* spp.), as well as habitat destruction or alteration as a result of agricultural development (Juárez-Romero et al. 1991). These impacts and threats lead us to consider the species endangered in Sonora and northern Sinaloa.

Although antagonistic territorial behavior of males makes this species difficult to keep in aquaria, a population has been established in captivity at the Sonoran Desert Museum in Tucson, Arizona for more than 15 years (Howard Lawler, pers. comm. 1994).

OTHER FISHES LIKELY TO OCCUR IN THE RIO FUERTE BASIN

We are certain that the species list of Table 1 will expand with future work. It would not surprise us to find any of the numerous primarily marine fishes that have been recorded from adjacent basins (Castro-Aguirre 1978), but not specifically from the less-collected Rio Fuerte. We also suggest that occurrence of *Catostomus cahita*, or a close relative of it, in headwater tributaries of the Fuerte would not be unexpected. It is known from headwaters of rivers Yaqui and Mayo (Siebert and Minckley 1986), where it often occurs in sympatry with *Gila pulchra*, which does occur in the Rio Fuerte. Specimens from the Rio Fuerte basin at the University of Michigan Museum of Zoology catalogued as *Catostomus* sp. may represent this species or a close relative, but we have not examined them. Finally, it unfortunately is probable that additional exotic species will be recorded from the Rio Fuerte in the future, as the result of both intentional and non-intentional releases, as well as unassisted natural dispersal. One we would be surprised not to find already introduced is the rainbow trout, *Oncorhynchus mykiss*, though we hope future studies will demonstrate that the only trout in the basin is the native Mexican golden trout.

OVERVIEW OF BIOGEOGRAPHY AND EVOLUTIONARY HISTORY OF THE ICHTHYOFAUNA

As indicated earlier, neotropical and nearctic freshwater faunas, as well as a significant marine component, co-mingle in the Río Fuerte. Mechanisms by which the neotropical species attained this distribution are not entirely clear, but it is likely that interconnections among distributaries of the Sinaloan rivers on the coastal plain have occurred in the past and thus allowed them to progress northward (and likely nearctic forms southward). Distributions also appear to have been influenced by hydrographic connections in large structural troughs (Hendrickson et al. 1980; Minckley et al. 1986) that are apparent in drainage alignments, especially in the Rio Yaqui. Dispersals through these structural troughs may date to their formation during Basin and Range block faulting of 27 to 10 million years before present (Minckley et al. 1986). Such hypothesized hydrographic connections correlate well with present distributions of numerous cypriniforms (e.g. *Gila robusta*, *Rhinichthys chrysogaster*, *Campostoma ornatum*, *Catostomus bernardini*, and *Ictalurus pricei*) *Poeciliopsis monacha-occidentalis* has a similar distribution from the Rio Mayo northward throughout much of Sonora. Yet other taxa may have attained present distributions via headwater captures across the continental divide, like those that occurred both north of the Rio Fuerte in the Rio Yaqui (Hendrickson and Minckley 1985), and south in the Rio Mezquital (Minckley et al. 1986; Smith and Miller 1986). Such events may explain existence of *Gila pulchra* and *Cyprinella ornata* in this basin, as well as the distribution of trouts along the continental divide (Minckley et al. 1986; Smith and Miller 1986). Finally, the considerable discharge of the Rio Fuerte undoubtedly facilitated access by marine species, including some very large ones, such as the now endangered Totoaba (*Cynoscion macdougalli*), which probably did not move far upstream, as well as smaller forms which penetrate far inland.

RioFuerte, like its surrounding drainages, has no endemic fish species, but further taxonomic studies may reveal some now cryptic endemics. Some clones of *Poeciliopsis* are undoubtedly endemic to the

RioFuerte, though this is sometimes not obvious from the literature. While the named unisexual forms (e.g. *Poeciliopsis monacha-lucida*) may have broad distributions, these artificial groups encompass often diverse assemblages of polyphyletic, genetically and ecologically distinct clones with independent origins (Avise et al. 1992) and often restricted distributions.

OVERVIEW OF THE CURRENT CONSERVATION STATUS OF THE NATIVE ICHTHYOFAUNA

As mentioned repeatedly above, the basin as a whole faces a multiplicity of threats and very little is known of the actual status of its native fish populations. What little is known of the status of individual species has been discussed in the species accounts above and we summarize by suggesting that a thorough intra-basin, and general regional faunal inventory (such as Hendrickson et al. 1980 provided for the Rio Yaqui) is much needed to provide specimens required for definitive taxonomic studies, basic life history studies, and accurate assessment of conservation status of the fauna. While some assumptions about ecology of some of the primary freshwater species may be drawn from studies of the same or related species elsewhere, life histories of some of the marine forms for which accounts are not provided above, such *as Gobiesox fluviatilis*, *Awaous banana* and *Agonostomus monticola*, are not well known (Gilbert 1992). These may or may not require access to marine waters to complete their life cycles. If they do still require such access, the extent of their penetration of the Río Fuerte basin, and persistence there, may now be limited by dams which block movements. Finally, there is little doubt that exotic species will continue to establish and disperse, additional dams will likely be built, and economic and social pressures will continue to assure that remote areas receive more human development. The importance of attention to conservation of the irreplaceable autochthonous natural resources of this area, which has great potential for rapid development and associated irreversible impacts, can not be overstated.

Some conservation initiatives have been taken. Relatively recent environmental protection legislation at the national level promises greater future attention to conservation. Broad opposition, both within and outside of Mexico, to a World Bank proposal for large-scale expansion of the logging industry in the region(Lowerre and English 1990), was likely responsible for recent withdrawal of the project. Elsewhere in the basin, the government of Sonora has wisely proposed that the Sierra de Alamos, Arroyo Cuchujaqui, and its tributaries be declared a protected zone (Rogero-Díaz 1993). The unique natural resources of this area are well known to biologists in general and the incredible scientific and societal values of the much-studied *Poeciliopsis* of this area can hardly be disputed. Their unique genetic properties, rapid life cycles and easy adaptation to laboratory studies have already caused them to be chosen for applied research on cancer and toxicity monitoring, as well as tests of conservation biology theory (Vrijenhoek et al. 1985; Quattro and Vrijenhoek 1989; Vrijenhoek and Leberg 1991; Leberg and Vrijenhoek 1994). While laboratory stocks of many species and their clones are maintained in several labs in the United States, these should never be considered replacements for wild populations, and much of what remains to be learned of the evolution and ecology of these fishes will be dependent on persistence of natural populations in intact habitats.

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Table 1 - Checklist of fishes recorded from freshwaters of the Rio Fuerte basin, Sonora, Sinaloa, Chihuahua and Durango, México, and their distribution-wide conservation status.Origin: N=native; Eu=Euryhaline (marine origin); X=Exotic. Conservation status: E=endangered, T=threatened, R=rare, SC=special concern, as indicated by the following sources: 1) Varela-Romero (1995); 2) Secretaria de Desarrollo Social (1994); 3) Espinosa-Pérez et al. (1991); 4) Williams et al. (1989). Only species for which we found museum, published, reputable personal communications, or government agency records specific to the basin are included. As a result of this restriction, some species, mostly of marine derivation, recorded in published literature as occurring in a broad geographic area that includes the Río Fuerte (typically "Sinaloan Coastal Rivers", e.g. Miller (1959); Castro-Aguirre (1978); Miller (1986); Minckley et al. (1986)), are not included here due to lack of records specific to the basin. Museum codons under "Authority" follow Leviton et al. (1985), and CES = Centro Ecológico de Sonora, Hermosillo. Data from museum catalogs were provided by collections managers (ASU, CES), or were obtained from databases searchable as of April 15, 1995 via World Wide Web on Internet (http://muse.bio.cornell.edu/taxonomy/fish.html).

		CONSERVATION SATUS				
TAXON	**ORIGEN**	**1**	**2**	**3**	**4**	**AUTHORITY**
Clupeidae						
Dorosoma smithi	N					(Withehead, 985)
Lile stolifera	Eu					CES
Cyprinidae						
Campostoma ornatum	N		T	E	E	(Burr, 1976)
Cyprinella ornata	N	T				UAIC
Cyprinus carpio	X					CES
Gila pulchra	N	T				UMMZ,UANIC
Gila robusta	N		SC	R		(Hendickson, 1983)
Gila sp.	N		SC			(apparently refers to *G. pulchra*)
Rhinichthys (Agosia) chrysogaster	N		T	T		(Hendrickson, et al, 1980)
Catostomidae						
Catostomus cf. Bernardini	N	T	R	R		(Hendickson, 1983)
Catostomus (Pantosteus) plebeius	N					UMMZ
Ictaluridae						
Ameiurus melas	X					Martín Ochoa, (Pers. Comm., 1994)
Ictalurus furcatus	X					Martín Ochoa, (Pers. Comm.,1994)
Ictalurus prisei	N	E	R	R		(Hendrickson, 1983), UMMZ, ASU
Ictaluris punctatus	X					Varela (unpubl. Data)

Table 1 (Continued).

TAXON	ORIGEN	CONSERVATION SATUS 1	2	3	4	AUTHORITY
Salmonidae						
Oncorhynchus chrysogaster	N	T	A	SC		(Needham and Gard, 1964)
Oncorhynchus sp.	N		T		SC	apparently *O. chrysogaster*
Mugilidae						
Agonostomus monticola	EU					UMMZ, ASU
Mugil cephalus	EU					UMMZ
Mugil curema	EU					CES
Atherinidae						
Atherinella crystallina	EU					(Chernoff, 1986) UMMZ, ASU, CES
Exocoetidae						
Hyporhamphus rosae	EU					UMMZ
Poeciliidae						
Gambusia affinis	X					(Varela-Romero, *et al*, 1990)
Poecilia butleri	N		SC	T	T	(Varela-Romero, *et al*, 1990)
Poeciliopsis latidens	N	T	T	A T		(Hubbs and Miller, 1954)
Poeciliopsis lucida	N	T				(Miller, 1960)
Poeciliopsis monacha	N					(Miller, 1960)
Poeciliopsis monacha- lucida	N					(Vrijenhoek, 1993)
Poeciliopsis Monacha-latidens	N					(Vrijenhoek, 1993)
Poeciliopsis 2 monacha-lucida	N					(Vrijenhoek, 1993)
Poeciliopsis 2monacha-lucida	N					(Vrijenhoek, 1993)
Poeciliopsis prolifica	N	T				(Miller, 1960)
Centropomidae						
Centopomus robalito	EU					CES
Cetropomus viridis	EU					CES

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Table 1 (Continued).

TAXON	ORIGEN	CONSERVATION SATUS 1	2	3	4	AUTHORITY
Moronidae						
Morone saxatilis	X					Martín Ochoa (pers.
Centrarchidae						
Lepomis cyanellus	X					Martín Ochoa (pers. Comm. 1994)
Lepomis macrochirus	X					Martín Ochoa (pers. Comm. 1994)
Micropterus salmoides	X					(Hendrickson, 1983)
Sciaenidae						
Cynoscion macdougalli						(Jordan and Evermann, 1896; Castro Aguirre (1978)
Cichlidae						
Cichlasoma beani	N		E ϕ			UMMZ,ASU
Oreochromis mossambicus	X					CES
Oreochromis niloticus	X					CES
Oreochromis aureus	X					(Hendrickson, 1983)
Tilapia sp.	X					(Varela-Romero, *et al.* 1990)
Gobiesocidae						
Gobiesox floviatilis	EU		T A	T		(Burr and Buth, 1977), ASU
Eleotridae						
Dormitator latifrons	EU					UMMZ, ASU
Eleotris picta	EU					UMMZ, ASU, CES
Gobiomorus maculatus	EU					UMMZ, ASU, CES
Gobiidae						
Awaous banana	EU					(Minckley *et al.*, 1986), UMMZ, CES
Gobionellis sagittula	EU					CES
Soleidae						
Citharichthys gilberti	EU					CES