Nonnative Fishes in Natural Ecosystems

and

A Strategic Plan for Control of Nonnatives

in the Upper Colorado River Basin

DRAFT REPORT

by

Harold M. Tyus and James F. Saunders, III
Center for Limnology
University of Colorado at Boulder
Boulder, CO 80309-0334

for the

Recovery Implementation Program for
Endangered Fish Species in the
Upper Colorado River Basin

Cooperative Agreement
No. 14-48-0006-95-923
U.S. Fish and Wildlife Service
P.O. Box 25486, Denver Federal Center
Denver, CO 80225

April 29, 1996

PREFACE

In August of 1995, the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin, acting through the US Fish and Wildlife Service contracting office in Denver, initiated a project with the Center for Limnology, University of Colorado at Boulder (Center) to review and report on the impacts of nonnative fishes on native Colorado River fishes, and to prepare a strategic plan for guiding control of nonnative fish in the upper Colorado River basin. The Center was responsible for obtaining information about fish control issues by reviewing pertinent documents produced by the Program, searching the scientific literature, contacting other experts, and by conducting and facilitating discussion at an interagency workshop. The Center had the tasks of evaluating the impact of nonnative fishes on aquatic ecosystems, identifying and discussing the positive and negative affects of introductions of nonnative fishes on big river fishes of the mainstream Colorado River, and proposing a strategy for mitigating the negative impacts of nonnative fishes. This document constitutes a report of findings and a strategic plan for guiding control measures in the Upper Colorado River Basin. The opinions and conclusions stated in this document do not necessarily represent the official position of the upper Colorado River recovery program or those of its cooperating agencies and groups.

Additional information about the upper basin recovery program can be obtained by contacting Ms. Connie Young, Public Information Coordinator, or Mr. John Hamill, Program Director, U.S. Fish and Wildlife Service, P.O. Box 25486 Denver Federal Center, Denver Colorado 80225 or at telephone 303-236-2985.

ACKNOWLEDGMENTS

Our tasks were made easier by the enthusiastic support of workshop participants (Appendix). Special appreciation is given to our program committee, and especially to Guy Burgess who served as workshop facilitator. D.J. Allen assisted with the workshop and also synthesized information for the report. The workshop benefitted greatly from excellent presentations by R.T. Muth, R.S. Wydoski, L.W. Hesse, F.P. Gelwick, T.A. Crowl, T. P. Nesler, and L.D. Lentsch. H.R. Maddux, project Technical Officer, provided much assistance and also made suggestions for improving an earlier draft manuscript. Biologists of the Colorado Division of Wildlife and the Utah Department Wildlife Resources, including T.P. Nesler, D. Langlois, P. Martinez, L. D. Lentsch, P. Thompson, and others reviewed an earlier draft of this document and provided many helpful comments. We are grateful for permission to use various tables, figures, and other information from documents previously prepared by the Program. John Hamill served as liaison for the Recovery Implementation Program and provided invaluable guidance and assistance.

EXECUTIVE SUMMARY

The native fish fauna of the Colorado River basin has been greatly affected by human actions that have occurred primarily since the 1930s. Four of the seven large species in the "big river" assemblage are endangered and federally listed, and the remaining three are species at risk. Dams, diversions, and extensive flow regulation have produced significant changes in the physical environment including habitat loss and fragmentation. These changes were undoubtedly a major factor in the decline of the endangered fish species, but changes in the biological environment now may be an equally significant threat.

Many nonnative fishes have been introduced into the Colorado River basin in this century. Nonnative fishes were introduced by various federal and state agencies, as well as by private individuals. Successful establishment of several nonnative fishes (e.g., channel catfish, common carp, fathead minnow, and red shiner) has presumably been facilitated by their "preadaptations" to the changed conditions now found in the Colorado River system. However well-intentioned the introductions may have been, the effects have been almost exclusively detrimental to the native fauna. A successful introduction results not only in the addition of nonnative individuals to the receiving waters, but almost always in displacement of natives, especially where the native fishes occur in low abundance in isolated habitat. In the extreme, displacement can mean local extirpation or complete extinction of one or more native species.

The threat to natural systems posed by nonnatives is by no means restricted to the Colorado River system; it is part of a nationwide problem that is particularly acute where species have been introduced intentionally to satisfy recreational or commercial demands. The possibility of hastening the decline of native fishes as a direct result of these fish introductions is real, and displacement has been documented in other river systems. Continued decline of rare species will ultimately lead to extinction and the irrevocable loss of biological diversity. This loss has widespread effects, because it encompasses not only the number of native species present, but also the ecological functions of those species and the genetic material they contain.

The scope of problems with nonnatives has been investigated at length in the Upper Colorado River Basin (UCRB). There have been numerous surveys documenting the distribution and abundance of nonnatives. Direct and indirect evidence for the adverse impacts of nonnatives on the native fishes and the precarious status of the native fauna is well-known. Researchers have identified control measures that may be applied to most of the common nonnatives. However, a strategic plan is needed to target specific nonnatives for control by selected methods in designated locations. Also needed are combined efforts of many agencies, governmental and private, and the cooperation of private citizens who may not be aware that nonnative fishes pose a threat to the Colorado River fauna. Finally, institutional recognition of and support for such a plan is urgently needed.

A workshop was held in Boulder, CO on Nov 30 and Dec 1, 1995 to seek answers to four basic questions concerning the kinds of solutions available for the UCRB: (1) In what geographic areas would control measures have the greatest benefit? (2) Which life history stages of the endangered fishes are most susceptible to negative interactions with nonnative fishes? (3) Which nonnative species pose the most serious threats? (4) Which control methods will be most effective? The workshop tapped the collective expertise of scientists and managers who were familiar with problems in the upper basin, and who represented perspectives from the various geographical areas and governmental agencies within the basin. Participants identified priority geographic areas for recovery of the native fishes in the Green River below Echo Park, the lower Yampa, and the Colorado above the Green River confluence. Larval and juvenile stages of all natives fishes were considered most susceptible to predation by a wide range of introduced predators. The channel catfish was considered the greatest threat, but green sunfish, fathead minnow, red shiner and others also were recognized as threats.

Workshop participants also proposed a number of control scenarios based solely on technical merits. The scenarios discussed included three basic themes: 1) prevent nonnative fishes from entering the system, 2) remove nonnatives from the main channel, and 3) exclude nonnatives from interactions with larval and juvenile native fishes. Installation of effective escapement controls on major reservoirs such as Elkhead, Kenney, Highline, and Starvation, and on other known source areas like Browns Park and Stewart Lake waterfowl management areas in Utah could reduce the supply of nonnative fishes such as common carp, northern pike, smallmouth bass, and black crappie. For the ponds in the floodplain, chemical techniques could be applied to eliminate nonnatives. Mechanical techniques such as trapping or electrofishing could be applied in critical habitat (e.g., lower Yampa, lower Green, and the Colorado above the Green) for the removal of larger nonnatives such as channel catfish, carp, and centrarchids. Flow management, especially in high gradient areas, has some potential for reducing populations of small cyprinids and the centrarchids. Active management of the inundation cycle for backwaters and floodplain ponds could be a principal mechanism for reducing negative interactions (i.e., predation) on larval nonnative fishes. Barriers, weirs, and other exclusion measures could be installed in certain high priority areas.

Scenarios developed by workshop participants form a large component of the technical basis of the proposed strategic plan, which will guide control efforts. The plan reaches beyond workshop scenarios because it must integrate control efforts in a basinwide context, and it ventures beyond a strictly technical framework because it acknowledges potential sociopolitical conflicts and major non-technical constraints.

From a practical perspective, successful plan implementation may depend on reducing conflict between control measures and other interests, especially recreational sport fishing.

The strategic plan uses a two-tiered approach in applying fish control measures to geographic locations. At the basin-wide level, control of nonnative fish would be facilitated by 1) changing stocking protocols, 2) increasing harvest (take) of nonnative fishes in target waters, and 3) reducing escapement from impoundments. At the scale of river reaches, the plan defines more specific measures for nonnative fish control in high priority recovery areas.

For at least 10 years, there has been a clear mandate from the Recovery Implementation Program to initiate actions that would reduce the negative effects of nonnative fishes on the listed native species. Specific tasks have been identified, but there remains a general institutional reluctance to agree that nonnative fishes are a significant problem and to proceed with nonnative fish control. Instead, there is a tendency to commission further evaluations and studies rather than to pursue specific control measures. The reluctance to take action may be attributed to an understandable prudence on the part of scientists and managers, who seek assurances of success before taking action. However, without control of nonnative fishes it is anticipated that extant stocks of listed fishes will continue to decline. As populations of the listed fishes dwindle, the probability of extinction rises. We conclude that there simply is not the time or the biological material to risk on time-consuming pilot studies that may or may not be sufficiently convincing to justify significant control actions. The pressing threat of extinction calls for a greater reliance on best professional judgment for assessing the available scientific evidence. The strategic plan embodies such an approach and offers direction for control efforts. The effectiveness of those efforts, which cannot be guaranteed at the outset, can be tested as they are implemented and the new information can enable program directors to redirect resources as necessary. Because of the extensive anthropogenic changes that have occurred, the insular nature of the entire Colorado River basin, and the fragmentation of native fish populations, we believe that bold steps are needed to maintain the native fauna of the upper Colorado River basin and to avert extinction of its endangered fishes.

TABLE OF CONTENTS

SECTION I. INTRODUCTION

The endemic fishes of the upper Colorado River Basin (UCRB; Figure 1) are declining in abundance. The problem is particularly acute for the so-called "big river" fishes that occupy main channel habitat. Four of the seven large species are endangered and federally listed. The other three are considered species at risk. Significant anthropogenic changes to the physical habitat have undoubtedly played an important role in the decline of these species, but changes in the biological environment may now be equally significant. Nonnative species have been introduced into the Colorado River Basin and have been so successful that they have displaced native species in some river reaches. However, the problem of introduced species is pervasive and by no means confined to the UCRB. Before reviewing the problems that nonnatives have caused in the UCRB, it is instructive to review the issue in a broader geographical and biological context.

Many nonnative species have been introduced into North America. A recent study by the Office of Technology Assessment (USOTA 1993) concluded that introductions of harmful species have produced cumulative impacts and "are creating a growing economic and environmental burden for the country." The report states that 4,500 foreign species have established populations in the United States. Many of these introductions were intentional, but others occurred unintentionally through human activities (Taylor et al. 1984).

Humans have a penchant for supplementing their local biological environment with imported plants or animals that are perceived to have special beauty or usefulness, or are simply reminders of a pleasing biological environment in another geographic location. Exotic species were introduced from Europe and other continents with the intent of benefiting their "new ecosystem," but most exotic species were the bane of, rather than a benefit to, the new environments (Kurdila 1988). There are many examples of these harmful introductions. The melaleuca (*Melaleuca quinquenervia*) was imported because it grows quickly and is fire resistant, but the tree is having devastating effects on the Florida Everglades. The attractive purple loosestrife (*Lythrum salicaria*) has become a major wetland weed and the water hyacinth (*Eichhornia crassipes*) is choking waterways. The salt cedar (*Tamarisk sp.*) is displacing native riparian vegetation in arid regions and changing river geomorphology. (USOTA 1993; Graff 1978). Introduction of the zebra mussel (*Dreissena polymorpha*) has imposed enormous economic hardships on water and power industries particularly in the Great Lakes region (Nalepa and Schlosser 1993).

Fish species have been introduced intentionally for such diverse purposes as food resources (e.g., the common carp *Cyprinus carpio*), for biological control (e.g., the mosquitofish, *Gambusia affinis*), or unintentionally by release of bait fish (e.g., sheepshead minnow, *Cyprinodon variegatus*). These examples, and many others, have become very abundant in river systems throughout the US. These introduced fishes have some practical or aesthetic value, but all have caused problems in natural ecosystems and resulted in unanticipated costs (USOTA 1993, Taylor et al. 1984, Courtenay and Robins 1989). Even seemingly innocuous species like grass carp (*Ctenopharyrodon idella*), which was introduced in 1963 to control aquatic vegetation (Stanley et al. 1978), is now suspected of altering native fish communities (Raibley et al. 1995).

If the impact of introduced species were simply to add some individuals to the existing biological community, it would be less of a cause for concern. Introductions do not happen in a biological vacuum, however. The complexity of fish communities, for example, makes it difficult to predict the outcome when introducing a new species in a native community (Li and Moyle 1981). Most introductions prove harmful and have unanticipated, and usually adverse, effects on native communities. The biological system receiving the invader will be altered, typically by displacement of a native species (Li and Moyle 1981, Courtenay and Robins 1989, Courtenay 1993). The problems caused by many introduced plants and animals seem to worsen with time (Leopold 1949, Laycock 1966). In the extreme, introduced species can cause the local extirpation or extinction of native species with the result that biodiversity is decreased (reviewed by USOTA 1993).

Native freshwater fish communities have been affected severely by human actions (Miller 1972, Williams et al. 1989). During the last 100 years, 27 of the native North American fishes (N= 1,003) have become extinct and 265 species are threatened with extinction (reviewed by Wilson 1992). The demise of species has been linked with more than one factor, but displacement by an introduced species was cited an agent in the decline of a native species in 68% of cases reported; introductions were about as important as destruction of physical habitat (73%; Wilson 1992). In a review of 31 case studies in which fishes had been introduced into stream communities, Robs (1991) found that 23 (74%) caused declines in native fish populations. Native populations also may experience reduced growth and survival rates as a result of their introduction (Moyle et al. 1986).

The adverse effect of introductions on the native fish fauna has been recognized by the American Fisheries Society (AFS), which is the premier fisheries organization in North America. While acknowledging the benefits that stocking has brought to recreational and commercial fisheries, the AFS states that stocking has had "undesirable effects on native species" and that stocking policy should be tempered by the need for preserving biological diversity (Starnes et al. 1996).

Biological diversity is at risk when nonnative species are introduced. Biological diversity is not simply the number of species present, but also encompasses the "ecological roles they perform, and the genetic diversity they contain" (Wilcox 1984).

Because biodiversity is a characteristic of natural ecosystems, it is not enhanced by the introduction of nonnative species. Biodiversity can be reduced by shifts in the natural patterns of relative abundance (Temple 1990). There is no doubt that biodiversity is declining on the planet and there may be serious and unanticipated consequences for humans (Ehrlich and Ehrlich 1983, Wilson 1992, Ward 1995).

Extinction results in an irrevocable loss of biodiversity. Three sets of factors are thought to contribute to extinction: biotic factors, isolation, and habitat alteration (Frankel and Soulé 1981). Most extinctions involve a combination of factors (Frankel and Soulé 1981, Soulé 1983, Wilson 1992). Biotic factors such as predation and competition from introduced species may reduce or alter the density, range, and habitat use of a native species. While these alterations may not eliminate a robust and widespread species, they are likely to cause its decline and make the native population more susceptible to other factors such as habitat alteration or isolation. Population decline results in small population size, and small populations are prone to problems such as demographic stochasticity, genetic deterioration, social dysfunction, and extrinsic forces (reviewed by Raup 1991). Extinction is more likely to occur in small populations that have fallen below the size of minimum viability (MacArthur and Wilson 1967; Simberloff 1974,1986; Raup 1991).

The case for conservation becomes most urgent as the population size of a species becomes very small. Random events such as a chemical spill that would have a relatively minor impact on a large and widely distributed population, could have catastrophic and perhaps permanent effects on a smaller, restricted population. In the interest of preserving the species and maintaining biodiversity, extraordinary measures may be required to prevent extinction. For species like the big river fishes of the UCRB that are threatened by biotic factors, control of introduced species becomes imperative. The task is not necessarily a simple one: control of introduced species has been called the "nasty necessity [because of] misconceptions about the nature and magnitude of the problem, fears of the negative public reactions...and intimidation by the inefficient labor-intensive nature of current eradication technologies" (Temple 1990).

Easy or not, the control of introduced nonnatives that are threatening the big river fishes of the UCRB has become a necessity, and control measures must be developed using an objective and structured approach. This report has four main objectives: (1) to assess the effects of nonnative fishes on aquatic communities from national and regional perspectives, (2) to identify and discuss the effects of introduced nonnative fishes on the endangered big river fishes of the mainstream Colorado River, (3) to identify measures appropriate for reducing or preventing negative impacts of nonnative fishes on the big river fishes, and (4) to provide a strategic plan for guiding measures for controlling nonnative fishes in the UCRB. The goal of this plan is mitigation of these biotic factors that could lead to the extinction of the native big river fishes.

SECTION II: SCOPE OF THE NONNATIVE PROBLEM:

General

Problems caused by introduction of nonnative species into aquatic habitats have become a national and international concern. In an extensive review of fish introductions in the United States, Taylor et al. (1984) stated that harmful effects to native populations should be a "foregone conclusion." The evidence was sufficiently compelling that these authors believed a "no effects" argument would be implausible to the point of straining "one's confidence in ecological principles." The scope of the problem is captured in a document prepared by the national interagency Aquatic Nuisance Species Task Force (ANSTF 1994).

> "By competing for resources, preying on native fauna, transferring pathogens, or significantly altering habitat, the introduction of a nonindigenous species may work synergistically with other factors, such as water diversions or pollutants, to alter the population and distribution of indigenous species. The factors are often cumulative and/or complementary. For example, habitat degradation may make a species more vulnerable to the introduction of nonindigenous species."

The ANSTF (1994) review found that the species cited most frequently for endangering native fishes nationwide was the largemouth bass (*Micropterus salmoides*), but other centrarchids such as green sunfish (*Lepomis cyanellus*), bluegill (*L. macrochirus*), crappies (*Pomoxis spp.*), and smallmouth bass (*M. dolomieu*) were also contributors. The family Ictaluridae, which includes channel catfish (*Ictalurus punctatus*) and bullheads (*Ameirus spp.*), was the second most cited group. Smaller species, including the red shiner (*Cyprinella lutrensis*) and fathead minnow (*Pimephales promelas*) also were mentioned (ANSTF 1994). All of these species have been introduced into the Colorado River Basin, either for recreational sport fishing or as baitfish (Miller 1952, Minckley 1982, Tyus et al. 1982).

Endemic Colorado River Fishes

The scope of the nonnative fish problem in the UCRB is best understood by considering the evolution of the native fauna, which originated in a system that was very different than the one that exists today. Native Colorado River fishes had a long evolutionary history of adaptations to a river system characterized by extreme seasonal variations in flow and generally turbid water. Peak flows produced extensive seasonal flooding of low-lying areas. Smaller tributaries were subject to flash flooding after unpredictable storm events. In the geologic past, the river system was wetter, and large lacustrine areas were prevalent (Minckley et al. 1986, Stanford and Ward 1986a). In more recent times, the climate has been characterized by extreme aridity. Stanford and Ward (1986a) consider the Colorado River basin one of the driest in the world. Because of its geographic isolation, Molles (1980) described the Colorado River as an "aquatic island in a terrestrial sea." The fishes have adapted to a system that historically exhibited a wide range conditions ranging from lacustrine to riverine, and they are considered extreme generalists (Smith 1981). They exploit every available habitat to their advantage, and developed some complex life histories in the process (e.g., see Minckley and Deacon 1991). The geographical isolation of the Colorado River fish fauna suggests that the concepts of island biogeography (insular ecology) provide an appropriate model for understanding the process of endangerment and possible extinction (Smith 1978, Molles 1980).

The native fish fauna of the Colorado River is characterized by a high level of endemism. Of the 467 native fishes (species and subspecies) present in recent times, 38 of these are classified as endemic (Miller 1958, Stanford and Ward 1986b). This high level of endemism was heavily influenced by the Quaternary history of the intermountain area of western North America. Populations were isolated by desertification and faunal composition was changed by local extinctions during the Pleistocene (Smith 1978, Stanford and Ward 1986b). At one point, native Colorado River fishes consisted of only 32 to 36 species, depending on taxonomic interpretation (Stanford and Ward 1986b, Carlson and Muth 1989), and they lived in three main habitat types. Native salmonids and sculpins live in cooler headwater or low order streams at high and intermediate elevations. These species also occur, or have close relatives in similar habitats of adjacent basins. A second group consists of daces and minnows in small warmwater streams at low and intermediate elevations. The third group of fishes, which are the focus of this document, inhabit the mainstream river channels and are called the "big river" fishes. These include seven large fishes of the mainstream channels, and two smaller forms that are restricted primarily to shallower habitat (Minckley et al. 1986).

Decline of Native Fishes

Fishes of the Colorado River basin have not fared well since the time of human settlement. Several fishes, including the Las Vegas dace (*Rhinichthyes deaconi*), Pahranagat spinedace (*Lepidomeda altivelis*), and the Monkey Springs pupfish (*Cyprinodon* sp.) are recently extinct, and bonytail chub (*Gila elegans*) may only survive due to hatchery stocks. Of the extant native species, 19 (40%) are federally listed or proposed for listing as threatened or endangered (Carlson and Muth 1989). Declining fish populations of the mainstream ecosystem are not restricted to listed species. The flannelmouth sucker (*Catostomus latipinnis*) and roundtail chub (*Gila robusta*) have been considered as candidates for listing as threatened or endangered species (USFWS 1994). The flannelmouth sucker, which was previously reported in various locations in the lower basin, has been extirpated south of Lake Mead (Minckley 1973).

Bluehead sucker (*Catostomus discobolus*) populations also may be declining. They are uncommon to rare in many mainstream habitats in the upper basin (Tyus et al. 1982), and may once have been more widely distributed. More species may be experiencing decline, but thorough study has been constrained by a lack of institutional interest and, therefore, funding.

The decline of native fishes in the lower basin has been extensive and the endemic fauna of the main channel is almost gone. It has been replaced by a new fauna consisting of about 44 forms (Minckley 1982), many of which were introduced from more mesic environments and apparently better suited (i.e. "preadapted"; Taylor et al. 1984) to the new conditions in the Colorado River basin. Many of the successful introduced species had certain attributes that enabled rapid colonization and population growth in these novel environments (Taylor et al. 1984). About 20 of these species are abundant locally or regionally. In the upper basin, more natural conditions support most of the native fishes, but 42 introduced fish species or subspecies occur and 10 of these are considered abundant (Tyus et al. 1982).

Habitat of the native Colorado River fish fauna has been greatly changed during the last 100 years by physical habitat alterations and the introduction of nonnative species. Alterations to the physical environment have been described elsewhere and resulted from construction of water development projects that began in the early 1900s (Fradkin 1984, Carlson and Muth 1989). By the 1960s, much of the mainstream river had been converted into a system of dams and diversions (Figure 2). As a result, extensive flow regulation substantially altered the timing, duration, and magnitude of annual flood flows. The large floods that were once normal in the Colorado River are now controlled by more than 50 mainstream dams and major diversions. These structures have caused changes in water temperature, sediment load, nutrient transport, and other facets of water quality (Carlson and Muth 1989). For example, silt load in some reaches has been reduced 90% (Fradkin 1984). Thus, most existing mainstream habitats are now different than the historic habitats in which the native fishes evolved.

Physical changes in the riverine habitat were accompanied by the introduction and proliferation of nonnative species, and concomitant declines in native species. Some introduced fishes have become very successful under the environmental conditions that now prevail in the Colorado River system. These fishes may compete with native species for food and space in some habitats. Although the native fishes were well adapted to their natural environment, conditions may have been tilted in favor of the introduced species by major environmental changes. For example, introduced visual predators may have benefited from the reduction in turbidity that is the result of new impoundments. The big river fishes evolved in turbid conditions and lack evolutionary "experience" with the introduced predators.

Native big river fishes have disappeared from about three-fourths of their original habitat while introduced fishes have become more widespread and abundant. Even where physical habitat has been altered relatively little, nonnative fish abundance has increased, and the abundance of native fishes has been reduced. Although it is obvious that suitable physical habitat is a requirement for the native fishes, the suitability of the physical habitat is no longer the only issue. Most suitable physical habitat now is occupied by introduced species, including many of which are predaceous, highly competitive, and harmful to the native fish fauna (Minckley 1982, Tyus et al. 1982, Carlson and Muth 1989). Because nonnative fishes have displaced native fishes even from habitats whose physical attributes should be ideal for the natives, there is a clear implication that natural physical habitat conditions are a necessary, but not a sufficient condition for recovery of the endangered species.

Introduction of Nonnative Species

As important as the physical changes have been in endangering native fishes, the most significant threat to the existence of the native fishes is probably not physical or chemical, but biological. At least 67 nonnative species have been introduced actively or passively into the Colorado River system during the last 100 years (Minckley 1982, Tyus et al. 1982, Carlson and Muth 1989, Minckley and Deacon 1981, Maddux et al. 1993). The creation of the US Fish Commission in 1872 is cited as the beginning of large stocking initiatives in the Colorado River basin (Miller 1961). The original recommendations for stocking were apparently based on the assumption that it would benefit the relatively depauperate Colorado River fauna (e.g., Jordan 1891). At least 36 fish species, mostly game fishes from the eastern US, were introduced from 1930 to 1950 (Miller 1961). By 1980, more than 50 nonnative species had been actively introduced into rivers and reservoirs of the Colorado River basin (Minckley 1982, Tyus et al. 1982, Carlson and Muth 1989). The desire to expand or enhance sport fishing opportunities was the reason for most intentional introductions; other reasons include forage for game species, biological control of unwanted pests, and for aesthetic or ornamental purposes.

The states of Colorado and Utah have curtailed stocking of nonnative fishes directly into waters of the Colorado River basin and now stock only coldwater salmonids such as brown and rainbow trout. The state of Wyoming continues to stock nonnative fishes above Flaming Gorge Reservoir and had been stocking channel catfish in the Yampa basin as recently as the late 1980s. Even though much of the direct stocking has ceased, previous stocking efforts have left a potent legacy that continue to effect native Colorado River species. Well-established populations of warm- and coolwater fishes are recruiting individuals in riverine habitat. For example, smallmouth bass in the Uinta River and northern pike in the Yampa River yield a steady supply of predators to the UCRB. Escapement of predaceous sunfishes, pikes and perches from impoundments and other water bodies results in the input of a substantial number of nonnatives to mainstem habitat.

Over time, escapement from various reservoirs has contributed a steady supply of predators and competitors to riverine habitats occupied by native Colorado River fish species. However, the magnitude of this contribution has not been quantified. For a perspective on the potential, escapement from reservoirs in the Missouri River system included 16 fish species (Walburg 1991), many of which also occur in the Colorado River basin (e.g., common carp, channel catfish, various centrarchids, and walleye). The number of escapees was remarkable; peak numbers ranged from 170,000 channel catfish to 10 million freshwater drum in a single 24-hr period (Walburg 1971). Although such releases have not been quantified in the Colorado River basin, there are many examples of fish that have been stocked in one location that are now found in other more distant locations (e.g., Courtenay and Robins 1989, Tyus and Beard 1990).

Escapement may eventually result in large numbers of individuals in the riverine environment. In the Yampa River system, for example, northern pike and smallmouth bass populations have increased dramatically since the 1970s when Holden and Stalnaker (1975) did not collect either species. By the early 1980s, northern pike and smallmouth bass were present in extremely low numbers (Tyus et al. 1982). By the end of the 1980s, northern pike were abundant in the Yampa system (Nesler 1995), and had dispersed into the Green River system (Tyus and Beard 1990). Smallmouth bass remained uncommon in the Yampa system as of 1991 (Nesler 1995). However, in September, 1995, the authors seined shoreline eddies and found that smallmouth bass were more common than the native fishes in these habitats. It is probable that the abundance of smallmouth bass in the Yampa River has now increased several orders of magnitude due to continued recruitment from stocked populations in the Yampa River basin. Modde and Smith (1995) present evidence that the relative abundance of northern pike and smallmouth bass increased greatly after 1992 due to escapement from Elkhead reservoir in Colorado.

Not all nonnative fish introductions have been sanctioned by those agencies officially responsible for managing fisheries. Some have been introduced unwittingly through release of bait fish or unwanted pets, others have been introduced accidentally, and some intentionally (Miller 1952, Minckley 1982, Taylor et al. 1984). Illegal transfers, typically of gamefish, are now thought to be a major mechanism by which some nonnative fish become established in new locations (L. Lentsch, Utah Division of Wildlife Resources, personal communication, 1996).

Effects of Nonnatives on the Endemic Colorado River Fauna

For at least 50 years, scientists have been concerned about the role nonnatives have played in the decline of native fishes. Early changes in the Western fish fauna noted in Colorado by Ellis (1914) who attributed declines, in part, to competition by introduced fishes. Dill (1944) was one of the first to suggest that nonnatives were responsible for declines observed in native fish populations in the lower Colorado River basin. He recognized that the decline began about 1930, and that it was coincident with a large increase in the abundance of nonnative fishes, especially channel catfish and largemouth bass. By 1960, populations of the big river fishes had been reduced greatly. Miller (1961) noted "drastic changes" in the fish fauna and observed that the "most impressive documentation for changing fish fauna" occurred in the lower Colorado River where it was associated with a replacement by introduced fishes. Schoenherr (1981) considered the evidence "overwhelming" for replacement of native fishes by aggressive introduced fishes, and he provided examples in which predation resulted in extirpation. More recent studies document a decline in the abundance of native fish species as nonnative species increased in abundance (Joseph et al. 1977, Behnke 1980, Osmundson and Kaeding 1989, Quaterone 1993).

An increasing body of evidence characterizes the negative interactions of nonnative fishes with the endangered big river fishes (Hawkins and Nesler 1991, Minckley et al. 1991, Maddux et al. 1983, Lentsch et al. 1995). Many of the reports present evidence that is indirect because they lack direct observations or absolute proof of predation on natives. Such indirect evidence may include inferences from field dat or results of laboratory studies. Direct evidence of predation includes native fishes obtained from stomach contents of the nonnative fishes and by visual observation of predation.

Indirect evidence connecting the decline of native fishes to the proliferation of nonnative fishes has been given by many workers (Dill 1944, Wallis 1951, Jonez and Sumner 1954, Miller 1961, Vanicek 1967, Rinne 1971, Vanicek and Kramer 1979, Baxter and Simon 1970, Moyle 1976, Holden 1977, Joseph et al. 1977, Allan and Roden 1978, Deacon 1978, Behnke 1980, Miller et al. 1982 and references therein, Kaeding and Zimmerman 1983, Minckley 1983, Wick et al. 1985, Bestgen and Propst 1989, Marsh and Minckley 1989, Tyus and Karp 1989, Tyus and Beard 1990, Tyus and Nikirk 1990, Valdez et al. 1990, Minckley and Deacon 1991 and references therein, Propst and Bestgen 1991, Rinne 1991, Rinne and Minckley 1991, Scoppertone 1993, Trammel et al. 1993, and Valdez and Ryel 1995). Other workers have studied dietary overlap and postulated that competition for food and/or space was occurring (Jacobi and Jacobi 1981, McAda and Tyus 1984, Grabowski and Hebert 1989, Muth and Snyder 1995, and Valdez and Ryel 1995). Laboratory studies have documented agonistic behavior, resource sharing, and vulnerability to predation (Papoulias and Minckley 1990, Karp and Tyus 1990, Ruppert et al. 1993, and Johnson et al. 1993).

A substantial body of indirect evidence for nonnative predation has been assembled for the razorback sucker. An almost total lack of recruitment to an adult size has been cited as the major cause of the decline and endangerment of the razorback sucker. Recruitment failure has been linked with loss of early life-history stages of the fish, and is the result of predation by nonnative fishes (reviewed by Minckley et al. 1991; Johnson et al. 1993). Marsh and Langhorst (1988) reported that larval razorback suckers in Lake Mohave survived longer and grew larger in the absence of predators. Loudermilk (1985) observed that young razorback sucker larvae exhibited little defensive behavior in the presence of potential predators. Johnson et al. (1993) compared predator avoidance of razorback sucker larvae with that of northern hog sucker (*Hypentelium nigricans*) and concluded that "larval razorbacks are not likely to survive in habitats that support high numbers of nonnative fishes" (Johnson et al. 1993). Smaller species such as red shiner and fathead minnow may attack or display agonistic behavior toward razorback sucker larvae (Karp and Tyus 1989). Young of some of the more aggressive game fish are highly agonistic (Sabo et al. 1996) and can be expected to consume the relatively naive young suckers (Tyus and Karp 1989).

Razorback suckers are susceptible to predation from several nonnative fishes. Green sunfish, common carp, and flathead and channel catfish have been observed feeding on eggs and/or larval razorback suckers (Medel-Ulmer 1983; Minckley 1983; Brooks 1985; Langhorst 1987, Marsh and Langhorst 1988; Marsh and Brooks 1989). An experiment performed by Karp and Tyus (1989) demonstrated voracious consumption of razorback sucker larvae by several nonnative fishes in 4-minute trials (green sunfish, consumed 90% present; red shiner, 50%; and redside shiner, 10%). A field experiment in Lake Mohave provided indirect evidence of the predation effect by monitoring larvae in habitats with and without predators. Razorback sucker larvae in a predator-free environment grew to 30 mm during the trial, while the size distribution of those exposed to predation was truncated at 10-12 mm (Brooks 1985; Langhorst 1987; Marsh and Brooks 1989). Competition with introduced fishes for food also may be a factor limiting the success of the razorback sucker as suggested by Papoulias (1988) and Papoulias and Minckley (1990), who demonstrated that some recruitment failure of young razorback suckers in Lake Mohave could be caused by starvation. Minckley et al. (1991) provided conclusive evidence that predation of nonnative fishes on young razorback suckers was the primary factor responsible for the near complete recruitment failure of this species.

Direct observations, including stomach content analyses, of predation by nonnative fishes have been reported for many species native to the Colorado River basin, which include the endangered big river fishes (Table 1). The table is supplemented by reports of humpback chub with characteristic bite marks that have been attributed to channel catfish. These marks could not have been made by native cyprinids or catostomids which lack jaw teeth (Kaeding and Zimmerman 1983, Karp and Tyus 1990). The list is extensive and should leave no doubt that predation by nonnatives is a powerful force. The number of predator species is great, especially for the early life history stages of the razorback sucker. Part of the difficulty in documenting predation in early studies is that the rapid digestion of some of the centrarchid fishes was not appreciated. Langhorst and Marsh (1986) found that razorback sucker larvae were only distinguishable in stomachs of green sunfish (*Lepomis cyanellus)* for about 30 minutes. After that time the larva essentially were dissolved.

Negative interactions with introduced fishes also have been well documented for some Colorado River basin fish species that occupy smaller habitats. Meffe (1985) demonstrated that direct predation on juvenile topminnows (*Poeciliopsis occidentalis*) by an introduced mosquitofish (*Gambusia affinis*) was the primary means for species replacement. Another introduced mosquitofish (*G. holbrooki*) exerted significant negative effects on the abundance of the least killifish *(Heterandria formosa*), and only complete removal of the predator reversed the effect (Lydeard and Belk 1993). In another investigation, Deacon (1978) documented competitive interactions between introduced goldfish and Pahrump killifish (*Empetrichthys latos latos*).

There are less obvious, but nonetheless potentially important adverse interactions that do not involve predation by nonnatives. Colorado squawfish are known to prey on channel catfish, but may choke on the catfish's spines (Vanicek 1967, McAda 1983, Pimental et al. 1985, Quaterone 1993). Hybridization of white suckers with other native Colorado River suckers has been reported and could compromise the genetic integrity of the native fishes (Burdick 1995).

The body of evidence documenting the deleterious effect of nonnatives on the native fishes of the Colorado River system is sufficiently compelling to have convinced most experts in the region. Hawkins and Nesler (1991) polled regional fisheries experts and found that 81% believed nonnative fishes were responsible for significant problems in the UCRB. Maddux et al. (1993) reviewed issues related to the recovery of the four endangered big river fishes and found that interactions with nonnatives were the primary factor limiting recovery in some areas. Lentsch et al. (1995) identified the nature of negative interactions of many nonnatives with the endangered species. The nonnative fish issue has been studied thoroughly and we believe the conclusion is inescapable that introduced species have played a significant role in the decline of the native big river fishes, and continue to adversely effect the native fishes and their habitats.

The adverse effects that nonnatives have on the native species makes the natives "more susceptible to extinction by chance, catastrophe, and habitat alteration" (Frankel and Soulé 1981). Whereas competition and predation would not be regarded as major forces for extinction of continental biota, they could be significant factors for small populations of an insular fauna (Frankel and Soulé 1981, Raup 1991). The endangered fishes of the UCRB have already been described as part of an insular fauna, and the extant populations are small and isolated. It is therefore an appropriate and necessary that the UCRB fauna be viewed in the context of present theories regarding insular ecology (Wilcox 1980, Smith 1978, Molles 1980, Stanford and Ward 1986b).

The island (insular) model originally proposed by MacArthur and Wilson (1967) has been expanded by various workers to include any system that is insulated by barriers so inhospitable that movement and dispersals of organisms into or out of the system is greatly restricted (reviewed by Wilcox 1980, Frankel and Soulé 1981). Studies of large insular systems have shown that faunal collapse of vertebrate communities (i.e., loss of most of the vertebrate species) may occur when isolated ecosystems (isolates) are invaded by more diverse faunas (Wilcox 1980, Frankel and Soulé 1981). This collapse occurs for various reasons, but lack of habitat diversity and lack of defenses to new predators are main reasons (e.g. see Frankel and Soulé 1981). Smaller isolates, such as reserves, have been shown to be universally sensitive to faunal collapse (Wilcox 1980). The increasing fragmentation of the Colorado River system is presumably very similar to these smaller isolates, and pressures on the limited fauna do not have to be very great to cause serious impacts to them. In this context, the impact of nonnative fishes must be considered as a great menace to isolates of the once larger native fish community.

Nonnative Species of Concern

All of the fishes introduced into the Colorado River basin are suspected of adversely affecting the native mainstream fishes in some fashion. Salmonid fishes potentially have the least effect because they seldom come in contact with the younger stages of the native fishes in the upper Colorado River. As an example, it has been the experience of the senior author (HMT) that only the adults of the endangered species are collected sympatrically with salmonids in the Yampa and Green rivers. However, there are cases in which unusual circumstances result in predation by brown and rainbow trouts on one or more of the endangered species. Valdez and Ryel (1995) estimated that brown trout consumed 230,000 humpback chub annually in the Grand Canyon, and that rainbow trout consumed 27,375 annually. In addition, these authors reported that the trouts also compete with the chub.

Warmwater gamefish are thought to have the greatest adverse effect on endangered native fishes. This is consistent with the ANSTF (1994) report which listed centrarchids (e.g., largemouth bass, green sunfish, bluegill, black crappie, and smallmouth bass) and ictalurids (e.g., channel catfish and bullheads) as frequent contributors to the demise of native fishes nationwide. All of these species have been identified as causing problems in the Colorado River system (e.g., Hawkins and Nesler 1991, Lentsch et al. 1995).

In a survey of regional fisheries biologists, Hawkins and Nesler (1991) identified 28 nonnative fish species in the Colorado River Basin that were threats to the endangered fishes. Of these, channel catfish was considered the biggest threat. Other species listed by at least 35% of the respondents included red shiner, northern pike, common carp, green sunfish, and fathead minnow. Lentsch et al. (1995) determined that 6 nonnatives were existing threats (red shiner, common carp, sand shiner, fathead minnow, channel catfish, and green sunfish), 7 were considered potential threats, and 21 were no threat to the endangered fishes. The findings of these authors agreed with most of the fishes identified by Hawkins and Nesler (1991).

SECTION III. INSTITUTIONAL FRAMEWORK

General

Prior to 1950, fisheries programs in North America were devoted largely to stocking gamefish. There were few ecologists, and "virtually all fisheries biologists were fish culturists" (Wiley 1996). The introduction of nonnative fishes caused considerable damage to native fish populations, but little concern was registered in the scientific literature. Only recently have federal and state fisheries agencies developed management measures for nongame species.

The roles and responsibilities of federal and state agencies for protecting natural ecosystems have evolved gradually. Changes in policies of traditional fish and wildlife agencies have occurred in response to a growing perception that biodiversity is worth preserving and due to legislative pressures. The nonnative problem is so serious and pervasive that proposals to extend federal responsibilities, which would have caused considerable controversy with state agencies in the past, now have been met with a majority of acceptance (63% of state game and fish Agencies; USOTA 1993). Even so, gaps in federal and state efforts "constitute a serious threat to the Nation's ability to exclude, limit, and rapidly control harmful fish and wildlife" (USOTA 1993). Recovery efforts in the UCRB require the cooperation of federal and state agencies, as well as local government. It will therefore be helpful to review the legal framework at the federal and state levels, within which control actions may be taken in the UCRB.

Federal Agency Responsibilities

Federal wildlife agencies share the responsibility of managing natural ecosystems in the United States with state agencies. Control of wildlife species by federal agencies has arisen through a patchwork of laws that generally augment those of the states (Gilbert and Dodds 1992). Direct control by federal agencies occurs on lands under their control (e.g., Trust Lands administered by the BLM; National Wildlife Refuges administered by the US Fish and Wildlife Service, National Parks administered by the National Park Service) or indirectly through regulation (e.g., Migratory Bird Treaty Act, Fish and Wildlife Coordination Act, Lacy Act, Endangered

Species Act). Actions of federal executive agencies also are influenced by Executive Orders and Policy Statements.

Endangered Species Act

The Endangered Species Act of 1973, as amended (ES Act; P.L. 93-205), and earlier versions of the act required federal agencies to protect threatened and endangered species. Listed freshwater fishes were placed under protection of the U.S. Fish and Wildlife Service (Service). In accordance with the act, the Service has published rules listing four of the big river fishes of the Colorado system (the Colorado squawfish and humpback chub in 1967, bonytail chub in 1980, and the razorback sucker in 1991). Critical habitat was designated for all of these fishes in 1994 (USFWS 1994). These rules and listings were followed by recovery plans that discussed the status of, threats to, and other information about these fishes, and proposed a recovery outline and narrative to guide recovery efforts for them. Included with recovery efforts were biological consultations and opinions issued for the construction and operation of water development projects pursuant to Section 7 of the Act.

The Service, in consultation with other federal agencies in the upper Colorado River basin, has issued over 100 Biological Opinions pursuant to Section 7 (Rose and Hamill 1988). In general, these opinions determined that water depletions and dam operations would likely jeopardize the continued existence of one or more of the endangered fishes. A Recovery Implementation Program (Program) was established in 1987 and it oversees recovery activities in the UCRB, except the San Juan River (USFWS 1987). The Program provides funds for evaluating habitat requirements of the fishes, and seeks ways to obtain flows needed by the fish. Of the five management elements developed by the Program for recovering the endangered fishes, the "Nonnative Species and Sportfishing Management" component has been one of the most difficult to implement.

Participants in the Program have produced draft or interim procedures to limit stocking of nonnative fishes and to control nonnatives already present. Stocking protocols are being developed to provide guidelines for stocking nonnative fishes in a way that would not adversely affect the recovery of the endangered species. The procedures would be implemented to manage stocking in both public and private water. The elimination or removal of problem fishes is also being considered by the Program and its cooperators, and several studies have stressed the need for some plan to identify problems and recommend solutions.

Nonindigenous Species Act

Passage of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NIS Act; P.L. 101-646) was in response to concerns of United States and

Canadian governments about introduction of the exotic zebra mussel and other nonnative aquatic species were largely the result of economic hardships to the power industry and other parties. This act was the first major Federal initiative designed to stop or slow the invasion of nonnative species into the waters of the United States and Canada. Objectives of the NIS Act include: to prevent unintentional introductions of nonnative species; to coordinate federally conducted research, prevention, and other activities for aquatic nuisance species; to develop and initiate environmentally sound control measures to prevent, monitor and control introductions of nonnative species; and for other purposes.

The Aquatic Nuisance Species Task Force (ANSTF) was established by the NIS Act and given the task of identifying and recommending measures for the control of aquatic nuisance species (i.e., a nonnative species whose presence threatens native species and their aquatic ecosystems). The ANSTF was also instructed (Section 1207) to identify and evaluate ways for reducing adverse impacts caused by intentional introductions of aquatic organisms, and to submit a report on the findings. The ANSTF (1994) found that most nonnative species constitute a threat to the maintenance of biodiversity that is "vastly under recognized".

<u>Lacey Act</u>

The Lacey Act (as amended in 1981) makes it illegal to import, export, transport, acquire, purchase, or sell fish, wildlife, or plants that were taken, possessed, transported or sold in violation of US or Tribal Law. The act also makes international or interstate transport of wildlife taken, possessed, or sold in violation of foreign or state law illegal. This law covers all species protected by the Convention on International Trade in Endangered Species, the Endangered Species Act, and by state law. In addition, the act discourages the introduction of "injurious" species, such as the zebra mussel.

The Lacey Act does not provide adequate protection for natural ecosystems (Kurdila 1988), and it has other shortcomings that limit its effectiveness (USOTA 1993). The USOTA report includes recommendations that could strengthen the the Lacey Act to further protect against introductions of nonnative species..

<u>Executive Orders and Policy Statements</u>

Regulations for effective implementation of the NIS Act have yet to be finalized. However, Executive Order 11987 (Sections 2a,b) states that Federal executive agencies shall, to the maximum extent possible, restrict the introduction of nonnative species into natural ecosystem on lands and waters that they own, lease, or administer, and shall restrict the introduction of these species into any natural ecosystem of the United States. Although there has been no rulemaking on the NIS Act (ANSTF 1994), it is clear that federal agencies must be concerned with the nonnative issue. It is possible that Federal funding, including that provided by the Federal Aid in Sport Fish Restoration Act, may be reviewed for problems where intentional introductions of nonnative species may be impacting native species, especially endangered species and their ecosystems. Additional emphasis could be placed on using these funds to aid in the nonnative fish control problem.

Executive Order 11987 restricts federal agencies from using funds for nonnative species introductions unless it has been determined that the introduction will not have an adverse impact of natural ecosystems. The ANSTF (1994) defined intentional introductions as species that are knowingly brought into an ecosystem beyond its historic range. In recent cases, federal funding for nonnative introductions have not been approved without an Environmental Impact Statement, and it is anticipated that Section 7 consultations under the Endangered Species Act may also be required. The Task Force also discussed accidental escapes of nonnative species, which in some cases also were classified as intentional introductions, and cautioned that "even when the purpose of such import or transport is not direct introduction into an open ecosystem [, the] eventual introduction into open waters as the result of escapement, accidental release, improper disposal . . . or similar releases are the inevitable consequence of the original import or transport, not an unintentional introduction" (ANSTF 1994).

One of the major conflicts that has constrained efforts to control of nonnative fishes has been the potential loss of recreational sportfish opportunities in affected areas. There is widespread concern that increasing federal powers would limit recreational sport fishing, because many of the species of concern are game fish that have been introduced outside of their natural ranges (ANSTF 1994). President Clinton signed Executive Order 12962 on June 6, 1995 in response to this conflict, and pledged the support of U.S. agencies in cooperative agreements with states and tribes in furthering recreational fishing opportunities. In addition, recreational interests (i.e., the Sport Fishing and Boating Partnership Council) have met with the Fish and Wildlife Service and National Marine Fisheries Service and jointly developed a proposed policy statement recognizing the importance of endangered species, but striving to balance endangered species needs with the need for mitigating losses to recreational fishing. The policy statement recognizes:

> "1) the irreplaceable intrinsic and ecological value of all indigenous species; 2) States have primary management responsibility for non-listed and candidate aquatic species; 3) the preeminence of the ESA in issues effecting conservation and recovery of listed or proposed species; 4) the nationally important societal and economic value of recreational fisheries programs; and 5) the necessity of effective partnerships between stakeholders to achieve mutual goals." (SFBPC 1995).

Lead federal fish and wildlife agencies responded and clarified their policy and intent in a proposed rule that would guide development of any future regulations (US Fish and Wildlife Service and National Marine Fisheries Service 1995). This proposed policy acknowledges the potential for conflict between recreational fishing and the need to protect and recover federally protected species. Furthermore, it pledges that the Services will work with other Federal and State, Tribal, and Local agencies to reduce conflicts.

State Responsibilities and Regulations

State agencies regulate take, transport, culture, and other aspects of resident fish and wildlife by statute and regulation. States also protect and manage migratory (non-resident) species of fish and wildlife. As indicated above, there are overlapping responsibilities between federal and state jurisdictions, and as an example, federal agencies must fully cooperate with states when dealing with endangered and threatened species. Section 6 of the Endangered Species Act states: "In carrying out the program authorized by this Act, the Secretary shall cooperate to the maximum extent practicable with the States. Such cooperation shall include consultation with the States concerned before acquiring any land or water, or interest therein, for the purpose of conserving any endangered species or threatened species."

The three states involved in the UCRB recovery program are Colorado, Utah, and Wyoming. The involvement of Wyoming in proposed nonnative fish control efforts is likely to be minimal because waters of that state do not support populations of the endangered fishes, and because the state fisheries agency no longer stocks fish species that might compete with or prey upon the endangered fishes. Colorado and Utah are directly involved with the development of fish control programs and are cooperating with the Program.

Both Colorado and Utah have issued regulations that prohibit the "taking" of protected species (e.g., Colorado Division of Wildlife Regulations Chapter 10, Nongame Wildlife; State of Utah Code 23, Natural Resources Proclamation R657). While these regulations are important and necessary, they may not be sufficient for protecting endangered species. For example, Wilson (1992) reported that excessive harvesting, or illegal taking, has been a factor in the demise of less than 15% of the endangered fishes in North America. In addressing this problem, some states have passed their own version of endangered species statutes (e.g, Title 33, Colorado Revised Statutes) in an attempt to restore populations of endangered species and to remove the need for Federal listing.

General protection of wildlife is similar in the states of Colorado and Utah, and the principle agencies regulating fish and wildlife (wildlife) within these states are the Colorado Division of Wildlife, and the Utah Division of Wildlife Resources. Wildlife authority of the State of Colorado is provided under Title 33, Article 1 of Colorado Law, and all wildlife not lawfully owned by private individuals is the property of the state. No "right, title, interest, acquisition, transfer, sale, importation, exportation, release, donation, or possession of wildlife shall be permitted only as provided. . ." by state laws or regulations (Title 33-1-102). Utah Code 23-15-2 states that "All wildlife within this state, including but not limited to wildlife on public or private land or in public or private waters within this state , shall fall within the jurisdiction of the Division of Wildlife Resources", who shall protect, propagate, manage, conserve, and distribute protected wildlife throughout the state." Wildlife laws in Utah are determined by the Wildlife Board, which has responsibility under Utah Code 23-14-3 for establishing the policies best designed to accomplish the purposes and fulfill the intent of all laws pertaining to wildlife and the preservation, protection, conservation, perpetuation, introduction, and management of wildlife."

Any collection, importation, transportation, or possession of wildlife species or their parts are prohibited or controlled in the UCRB by state law. In general, this includes the operation of a private fish installation or pond requires (See Utah proclamation R657-3. Collection, Importation, Transportation, and Possession of Zoological Animals, Part IV. Certificates of Registration). Private fish facilities cannot be installed or developed on natural lakes or natural flowing streams, or reservoirs constructed on natural stream channels within these states without regulation.

Management policies for state wildlife agencies have been influenced by the fact that the agencies were established to regulate hunting and fishing (Gilbert and Dodds 1992) and most revenues are derived from sales of hunting and fishing licenses. Now that states are also responsible for managing federally protected species (e.g., migratory birds, endangered species) by permit, the task has become more complex and subject to controversy. For example, states have stocked game fish to expand recreational opportunities, but these nonnatives now pose a threat to endangered fishes. All upper basin states are now active participants in the Program and have expressed their desire to control nonnative fishes. However, little action has been taken because no final decisions have been reached about the fish species that should be controlled, where this control should take place, and what control methods should be used. There is a valid concern held by the states and others that actions taken in the UCRB to restrict intentional introductions (i.e., to remove the game fish, stop their release, or prevent their escapement) of certain injurious species would be met with political resistance, as has occurred elsewhere (Goodrich and Buskirk 1995).

SECTION IV: NONNATIVE FISH CONTROL

Conflicts, Attitudes, and Progress

Implementation of control measures for nonnative fish would bring this recovery need of the endangered species into conflict with established sport fishing interests in some locations. The issue is sociopolitical, and thus beyond the formal purview of this document, but an understanding of the potential for conflict must accompany any proposal for control measures.

A recent survey of nearly 900 people in eastern Utah and western Colorado reveals much about public attitudes and awareness about endangered Colorado River fishes (Vaske et al. 1995). A majority (66%) of those surveyed were not aware that the stocking of nonnative sportfish was detrimental to the endangered fishes. The survey also assessed attitudes about the extent to which the stocking of nonnative gamefish would improve the quality of fishing. Only about 50% of the general public, elected officials, and persons in environmental groups believed stocking improved fishing; but 69% of anglers believed that fishing quality was improved. When respondents were informed that stocking harmed endangered fishes, 75% believed that stocking should not occur. It is pertinent that the respondents lived in the area that could be affected by changes in sportfishing policies, and it is anticipated that support for endangered species would have been even higher if the poll had included the large metropolitan areas of those states, or if respondents had been made aware that the potential loss of sport fishing opportunities could be mitigated by opening new fishing areas.

The issue of nonnative fish control will have to be discussed more thoroughly in the public arena. The public is insufficiently aware of the threats that introduced species pose to the endangered fishes of the Colorado River system, and probably almost entirely ignorant of the possibility that inaction will lead to irreparable harm to the natural ecosystem. Awareness may be increasing now that some environmental groups have expressed dissatisfaction with proposals to stock predaceous game fish in the UCRB because they are concerned about potential threats to the native fish fauna (Wigington and Pontius 1996).

The ramifications of the conflict between control of nonnatives and sportfishing interests are felt acutely by the AFS, which strongly supports recreational and commercial fishing interests. The society is being forced to make some very difficult choices, but recognizes that "the integrity of ecosystems cannot be compromised to achieve fisheries management goals" (Wiley 1996). In a recent position statement (Starnes et al. 1996), the AFS asserts that fish introductions which have the potential to affect threatened and endangered species "should be very carefully regulated and ecological risk minimized." Furthermore the AFS recommends that potential effects on the entire watershed be thoroughly evaluated prior to stocking (Starnes et al. 1996).

The AFS had previously adopted protocols for introducing fish species (Kohler and Courtenay 1986).

There is little doubt that control of nonnative fishes will cause some reduction in recreational fishing opportunities; it is a necessary tradeoff. However, there are ways to mitigate such losses. On the other hand, if no action is taken to control nonnatives, and endangered species are lost, damage to the natural ecosystem cannot be mitigated. Both Federal and State agencies have responsibilities for protecting nongame species and for providing recreational spot fishing opportunities. Both are evaluating solutions. State agencies are working to refine stocking protocols and assisting with identifying potential problem areas. Federal designation of critical habitat (USFWS 1994) included a predator-free environment as a primary constituent element of critical habitat needed for recovery of the endangered Colorado River fishes. All federal agencies are mandated by the ES Act to do everything in their power to assist with those provisions needed in critical habitat, including aiding control measures for nonnative fishes or by assisting in mitigating losses in sportfishing.

Present Technology, Constraints, and New Options

Fish control measures have been so widely used in the US that almost all fish species have been the object of some control program (Wiley and Wydoski 1993). The most commonly controlled fish include herrings, minnows, and sunfishes (54% of effort), suckers (11%) and bullhead catfishes (11%). Wiley and Wydoski (1993) provide a comprehensive review of techniques, which fall generally into three categories: mechanical, chemical, and biological. Most of the techniques have been in use for many years and are well understood. Some of the more recent, and exotic, techniques (such as filtration of small life stages or establishment of fish guidance/removal facilities) are costly to implement.

A simple recitation of techniques without context is of little interest, because the choice of techniques is heavily influenced by the target species and the habitat in which the technique will be applied. It is therefore more useful to survey techniques that might be applied for controlling nonnatives in the UCRB.

There have been several reviews of control techniques that might be applied in the UCRB (Hawkins and Nesler 1991, Nesler 1995, Lentsch et al. 1995). In general, these reviews cover control methods that are well known among fisheries managers. Those authors advocate a cautious approach of establishing test areas and evaluating control effectiveness before applying a technique to other areas. The authors justified their caution by stating that the performance of individual control techniques has not been adequately studied in the UCRB. Some recommendations provided by Lentsch et al (1995) included: liberalizing fishing regulations to promote higher angler take; mechanical removal by nets, traps and shocking; barriers to keep out nonnative fishes;

use of fish toxicants to kill nonnative fishes in certain areas; biological controls by stocking Colorado squawfish; and management of flows to confer advantage on the natives and disadvantage on the nonnatives.

From a technical perspective, a control technique should be selected for its potential to remove the target species from a specific habitat without harming the beneficiary (i.e., endangered) species. The technical considerations, which alone present a formidable challenge, are complicated by sociopolitical (e.g., angler opposition) and economic factors. Predicting the effectiveness of a control technique can be difficult and imprecise. In a recent review of 250 fish control projects in the US, Meronek et al. (1996) found that only 43% met their objectives for controlling fish. The typical project involved mechanical removal of "rough fish" (e.g., minnows, catfish, suckers) from a small impoundment for the purpose of altering community composition in favor of gamefish. The authors also pointed out that a successful outcome of any control measure depended on providing suitable habitat and water quality for those fishes that were intended beneficiaries.

The endangered fishes, which are the presumed beneficiaries of any control project in the UCRB, are residents of the main river channel and complete their life cycle in the river and the adjacent floodplain. The introduced nonnative species, which would be the target of control measures, also occur in the main channel habitat and must be removed. Because many of the nonnatives do not reproduce in main channel habitats, consideration must also be given to control measures that will eliminate the source of nonnatives. Control measures for main channel habitats are constrained by the presence of endangered fishes and the physical complexity of the habitat. Chemical control techniques are therefore undesirable for the riverine habitat because it would be virtually impossible to prevent the loss of native endangered fishes. Control techniques which are suitable for use in the main stem, and which minimize the by-catch (incidental capture) problem, are chiefly mechanical, but may also include some flow manipulation options. Because the appropriate control measures are unlikely to be 100% effective, complete eradication of the target species is not a realistic goal where recruitment cannot be prevented. If the target species can restore its population through recruitment, the removal effort must be repeated. Managers must be prepared for a continuing investment in control measures.

The list of mechanical control techniques is extensive, but can be divided generally into the following categories: physical barriers (e.g. screens and nets), structural guidance devices (e.g. racks, louvers, collectors), modification to existing structures (e.g. bypass chutes, sluiceways), behavioral guidance devices (e.g. acoustic, visual, and electric barriers), and physical removal (e.g. traps, pumps)(Bates 1993, USOTA 1995). Once the nonnatives have been removed, they may be transported to another location if it is desirable to retain these individuals for recreational purposes. Because the traditional technologies are relatively well known among fisheries managers and have been reviewed elsewhere, the remainder of this review will focus attention on special considerations for main channels and more exotic techniques.

Fish passage, diversion, salvage, and removal facilities have been in place in various locations across the country for many years. These facilities are operated by public and private agencies, and usually have been constructed in an effort to reduce the loss of fish drawn into intakes for irrigation canals, power generation facilities and the likes (Bates 1995; USOTA 1995). One example with characteristics that might be suitable for the UCRB is a fish salvage project operated jointly by the US Bureau of Reclamation (USBR) and the State of California near the town of Tracy in the Central Valley (USBR 1985, California Dept. of Water Resources 1991). One facility was constructed in the 1950s and a second in the 1970s for the purpose of reducing the loss of fish (primarily striped bass and chinook salmon) when water is pumped from the Sacramento-San Joaquin River delta. A louver system separates fish from the intake water and the fish are transported to another location. The system takes advantage of fish movement in a manner that could be applied in the UCRB. Nonnatives could be separated from natives and the nonnatives could be relocated or destroyed.

Barriers can prevent fish movements permanently or selectively. The effectiveness of a barrier depends on a thorough knowledge of the behavior (e.g., dispersal, migration, home range movements) of both target and beneficiary species. Physical structures and electrical devices have been used to block fish movement at various locations in the Colorado River system. For example, the Arizona Game and Fish Department operates the Granite Reef Electric Fish Barrier on the Arizona Canal in the Salt River drainage (Wright and Sorenson 1995). Barriers could be used permanently or seasonally to prevent nonnative fishes from entering high priority habitat such as spawning areas or special recovery areas.

One scenario for a long-term control effort could be based on increased exploitation of channel catfish. The channel catfish is a predator that poses a serious threat to the endangered big river fishes of the UCRB. It is abundant and is able to reproduce in the riverine environment; complete eradication is not a realistic goal. The best a control strategy can anticipate for this species would be to minimize its negative impacts on the native fishes. This can be accomplished by focusing effort on the larger channel catfish, which are more likely to be piscivorous. Hill et al. (1995) found that channel catfish in South Dakota did not become highly piscivorous until they exceed 400 mm, at which time the relative importance of fish in the diet increased 25 times or more relative to that of smaller fish. Similar results were obtained by Tyus and Nikirk (1990) in the Green River basin. Although the size threshold for predominant piscivory may vary among river systems (Zurlin 1982), larger catfish still consumed more fish. Reduction in the abundance and size of channel catfish should aid the native fish communities by reducing predation risk.

Increased exploitation has the potential to cause a major shift in the size distribution of a channel catfish population, especially in locations where growth is slow due to natural conditions. In the Powder River system of Wyoming, effective exploitation virtually eliminated larger channel catfish (Gerhardt and Hubert 1991). The age and growth rates of channel catfish in Wyoming are very similar to that reported for the UCRB (Tyus and Nikirk 1990).

Commercial harvesting of channel catfish in the Missouri River was so effective at removing the larger, and commercially desirable, fish that the fishery had to be closed (Hesse 1994). The response of the fish population to closure of the fishery was dramatic. In six years, the proportion of larger fish (>330 mm TL) increased by 36%. If channel catfish in the UCRB could be exploited to a similar degree, the threat of predation could be greatly minimized. The level of effort is likely to be high and may not be sustainable without a commercial operation.

Fish control technology is an active area of research for public and private entities (e.g., Stone and Webster 1986, EPRI 1988, Cada and Sale 1993). Entirely new approaches, like guidance systems that rely on fish behavioral responses for redirecting fish movements (Bell 1990), have been developed in recent years. Although a detailed accounting of emerging technology is beyond the scope of this report, it is encouraging that new options are becoming available.

In addition to the use of mechanical techniques for controlling nonnative fishes in the main channels of the UCRB, physicochemical methods also may have merit (Lentsch et al. 1995). Flow regulation helped meet habitat needs of the endangered species, especially the Colorado squawfish in the Green River (Tyus and Haines 1991). There is some indication that the timing and duration of instream flows may not only benefit the native fishes, but also place some of the nonnative fishes at a disadvantage. Enhanced flow regimes can shift fish communities to a more diverse fluvial community of native species (e.g., Travnichek et al. 1995). According to Muth and Nesler (1993): "Management of flow regimes to approximate natural hydrographs and periodically provide above-average magnitudes in spring-summer discharges may benefit native fishes and inhibit certain prolific nonnative fishes."

Physicochemical manipulations may also influence the growth and survival of nonnative fishes. For example, increasing turbidity may be disadvantageous to visual predators, thereby advantageous to native prey species (Wootton 1990; Miner and Stein 1996). Also, manipulating water temperature holds potential as a control mechanism for species that are marginal under present conditions (see Tyus and Nikirk 1990, Rutherford et al. 1995).

Flow manipulation may be the only available control option for some of the small cyprinid species, such as fathead minnow, red shiner, sand shiner, and redside shiner.

There is some evidence that the abundance of these species is reduced by high river discharges and lower water temperatures (reviewed by Lentsch et al. 1995). Management of flow regimes to approximate natural hydrographs could suppress the abundance of these cyprinids. Muth and Nesler (1993) found that moderately high daily mean discharges were associated with later initiation of spawning and shorter spawning season for the red shiner, sand shiner, and fathead minnow. Higher discharges resulted in an earlier initiation of spawning for the redside shiner, probably due to the preference of this species for cooler water. Smaller life history stages of cyprinids and centrarchids may be especially susceptible to flow changes, and Harvey (1987) found that fishes 10mm or less in length were very susceptible to downstream displacement by flooding. However, displacement of the small life stages may depend on "small differences in the timing of reproduction and of flooding" (Harvey 1987). Cause and effect relationships between discharge and the abundance of cyprinid populations in the UCRB appear to be weak at this time.

For some of the nonnative species, the principal source of recruitment is not the riverine environment. Nonnatives, especially most of the centrarchids, are reproducing in impoundments or floodplain ponds. Escapement from these areas provide a steady source of individuals into the river system. Control of these nonnative species would be more effective if the sources were eliminated. Chemical removal techniques could be applied very effectively in isolated water bodies, but may not be palatable to the public where recreational opportunities would be lost. Escapement controls might be an acceptable alternative. Many traditional devices exist for preventing escapement. In addition, new technologies have recently been developed for filtering and/or destroying small organisms from discharges and intakes. These new technologies are the result of recent invasion of the zebra mussel into the Laurentian Great Lakes, and the zebra mussel veliger, which is smaller than ichthyoplankton, is now being completely removed (e.g., see Nalepa and Schlosser 1993 and references therein). The technology is available for preventing the escapement of even the smallest fish.

SECTION V. DEVELOPING SOLUTIONS

Background

Considerable scientific effort has been devoted to understanding how nonnative fishes have affected the endangered big river fishes of the upper Colorado River basin. The scope of the problem is well known, albeit complex: predation and competition by nonnative fishes have contributed to the decline of endangered native fishes. Resolution of the problem, in a broad sense, will require removal or reduction of nonnative fish populations that threaten listed fishes. The problem and the general solution were clearly defined in element 4.4 of the Recovery Implementation Program (Program; USFWS 1987).

Much less effort has been expended on developing practical solutions and prioritizing tasks. In essence, the Program lacks a strategic plan that will guide efforts to control nonnatives. A formal strategic plan is presented in the final section of this document. In developing a useful strategic plan, answers to four basic questions were required: (1) In what geographic areas would control measures have the greatest benefit? (2) Which life history stages of the endangered fishes are most susceptible to negative interactions with nonnative fishes? (3) Which nonnative species pose the most serious threats? (4) Which control methods will be most effective? Answers to questions 1 and 4 are required for developing more site-specific implementation plans, which are beyond the scope of this document.

The Program specified that a logical step in the development of a strategic plan would include a workshop to tap the collective expertise of scientists and managers familiar with problems in the UCRB. The workshop would focus on nonnative fish control issues as perceived by experts from different geographical areas and governmental agencies within the basin. It would provide an opportunity to expand the information base for control options, and be a forum for reviewing the problem and establishing priorities for future action.

Workshop Format

A facilitated workshop on control of nonnative fishes in the UCRB was held on November 30 and December 1, 1995. Every effort was made to identify and include all major stakeholders, and to involve a wide range of technical and managerial expertise. The agenda and a list of participants with their agency affiliations are given in the Appendix. The workshop dealt with the technical issues and consisted of three parts. In Part 1, six presenters discussed potential control measures and factors that could affect the success of those measures in the UCRB. In Part 2, state representatives discussed present opportunities for fish control in their respective jurisdictions. In Part 3, all workshop participants assisted in developing elements of the strategic plan. The workshop specifically avoided sociopolitical and economic issues. The workshop provided an opportunity for mapping areas where consensus already exist and for identifying areas where additional information is urgently needed. It was not intended as a vehicle for forging consensus.

The first workshop session consisted of formal presentations by experts familiar with fish control issues and techniques. National and regional perspectives of technical and management issues immersed participants in the various facets of fish control. In the second session, representatives of State fish and wildlife management agencies in Colorado and Utah described fish control practices and possibilities appropriate for their jurisdictions. The third session began at the end of the first day when all participants received a packet of handouts (see Appendix) that outlined the major questions posed for the next day. The handouts included information sheets to serve as a focus for discussion and for mapping consensus on priorities. Each participant reviewed the materials and marked rankings for those items for which he or she had sufficient expertise. On the next day, participants were assigned to one of four subgroups in which there was a mix of scientists, managers, and interested parties from different parts of the basin. Each group reviewed individual responses to the handouts and produced a single set of responses that was a distillation of group views. Where consensus was easily achieved, a single ranking might be shown, but where group members differed, a range of rankings might be shown. At the conclusion of the small group discussions, the entire group assembled to review and comment on the small group findings.

After the worksheets and priorities had been discussed, participants returned to subgroups for developing control solutions that would address priority needs. Each subgroup then presented control scenarios to the whole group and discussed potentials and problems.

Workshop Results

The tangible products of the two-day workshop consist chiefly of a set of priorities that focused attention on 1) the geographic areas where nonnatives imperil endangered species, 2) which nonnatives pose the most serious threats, and 3) what techniques were the most promising for control of the nonnatives. The list of priorities was supported and explained by extensive notes recorded during discussions, and transcriptions of the formal presentations (see Appendix for a brief synopsis of topics). Results of the workshop provided guidance in developing the Strategic Plan (Section VI of this document), but did not cover all areas addressed in the strategic plan.

<u>Geographic priorities</u>

The list of river reaches used in the workshop (Figure 2) is only one of the possible classification systems. It reflects years of experience with the fishes and their distributions, and conforms more or less to major geomorphologic features. A more formal geomorphologic scheme is under development, but was not ready for use at the workshop (Frank Pfeifer, USFWS, personal communication, 1996). The correspondence between river reaches identified for the workshop and critical habitat as defined by the USFWS (1994) is also shown in Figure 1.

The geographical distribution of life history stages (Table 2) was compiled prior to the workshop (based chiefly on Tyus et al. 1982) and amended by participants based on their experiences. Certain river reaches, for example the lower Yampa (Y1) and the Green River from Split Mountain to Echo Park (G3 and G4), are important for most or all life history stages of the three endangered species. Other river reaches (e.g., Y3, G6, DO1) do not support populations of these species. The geographical distribution of the endangered fish was an important determinant of control strategies.

Within each of the four small groups of the workshop, there was extensive discussion regarding the assignment of priority for recovery to each of the geographic reaches. The rankings presented in Table 3 reflect the outcome of some negotiations that occurred within each small group. Groups differed somewhat in terms of the criteria on which priorities were based. For example, one group attached a higher ranking to an upstream reach or a tributary if it provided flows or influenced water quality in a manner beneficial for the maintenance of one or more life history stages of the endangered species. The importance of physicochemical parameters such as flow, temperature, and sediment was also recognized in terms of their effect on possible reintroductions. Some participants assigned recovery priorities mainly on the basis of the current distributions of the endangered species, while others included reaches with potential for recovery. Because the small groups employed somewhat different evaluation strategies, the authors have had to exercise some judgment when summarizing the information for the Strategic Plan.

Concern for the presence of nonnatives in various locations was governed by some of the same geographical considerations that influenced priorities for recovery of natives, but other factors also came into play. Discussion at the workshop revealed a pragmatic assessment of priorities. The predominant approach involved assigning priorities on the basis of the following question: "If you were going to kill nonnative fish today, where would you go?" Not surprisingly, the ranking of reaches on the basis of control prospects shows a somewhat narrower scope than priorities for recovery (Table 4). Concern for nonnative fishes occurred chiefly, but not exclusively, where the listed species are most abundant. In general, there was much less concern about the potential for interactions than for those interactions that are likely to be occurring now. There were also two reaches (Y3 and D1) where the concern for interactions exceeded priorities for recovery. These selections are significant because they acknowledge importance of upstream reservoirs as sources of nonnatives that should be controlled.

The importance of geographic areas for fish control were assessed after the workshop was over. Each participant received copies of tables summarizing workshop results and was asked for additional comments. Workshop results and supplemental comments were used to prepare a summary (Table 5) for each geographic area addressed in Tables 2-4. For information given in tables 3 and 4, a Low score was assigned if three or four of the small groups had given the geographic area a low priority. In cases where three or four small groups assigned a rank of High or Medium/High, a score of High is given in Table 5. Other combinations of small group scores resulted in a summary score of Medium. In case of even divisions among the work groups (e.g., 2 medium and 2 high rankings), the summary score would include both rankings (e.g., M/H). The information on Table 2 was not ranked by workshop participants, and presented as the sum of all life history stages.

Interactions with Nonnative Fishes

The geographic assessment of concerns for the presence of nonnative fishes does not reveal the identities of the nonnative species or the type of threat posed to the native species. However, much of this work has been done previously and is essential for developing control strategies. Using information compiled from Hawkins and Nessler (1991) and Lentsch et al. (1995), a table was prepared to indicate major nonnative fish threats to listed species, the type of interaction, and the location that provides the source of each nonnative species. The information in the table was refined and expanded with the expertise of the participants (Table 6).

At least 20 nonnative species may have negative interactions with the listed species. The riverine populations of most of these species are maintained by reproduction in the river or escapement from ponds in the adjacent floodplain. Some species are derived chiefly by escapement from reservoirs. Smallmouth bass, crappies, bluegill, green sunfish and northern pike, for example, have entered the system from reservoirs in the upper part of the basin, and striped bass enter the system exclusively from Lake Powell. Only trout are still stocked directly to the rivers of the system below Flaming Gorge Dam.

Negative interactions occur primarily through predation or competition; predation on eggs and larvae is particularly troublesome because it precludes recruitment. Hybridization of the razorback sucker with the white sucker is a concern because white suckers are known to hybridize with other native Colorado River suckers (Burdick 1995).

Nonnative Threats

Workshop participants identified numerous negative interactions, actual and potential, between introduced species and listed species. However, not all interactions were considered equally important. The relative importance varied according to the life history stage of the listed species. White sucker and trout, both of which were listed on Table 6, were not assigned a rank for the strength of negative interactions. Therefore those species were deleted from further consideration.

Predation was the primary basis for ranking the negative interactions. In general, the rankings for the Colorado squawfish and the razorback sucker were very similar and will be discussed together. Nonnative predation on eggs and adults was regarded as relatively minor. Threats to juveniles were typically less of a priority than threats to larvae, because the larger size of the juveniles (130 to 150 mm at the end of the first year for razorback suckers) would greatly reduce their vulnerability to predation. Green sunfish, channel catfish, red shiner, and fathead minnow were considered the most serious threats to larvae of both of the native species. Concern for interactions with centrarchids was generally high.

As mentioned previously, negative interactions of nonnative fishes on the juveniles of Colorado squawfish and razorback sucker were less than that for the larvae. Channel catfish, smallmouth bass, and pike were a greater concern for the juveniles of the two natives. From a control perspective, channel catfish, small cyprinids, and centrarchids merit attention.

The rarity of the humpback chub and lack of knowledge about its interactions with nonnative fishes in the UCRB made it difficult to identify chief threats them. Most participants felt they did not have sufficient information to evaluate those threats with any certainty. Nevertheless, the general opinion held that threats from channel catfish were the most serious.

Channel catfish was regarded as a highly significant threat to the listed species. It was accorded a high level of concern for interactions with larvae and juveniles of all listed fishes, and no other species received as many high rankings. The fish species representing the next most important threats were the green sunfish, fathead minnow, and red shiner.

Control Measures

Most of the control measures suitable for use with nonnative species in the UCRB were reviewed recently in Lentsch et al. (1995). These fall into four general categories: mechanical techniques (traps, nets, seines, and electrofishing), chemical removal (i.e., poisons), biological techniques (introduce other predators, infectious agents like channel catfish viral disease), and physicochemical manipulations (altering flow regime or water chemistry through reservoir releases). During the workshop, experts suggested four measures not treated in Lentsch et al. (1995). Larry Hesse presented insight into commercial harvesting, which relies on mechanical techniques, on a large scale that could greatly reduce channel catfish populations. Todd Crowl discussed the use of exclusion structures for protecting nursery habitat and enhancing the recruitment of native fishes. Escapement controls were suggested for reservoir outlets to prevent the nonnative fishes from reaching surface waters connected with the river. Larry Hesse also brought up the possibility of using a Llewellyn weir, which incorporates electroshock.

Not all nonnative species are equally susceptible to specific control measures (Table 8). Furthermore, the listed species also will be removed by many of the control measures. The chief problem with any fish removal measure is one of selectivity. How can the method be applied in space or time so that the "by-catch" of natives is minimized? The decision process by which a method is selected must include consideration of any adverse effects the method may have on natives.

Workshop participants ranked control measures according to their potential for controlling nonnatives (Table 9). Some participants expressed great hope in the potential of commercial harvesting to remove channel catfish and perhaps common carp. However, the fear of unintended mortality to some of the native fishes also was of concern. It was thought that choice of bait and placement of traps could make the harvesting technique sufficiently selective to minimize concerns about by-catch. Northern pike and common carp are thought to be relatively susceptible to other mechanical techniques such as nets, electrofishing, or traps. Centrarchids are also susceptible to mechanical techniques but may not be present in sufficient abundance in the main channel to justify the effort.

Management of the flow regime has been suggested as a mechanism for reducing populations of small cyprinids that are reproducing in the main channel as well as centrarchids. There is some concern however that the potential for success with this technique is unproven.

Most mechanical techniques have potential for reducing the abundance of nonnatives in the river. However, if the recruitment of nonnatives cannot be curtailed or eliminated, removal becomes a continuing obligation. The single most important mechanism for reducing recruitment of those nonnatives that do not spawn in the river channel is either to eliminate stocking in the floodplain or to install effective escapement controls on reservoirs and smaller water bodies connected to the river. Populations in the floodplain can be eliminated by chemical techniques, but the risk for loss of natives in the main channel may be too high for chemicals to be applied in some locations.

Ultimately the control measures must reduce the threat of negative interactions to the point where natives will have successful recruitment. To the extent that exclusion structures may enhance recruitment of natives, they would be worth considering. However there are considerable logistical obstacles.

The goal for controlling the nonnative fish populations is to increase recruitment of native fish populations. Control efforts should therefore be focused on various nonnative species that pose the most serious threats and in the locations where control of nonnatives would be the most beneficial. Ideally, each of the promising techniques should be evaluated in scientific trials that would test efficiency and cost effectiveness. Unfortunately, stocks of some native fishes are dwindling and, despite a clear need for more research, the urgency of the situation dictates that actions be taken on the basis of best professional judgment. Participants were therefore asked to describe scenarios that could be used for applying a specific control technique for the control of one or more nonnative species at particular geographic locations.

Solutions

Scenarios for control of nonnative fishes involve four significant dimensions: (1) geographic scope, (2) nonnative species, (3) source of the nonnatives, and (4) control techniques. The geographic considerations are arguably the most important of the four dimensions for defining a scenario. For example, a scenario could target critical habitat of one or more listed species, or it could specify the most important sources of the nonnatives. The selection of a target nonnative species is an important consideration that will shape a control scenario. Once the target location and nonnative species have been selected, the control technique can be tailored to the target species and the principle source of the nonnatives.

An abbreviated version of the many scenarios presented at the workshop is shown in Table 10. The scenarios generally follow three basic themes. The first theme involves preventing nonnative fishes from entering the system. For example, escapement controls could be installed on major reservoirs like Starvation, Elkhead, Kenney, and Highline. For ponds in the floodplain, chemical techniques can be applied to eliminate nonnatives. In general, however, stocking policy may be very important especially for floodplain sources. The second theme deals with removal of nonnatives from the main channel. Typically mechanical techniques such as trapping, would be applied in critical habitat for the removal of larger nonnatives such as channel catfish, carp, and perhaps some centrarchids. Flow management, especially in high gradient areas, has some potential for reducing populations of small cyprinids and the centrarchids, if timed correctly. The third theme involves excluding nonnatives from interactions with native fish species chiefly during early life history stages. Backwater exclusion devices and the active management of the inundation cycle for backwaters and floodplain ponds could reduce predation on larval nonnative fishes.

The specific geographical area selected for applying control techniques would depend on the theme being pursued and the scope of the control activity. Participants adopted a two-tiered approach in which control strategies were proposed basin wide, or they focused on specific geographic locations. In general, the geographic locations identified in Table 10 conformed with priority areas designated for recovery and for interactions with nonnative fishes (Tables 3 and 4). Important geographical locations included the Lower Yampa and Green rivers (Y1, G1-4) and the upper Colorado River, UC1 and UC2). A few of the strategies were less specific about geographic locations (e.g., "critical habitat", or "nursery areas"), but it was relatively easy to associate the strategies with important habitats described in Tables 3 and 4. Thus, for the most part, participants recommended only a few key geographic areas for implementation of control strategies, especially for those strategies that required a large investment of labor.

Virtually all of the scenarios focus control efforts on nonnatives that have been identified as predators. This is not surprising, due to significant problems that have been reported for some of the fishes. Of all the predators discussed, the channel catfish was mentioned most frequently in the scenarios. Common carp and several centrarchids were also mentioned frequently, perhaps due to the possibility for using the same control method for all three of these species.

Most participants were concerned with predation of nonnative fishes on larval and juvenile life stages of the listed fishes and many of the scenarios directed effort at reducing the abundance of predators in the channel or in nursery areas. Other scenarios were directed at controlling the input of nonnative fishes from lentic habitats (e.g., floodplain ponds and reservoirs) or from stocking.

The recommended control measures were a diverse mix of techniques and methods that have been recommended in the past. The most commonly mentioned method was mechanical removal by use of traps. The most unusual technique involved establishment of a commercial fishery for channel catfish and common carp. Other methods involved policy changes that would govern stocking, or set fishing regulations to assist in removal of nonnative fishes. Flow management for nonnatives is already part of the Program and presumably will be implemented as part of a program that improves habitat for the native fishes as well. Some techniques were intended to prevent or reduce the movement of nonnatives into the mainstream river, and included pond reclamation (chemical fish removal), escapement control, and nursery protection.

The beneficiary native species was not always specified in the scenarios (Table 10). Nevertheless, it was clear from the workshop discussions that threats to the Colorado squawfish and razorback sucker were very similar (Table 6). There was less certainty about interrelationships between nonnatives and the humpback chub, due to a general lack of information about the humpback chub in the UCRB.

Workshop discussions also included the need for pursuing some control actions in a particular sequence. For example, northern pike now exist in the Gunnison River because of escapement from Paonia Reservoir. There are plans to improve floodplain and backwater habitats in this area to benefit native species. However, these improvements also could harbor nonnative species such as northern pike. It would be prudent to remove the pike from the system before preceding with the habitat improvements.

The scenarios developed by workshop participants represented a range of possibilities, but should not be taken as an exhaustive list. A limited amount of time was available at the workshop for discussing solutions. Proposals reflect clearly the priorities identified for geographic location, target species, and control measures. Rationales for additional scenarios should incorporate these priorities. However, the workshop was limited only to discussing technical problems and solutions. Obviously, sociopolitical issues will have bearing on any control strategy, and those issues were not discussed in this forum.

SECTION VI. THE STRATEGIC PLAN

DEVELOPMENT AND PRESENTATION

Preceding sections of this document have discussed the problem that nonnatives pose for the native fishes of the UCRB and the elements required for its solution. The final section of the document will present a strategic plan that outlines steps for facilitating the recovery of the endangered fishes. The formulation phase of the plan consists of defining problems and proposing strategies for solving them. The plan also includes an implementation phase to anticipate problems and conflicts that may hinder implementation of each strategy. For each potential problem or conflict, the plan identifies some action or resolution. Although the strategic plan includes the aforementioned implementation phase, the plan is expressly not a forum for presenting the detailed operational plans necessary for implementing proposed strategies. The specific details of implementation, as well as the assignment of responsibilities for each task, are beyond the scope of this document.

The strategic plan is presented in three sections. The Overview, which lists the goal and objectives in general terms, includes no details about geographic areas, target species, or beneficiary species, and it dwells only briefly on control methods. The Strategic Plan Outline applies the organizational framework of the Overview to specific geographic areas. Details of target species, beneficiary species, and control method are supplied as appropriate. The Narrative casts the Strategic Plan Outline in a paragraph format and supplements the outline with justifications for actions and clarifications of issues.

Three main objectives are defined under the single goal of this strategic plan. The first two objectives focus on the technical aspects of prevention and control of nonnative species. The third objective involves mitigation of potential sociopolitical problems. Basin-wide problems have been assigned the highest priority for implementation. The next level of priority was assigned to three river reaches selected on the basis of information from workshop participants and from synthesis of additional information. Adjacent geographic areas may assume greater importance in the plan than was assigned during the workshop because the nonnatives they harbor have direct bearing on recovery efforts in each of the three high priority reaches. Within each geographical area, the order of priority for addressing problems is: 1) prevention, 2) control, and 3) mitigation.

OVERVIEW

GOAL: FACILITATE SUCCESSFUL RECOVERY OF THE ENDANGERED BIG RIVER FISHES OF THE COLORADO RIVER (CR) BY CONTROLLING THE INTRODUCTION AND PROLIFERATION OF NONNATIVE, NONSALMONID (NN) FISHES IN THE UPPER COLORADO RIVER BASIN (UCRB).

OBJECTIVES:

OBJECTIVE 1: Prevent further spread of NN fishes into habitats of endangered fishes of the UCRB. Achieving the objective will generally require:

a. Preventing escapement of NN fishes from waters actually or potentially connected with habitats of endangered fishes.

b. Preventing further introductions of NN fishes that might invade habitats of endangered fishes.

c. Preventing further range expansion of NN fishes in habitats of the endangered fishes.

OBJECTIVE 2: Control NN fishes and their negative interactions on the native CR fishes. Achieving the objective will generally require:

a. Using mechanical methods and techniques such as barriers, traps, weirs, seines, electrofishing, and harvesting to reduce or eliminate NN fishes in habitats of the endangered fishes.

b. Using chemicals to remove NN fishes from isolated water bodies provided that the use of chemicals will pose no threat to the endangered fishes.

c. Using flow management to reduce or eliminate NN fishes without reducing the potential for recovery of endangered CR fishes.

OBJECTIVE 3.

Resolve sociopolitical issues of implementing NN fish control through enhanced cooperation between federal, state, and local agencies, and by establishing partnerships with nongovernmental entities. Achieving the objective will generally require that:

a. Federal and state agencies work together on selecting and implementing appropriate fish control measures after careful consideration of technical and sociopolitical factors that may constrain choices. Agencies should assist one another in planning future activities, developing sport fisheries mitigation, and implementing activities in a timely manner.

b. More effective dissemination of information to inform the public about the importance of preserving endangered fishes and the consequent need to control nonnative fishes, as well as efforts being made to offset any potential losses of recreational fishing opportunities.

STRATEGIC PLAN OUTLINE:

Formulation Phase | Implementation Phase

Basin wide Planning

Problems	Strategies	Potential Problems and Conflicts	Action/Resolution
1. Continuing NN fish introduction, escapement, and range expansion into endangered fish habitats.	a. No stocking of NN fishes except as permitted under formal stocking procedures that ensure protection of the endangered species.	a. Loss of desirable recreational fisheries. Control of private stocking.	a. Mitigate fishing loss. Need for additional regulation governing private stocking.
	b. Prevent escapement of NN species from current sources.	b. Private land ownership, management of recreational fishing.	b. Obtain easements, provide mitigation. Provide incentives for pond renovation.
	c. Implement chemical control measures in suitable areas.	c. Loss of recreational fisheries; toxin containment; effectiveness; cost.	c. Review protocols for toxin containment; information and education.
	d. Construct and maintain barriers or guidance systems that prevent range expansion of NN species.	d. Cost. Need to Identify lead agencies for O&M.	d. Interagency agreements.

Problems	Strategies	Potential Problems and Conflicts	Action/Resolution
2. High abundance of nonnative fishes (predators and competitors) in UCRB.	a. Mechanical removal by :		
	i. Capturing NN species at fish passage facilities.	I. Effectiveness unknown.	I. Evaluate effectiveness at Redlands facility.
	ii. Increasing harvest by anglers	ii. Fishing regulations.	ii. Change creel limits.
	iii. RIP-sponsored harvesting program	iii. Costs; angler dissatisfaction	iii. Promote alternative fishing opportunities.
	iv. Commercial harvesting.	iv. Expertise, bycatch, marketing, disposal.	iv. Obtain expertise, control logistics, marketing survey, possible subsidies.
	b. Continue present program of flow management.	b. Water rights and flow-regulation; long-term effectiveness.	b. Monitor effect on NN populations. Acquire additional rights as needed.
3. Loss of sport fishing opportunities.	a. Replace lost recreational fishing opportunities through cooperative efforts of state and federal agencies.	a. Little precedent for mitigation of this kind.	a. Develop action plan including information and education components.

Yampa River Basin- Highest priority reach= Deerlodge to Echo Park

Problem	Strategies	Potential Problems and Conflicts	Action/Resolution
1. Movement of NN fishes (chiefly large predators such as northern pike and smallmouth bass) into mainstream from impoundments (e.g., Elkhead Reservoir), water bodies in the floodplain, and adjacent main channel areas (upstream Yampa).	a. Remove cool/warmwater fishes from reservoirs and other water bodies for which effective escapement controls are not installed.	a. Loss of cool/warmwater fishing opportunities.	a. Replace with salmonids. Mitigate by developing cool/warmwater fishing opportunities elsewhere.
	b. Control escapement of NN species by methods such as screens or filters.	b. Technology expensive and may fail under high flow conditions.	b. Pilot project on Elkhead Reservoir.
2. NN predators in mainstream habitats prey on natives (especially humpback chub and larval Colorado squawfish).	a. Agencies remove predaceous fishes, including pike and bass by any available means.	a. Angler resistance to potential loss of recreational opportunities.	a. Develop mitigation program that will replace lost recreational opportunities.
	b. Increase harvest of NN species (especially pike, bass, and channel catfish) by anglers.	b. Fishing regulations.	b. Suspend creel limit.
	c. Harvest channel catfish and carp by commercial or RIP-sponsored exploitation.	c. Regulatory issues; available expertise; interagency cooperation.	c. Obtain expert assistance, change regulations.

Problem	Strategies	Potential Problems and Conflicts	Action/Resolution
3. Movement of NN fishes into Yampa from Green River.	a. Control fishes from the Green River by implementing Green River control program. b. Install barriers, guidance systems.	a. May be expensive to operate Yampa and Green programs concurrently. b. Cost. NPS objections.	a. Examine tradeoffs as necessary. b. Evaluate.

Green River- Highest priority reach= Echo Park to Desolation Canyon

Problems	Strategies	Potential Problems and Conflicts	Action/Resolution
1. Movement of NN fishes into mainstream from impoundments (e.g., Kenney, Starvation, Bottle Hollow reservoirs), water bodies in the floodplain, and adjacent main channel areas (e.g., Yampa, White, Green).	a. Control fishes in Yampa by implementing Yampa River control program.	a. See Yampa plan.	a. See Yampa plan.
	b. Control carp in upper Green system (e.g., Browns Park bird refuges) by removal or exclusion.	b. May be expensive. Interagency cooperation.	b. Coordinate planning efforts between agencies.
	c. Prevent escapement or remove centrarchids from Kenney Reservoir.	c. May create angler dissatisfaction at Kenney Reservoir and elsewhere in the White River basin.	c. Mitigate angler dissatisfaction through incentives.
	d. Control centrarchids in Duchesne River system by mechanical (e.g., block and seine) or chemical methods.	d. Tribal agreements.	d. Coordinate planning between agencies and tribes.

Problems	Strategies	Potential Problems and Conflicts	Action/Resolution
2. NN predators in mainstream habitats prey on natives (especially young razorback sucker, Colorado squawfish, and humpback chub).	a. Increase harvest of NN species (especially channel catfish, carp, and centrarchids) by anglers.	a. Fishing regulations.	a. Suspend creel limits and provide incentives.
	b. Implement commercial or RIP-sponsored programs to increase harvest of NN fishes (especially centrarchids, walleye, and channel catfish).	b. Regulatory issues, interagency cooperation, expertise.	b. Obtain expert assistance. Change regulations.
	c. Determine feasibility of barriers and guidance systems for removing NN fishes.	c. Expense, location of suitable site, O&M costs, unknown effectiveness.	c. Evaluate.
3. Flooded bottoms may create reservoir of NN fishes (especially carp).	a. Discourage establishment of NN fishes by keeping flood duration brief, by preventing access, and by preventing escapement.	a. Flow management program is new and of uncertain capabilities.	a. Obtain technical assistance, evaluate, monitor, develop new options.

Upper Colorado River Basin- Highest priority reach= Government Highline Diversion to Cataract Canyon.

Problems	Strategies	Potential Problems and Conflicts	Action/Resolution
1. Movement of NN fishes into mainstream from impoundments, water bodies in the floodplain, and adjacent main channel areas (e.g., Gunnison).	a. Remove NN (chiefly centrarchids) from floodplain ponds.	a. Ponds in private ownership.	a. Develop means for compensation.
	b. Remove or control escapement of NN (e.g., pike, centrarchids) from upstream areas, including Gunnison River.	b. Loss of recreational opportunities.	b. Provide incentives for landowners to control escapement.
	c. Stop stocking NN in 100 year flood plain.	c. Management of recreational fishing.	c. Mitigate lost fishing opportunity.
2. NN predators in mainstream habitats prey on native fishes (especially humpback chub and larval Colorado squawfish).	a. Increase harvest of NN fishes (e.g., channel catfish) by anglers.	a. Fishing regulations.	a. Suspend creel limits.
	b. Evaluate RIP-sponsored and commercial fishing feasibility.	b. Expertise. Regulatory issues. Interagency cooperation.	b. Obtain expert assistance; change regulations.

NARRATIVE OF STRATEGIC PLAN ELEMENTS

Basin wide planning

1. Continuing NN fish introduction, escapement, and range expansion into endangered fish habitats.

Problems--The endangered fishes, and the native fish community to which they belong, have been adversely affected by the introduction and proliferation of nonnative fishes. Nonnative fishes continue to invade endangered fish habitats by introductions, escapement, and range expansions. All nonnative fishes are suspected of having negative interactions on the native fish community. Predation on endangered species by the larger, more aggressive species has been documented, and agonistic behaviors have been documented for smaller species. The nonnative fishes of primary concern are nonsalmonids. Most salmonids are coldwater species that do not occupy the same habitat used by the native fishes. Preventing the movement of additional nonnatives into main channel habitat is a key step in any control program. Failure to do so could undermine efforts to control nonnatives already in main channel habitat.

Strategies-- Nonnative fishes continue to escape from reservoirs, impoundments, tributaries, and other water bodies. Recovery of endangered fishes will be difficult, if not impossible unless this continued input of nonnative fishes is prevented. Stocking of nonnative fishes must be discontinued except where permitted by stocking protocols that ensure protection of endangered species. In locations where nonnatives fishes are desired for sportfishing programs, their escapement must be prevented. Some barriers already exist to limit the range of nonnatives fishes. These barriers should be maintained where necessary to prevent further invasion and others could be developed if needed. Fish guidance and passage structures may have promise for nonnatives fish removal in some cases. Where escapement cannot be managed at an acceptably low level, removal by chemical methods will be necessary.

Potential problems and conflicts-- The public has become accustomed to sport fishing opportunities in areas from which nonnative fishes escape into endangered fish habitats. Some of these sportfishing areas are on private lands, and some fish have been stocked illegally. Existing regulations may not adequately cover stocking and escapement from private ponds. Control of escapement may be difficult and costly. Eradication of problematic nonnative fish may be complicated due to technical and sociopolitical problems. Barriers may be expensive to construct and each will have continuing operation and maintenance costs. Toxin containment will be critical when chemical methods are used in close proximity to main channel habitat. The dynamics of alluvial groundwater movement, especially as it relates to interactions with main channel flows, may become a troublesome issue when toxicants are considered for use in gravel pits near rivers.

Action/Resolution-- Control will require the identification of problem areas and formulation of site-specific action plans. Conflicts with sport fishing interests can be mitigated by a variety of measures. Private citizens need to be informed of their responsibilities, but also should be provided with incentives to cooperate with new fishery management programs. New regulations may be required for privately owned and managed waters to reduce escapement or replace nonnative fish stocks with more acceptable ones.

2. High abundance of nonnative fishes (predators and competitors) in UCRB.

Problems-- Many nonnative fishes have been introduced into waters occupied by native Colorado River fishes. These introduced fishes prey on and compete with the native fishes. Existing habitat conditions (altered flows, temperatures, etc.) are well-suited for some of these nonnative fishes and will make it more difficult to control those fishes.

Strategies-- Reduce the abundance of nonnative fishes by cost-effective and timely control measures (chiefly mechanical). Increasing harvest by anglers may have benefit in some areas. Program cooperators could assist by mechanical removal of smaller species from backwater areas in the spring and early summer. Establishment of a large-scale harvesting program that is either RIP-sponsored or a commercial enterprise could be effective for species like channel catfish and carp. Management of flows from some major reservoirs is already in effect, or being tested, for providing or improving habitats for the native fishes. These flows will aid in increasing native fishes and decreasing some of the nonnative fishes. Fish passage facilities offer the prospect of selectively removing nonnatives.

Potential problems and conflicts-- Control through increased harvest by anglers may require changing regulations that now restrict the recreational take of nonnative fishes like channel catfish. Effectiveness of selective removal at passage facilities is not known. No commercial fishing industry presently exists in the Upper Colorado River basin, but it is possible that one could be established. There is some indication that markets in the Midwest would be willing to exploit channel catfish and carp. Incentives may be necessary to facilitate the establishment of such an industry. State agencies may not be willing to accept and support commercial fishery establishment for a variety of reasons. All mechanical removal methods may increase the take of nonnative fishes result in some take of protected species as well. If increasing flows are required, or instream protection is needed, some water rights may have to be acquired.

Action/Resolution-- Regulations restricting angler take of nonnatives can and should be changed. The new fish passage facility at Redlands should be monitored to determine the effectiveness of fish removal. Increased take by agencies could be beneficial if captured fish are transported elsewhere and stocked outside of the basin. A commercial fishing industry could be established and monitored. Because of a lack of expertise in dealing with commercial fishing interests, it would be beneficial to obtain the services of a consultant or another state agency that has more information and is willing to work with the upper basin program. Bycatch could be reduced by proper protective measures (e.g., methods used, time of year, location). Program cooperators should consider backwater seining to remove smaller nonnative fishes. Stream flows are under evaluation at this time, and results of this evaluation should be used in determining if water rights are needed.

3. Loss of sport fishing opportunities.

Strategy-- Recreational fishing is important, and recreational fishing that is lost due to the program should be replaced. Replacement will require innovative efforts by agencies.

Potential problems and conflicts-- Sport fishing interests may be wary of control efforts by government agencies, and may view agency actions as threats to recreational fishing.

Action/Resolution-- Before government agencies propose to limit recreational fishing, there should be a concerted effort to mitigate this loss with replacement and/or incentives. Plans must be developed that target problem areas and agencies must develop alternatives for replacement of lost fishing opportunities. Innovative approaches should be solicited.

High Priority Recovery Areas

YAMPA RIVER BASIN

Highest priority reach- Deerlodge to Echo Park

--High priority recovery area
--Medium to High concern for nonnative fish interactions in this reach
--11 life history stages of endangered fishes present

Related reaches of concern: all upstream areas of Yampa River due to presence of highly predaceous and aggressive nonnative gamefish, and downstream areas of the Green River from which nonnatives may enter the Yampa.

1. Movement of nonnative fishes (chiefly large predators such as northern pike and smallmouth bass) into mainstream from impoundments (e.g., Elkhead Reservoir), water bodies in the floodplain, and adjacent main channel areas (upstream Yampa).

Problem-- Highly predaceous game fishes have been introduced into the upper Yampa River system. One of the main problem areas has been Elkhead Reservoir, from which northern pike and smallmouth bass have escaped into the mainstream river, and have spread into downstream areas of the Green and Colorado rivers.

Strategies-- Escapement of highly predaceous sportfish species from impoundments can be prevented or reduced greatly by the installation and operation of escapement control devices, improving outlets, constructing bypasses, and building hydrologic barriers. Backwaters, sloughs, and other semi-isolated areas can be trapped or isolated with barriers. Where effective escapement controls are not feasible, removal will be necessary.

Potential Problems and Conflicts-- Loss of sportfishing opportunities may result in some riverine areas. Escapement control technology involved may be expensive and prone to failure especially under high flow conditions. Access to backwater areas on private land may be denied.

Action/Resolution-- Develop fisheries and conservation management plan that emphasizes public relations and acceptable alternative fishing opportunities. Replace lost coolwater and warmwater fishing opportunities with comparable opportunities elsewhere. Initiate information programs for educating the public. Employ conflict resolution techniques for refining and implementing plan. Evaluate all feasible alternatives for accomplishing fish control objectives. Develop pilot project for escapement control at Elkhead Reservoir.

2. Nonnative predators in mainstream habitats prey on natives (especially young razorback sucker, Colorado squawfish, and humpback chub).

Problem-- Nonnative fishes (especially ictalurids, centrarchids and esocids) consume humpback chub and young Colorado squawfish, and compete directly and indirectly with the native fishes. Because of the upstream position of the Yampa River, these gamefishes are moving downstream and throughout the entire upper basin. Thus the problem is pervasive and impacts are not restricted to the Yampa River.

Strategies-- Reduce the abundance of nonnative fishes. The most cost-effective and timely approaches are chiefly mechanical control measures. Agencies could undertake removal efforts. Harvest of predaceous fishes (pike and smallmouth bass) by anglers could be increased. Establish a large-scale harvesting program that is either RIP-sponsored or a commercial enterprise.

Potential Problems and Conflicts-- Some anglers may resist attempts to remove centrarchids and esocids from the riverine habitats. Removal of some species, like channel catfish and carp, will be difficult. Existing fishing regulations limit angler take. There is no local expertise for operating a commercial fishery. Regulatory issues must be resolved before a commercial fishery could be implemented.

Action/Resolution-- Loss of river fishing opportunities for northern pike can be met with fishing elsewhere. In addition, coolwater fishing opportunities can be enhanced to meet some local demand. Reduction of channel catfish and carp may be facilitated by construction of barriers, encouragement of increased harvest. Northern pike could be reduced by trapping and removal, and by isolating backwater and slough habitats. Some fishes, like smallmouth bass, are expected to decrease in time if escapement from reservoirs and other areas is prevented. Contract for expertise regarding commercial fishery.

3. Movement of nonnative fishes into Yampa from Green River.

Problem-- Higher base flows are maintained in the Green River during summer and winter due to flow regulation by Flaming Gorge Reservoir. The Green River thus provides a refuge from some of the riverine species like channel catfish that can reinvade the Yampa River during other times of the year.

Strategies-- Reduction of nonnative fish abundance in the Green River (by implementation of the Green River Program) should reduce the resupply of nonnatives to the Yampa River. In addition, barriers and fish guidance systems should be evaluated for possible use during certain times of the year.

Potential Problems and Conflicts-- Yampa and Green River programs may be expensive to operate concurrently. Dinosaur National Monument may not allow barriers, guidance systems, or fish removal at mouth of Yampa River due to logistics and public reaction.

Action/Resolution-- Implement Green River program as soon as possible. Work with National Park Service to review prospects for fish control using barriers and guidance systems. Examine feasibility of conducting Yampa and Green river programs simultaneously.

GREEN RIVER BASIN

Highest priority reach: Echo Park to Desolation Canyon

-- High priority recovery area
-- High level of concern for nonnative interactions in this reach
-- 10 life history stages of endangered fishes present

Related reaches of concern: upstream reaches of Green and Yampa rivers, Duchesne and White rivers,

1. Movement of nonnative fishes into mainstream from impoundments (e.g., Kenney, Starvation, Bottle Hollow reservoirs), water bodies in the floodplain, and adjacent main channel areas (e.g., Yampa, White, Green).

Problem-- Upstream areas of the Green, Yampa, Duchesne, and White rivers are sources of predaceous gamefishes that enter this important reach of the Green River. In addition, local areas including Stewart Lake also harbor nonnative fishes.

Strategies-- Implementation of the Yampa River control program will reduce nonnative fishes coming from that system. Upstream areas of the Green River in Browns Park should be evaluated for control of carp, especially at prime habitats afforded by Browns Park wildlife refuges. Additional predaceous fishes come from the White and Duchesne rivers, which deliver predaceous fishes into major Colorado squawfish nursery habitats. Escapement controls should be installed at Kenney Reservoir to prevent release of nonnatives, especially sunfishes. Smallmouth bass escapement from Starvation Reservoir may be a problem and also should be evaluated. Self-sustaining stocks of centrarchids in the Duchesne River should be eradicated.

Potential Problems and Conflicts-- Effective control of nonnative fishes in the Yampa River will involve problems and conflicts already identified. However, control of some nonnative fishes in the Green River (e.g., northern pike in Stewart drain) could be undermined if supply continues from upstream. Control of carp in the upstream Green River will depend on the successful cooperation of several agencies. Control of escapement or replacement of predaceous nonnative fishes in Kenney and Starvation reservoirs will meet some sportfishing opposition. Control of smallmouth bass in the Duchesne River may be hampered by previous agreements with the Uintah and Ouray Tribe.

Action/Resolution-- Implement Yampa River control program. Provide incentives and mitigation measures for potential loss of sportfishing opportunities. Develop partnerships with other agencies and tribes.

2. Nonnative predators in mainstream habitats prey on natives (especially young razorback sucker, Colorado squawfish, and humpback chub).

Problem-- Nonnative fishes are present in the main river channels. These introduced fishes consume young razorback sucker, Colorado squawfish, and humpback chub, and potentially compete with all life stages of native fishes. Nonnative fishes occur in main channel runs, connected backwaters, and eddies.

Strategies-- Increased angler take of channel catfish and other species may aid fish control to some degree. RIP-sponsored or commercial harvesting may provide a mechanism for large-scale removal of nonnatives. Removal of smaller species by Program cooperators could be accomplished in the Spring and early Summer period. Construction of barriers, passage, and/or fish salvage facilities should be evaluated.

Potential Problems and Conflicts-- Increased angler take would probably be very site specific and not very effective. Commercial fishery has promise if harvest is substantial and sufficient markets exist. Subsidies may be necessary for initiating a commercial program. Unlimited angling and commercial fishery would be hard to effectively administer. Bycatch of endangered species could be a problem. Fish entrainment and removal facilities are in use elsewhere but have not been evaluated for use in the UCRB.

Action/Resolution-- Increased angler, commercial and program harvest are valid options and should be explored for implementation. Because commercial fishing is new to the UCRB, outside consultants from private industry or other agencies should be retained to assist in evaluating the risks and benefits of commercial fishing. Efforts should include evaluation of potential markets and disposal of unwanted fishes. Program efforts could be used to remove smaller fishes by seining backwater areas in the Spring and early Summer period. Siting, construction, operation, and maintenance of fish removal facilities should be evaluated for use at sites that have merit.

3. Flooded bottoms may create reservoir of nonnative fishes (especially carp).

Problem-- This section of the Green River has extensive bottomlands that are flooded to aid native fishes. Unfortunately these flooded habitats also are used by some nonnative fishes, especially carp.

Strategies-- Discourage establishment of nonnative fishes by keeping flood duration in tune with natural flood fluctuations, by preventing access by nonnative fishes, and removing nonnative fishes that are present. Flows should be used to create ephemeral habitats for native species rather than perennial habitats that are favored by nonnative species.

Potential Problems and Conflicts-- A program for providing naturally-flooded bottomlands is new and in testing stages. Use of flood control structures to sustain impoundments has created problems in the past by aiding in the proliferation of some nonnative species.

Action/Resolution-- Seek technical assistance, evaluate, monitor, and develop new options for preventing nonnative proliferation and removal of nonnative fishes. Evaluate use of fish guidance and removal structures (such as louver devices) for potential use in control of nonnative fishes.

UPPER COLORADO RIVER

Highest priority reach= Government Highline diversion to Cataract Canyon

--High priority recovery area
--High level of concern for nonnative interactions in this reach
--7 life history stages of endangered fishes present

Related reaches of concern: Gunnison and Dolores rivers.

1. Movement of nonnative fishes into mainstream from impoundments, water bodies in the floodplain, and adjacent main channel areas (e.g., Gunnison).

Problem-- Numerous ponds in the floodplain are providing inputs of predaceous game fishes, including largemouth bass, into this important reach of the Colorado River. In addition, nonnative fishes are escaping from upstream areas, including the Gunnison River and entering mainstream habitats.

Strategies-- Use of toxicants to remove nonnative fishes in areas where they are escaping, or install effective escapement control devices in areas such as Highline Reservoir. Use mechanical techniques to remove nonnative fish from the Gunnison River. Discontinue stocking nonnative fishes in 100 yr floodplain from which the fish may escape into the main river channels.

Potential Problems and Conflicts-- Control of some nonnative fishes in the Colorado River could be undermined if supply continues from upstream. Control of escapement or replacement of predaceous nonnative fishes in reservoirs and ponds has already met some sportfishing opposition. Some recreational opportunities may be lost.

Action/Resolution-- Implement Colorado River control program. Initiate fish removal projects in the upper Gunnison River. Provide incentives and mitigation measures for potential loss of sportfishing opportunities. Develop partnerships with other agencies and tribes. Expedite completion of stocking protocols that are in review.

2. Nonnative predators in mainstream habitats prey on native fishes (especially humpback chub and larval Colorado squawfish).

Problem-- Nonnative fishes are present in the main river channels. These introduced fishes presumably consume Colorado squawfish, humpback chub, razorback sucker, and compete with all life stages of native fishes. Nonnative fishes occur in mainchannel runs, connected backwaters, and eddies.

Strategies-- Increased angler take of channel catfish and other species may aid fish control to some degree. Commercial removal for profit may provide an alternative to an expensive removal program. Program cooperators could aid by removing smaller species in the Spring and early Summer period. Operation of the Redlands fish passage structure will permit removal of nonnative fishes. Removed fish could be sold, or considered for use in stocking in areas outside of the basin.

Potential Problems and Conflicts-- Increased angler take would probably be very site specific and not very effective. Fishing regulations restrict angler take. Commercial fishery has promise if quantities are substantial and sufficient markets exist. Unlimited angling and commercial fishery would be hard to effectively administer. Bycatch of endangered species could be a problem.

Action/Resolution-- Increased angler and commercial harvest are valid options and should be explored for implementation. Because commercial fishing is new to the Upper Colorado River basin, outside consultants from private industry or other agencies should be retained to assist in evaluating the risks and benefits of commercial fishing. Efforts should include evaluation of potential markets and disposal of unwanted fishes. Program cooperators could remove small nonnative fishes by seining backwater and gravel pit areas.

SECTION VII. LITERATURE CITED

Allan, R.C. and D.L. Roden. 1978. Fishes of Lake Mead and Lake Mohave. Biological Bulletin Number 7, Nevada Department of Wildlife. Reno. 105 pp.

ANSTF. 1994. Findings, conclusions, and recommendations of the intentional introductions policy review: Report to Congress. Aquatic Nuisance Species Task Force, U.S. Fish and Wildlife Service, Washington, D.C. 53 pp.

Banks, J.L. 1964. Fish species distribution in Dinosaur National Monument during 1961 and 1962. M.S. Thesis, Colorado State University, Fort Collins. 96 pp.

Bates, K. (Editor). 1993. Fish pasage policy and technology. Proceedings of a symposium. Bioengineering section of the American Fisheries Society. American Fisheries Society, Bethesda, Maryland. 209 pp.

Baxter, G.T. and J.R. Simon. 1970. Wyoming Fishes. Bulletin 4, Wyoming Game and Fish Department, Cheyenne.

Bell, M.C. 1990. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, Portland, Oregon.

Behnke, R.J. 1980. The impacts of habitat alterations on the endangered and threatened fishes of the Upper Colorado River Basin. Bulletin 503A. Cooperative Extension Service, Colorado State University, Fort Collins. 34 pp.

Bestgen, K.R. and D.L. Propst. 1989. Distribution, status, and notes on the ecology of *Gila robusta* (Cyprinidae) in the Gila River drainage, New Mexico. Southwestern Naturalist 34(5):402-412.

Bozek, M.A., L.J. Paulson, and J.E. Deacon. 1984. Factors affecting reproductive success of bonytail chubs and razorback suckers in Lake Mohave. Final Report. U.S. Fish and Wildlife Service Contract 14-16-0002-81-251. University of Nevada, Las Vegas.

Brooks, J.E. 1985. Annual reintroduction and monitoring report for the razorback sucker (*Xyrauchen texanus*) in the Gila River basin, Arizona, 1985. U.S. Fish and Wildlife Service, Albuquerque, NM.

Burdick, B.D. 1995. Ichthyofaunal studies of the Gunnison River, Colorado, 1992-1994. Final Report. U.S. Fish and Wildlife Service, Grand Junction, Colorado.

Cada, G.F. and M.J. Sale. 1993. Status of fish passage facilities at nonfederal hydropower projects. Fisheries 18(7):4-7.

California Department of Water Resources. 1991. John E. Skinner Delta Fish Protective Facility. Sacramento, California. 8 pp.

Carlson, C.A. and R.T. Muth. 1989. Lifeline of the American Southwest. Pages 220-239 in D.P. Dodge, editor. Proceedings of the International Large Rivers Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Coon, K.L. 1965. Some biological observations on the channel catfish, *Ictalurus punctatus* (Rafinesque), in a polluted western river. M.S. Thesis, Utah State University, Logan.

Courtenay, W.R., Jr. 1993. Biological pollution through fish introductions. Pages 35-61 *in:* B.N. McKnight (editor). Biological pollution: the control and impact of invasive exotic species. Indiana Academy of Sciences, Indianapolis. 261 pp.

Courtenay, W.R. Jr. and C.R. Robins. 1989. Fish introductions: Good management, mismanagement, or no management? Reviews in Aquatic Sciences 1:159-172.

Crowl, T.A. and L. Lentsch. 1995. Estimating pike predation on Colorado River squawfish Recovery Implementation Program Project F-47-R, study number 8, U.S. Fish and Wildlife Service, Denver, Colorado.

Deacon, J.E. 1978. Endangered and threatened fish of the West. Great Basin Naturalist Memoirs 3:41-64.

Dill, W.A. 1944. The fishery of the lower Colorado River. California Fish and Game 30:109-211

Ehrlich, P.R. and A.H. Ehrlich. 1983. Extinction: The causes and consequences of the disappearance of species. Bantam Books edition, New York. 384 pp.

Ellis, M.M. 1914. Fishes of Colorado. The University of Colorado Studies XI(1):1-136 + 12 plates. Boulder.

EPRI. 1988. Proceedings: fish protection at steam and hydroelectric power plants. Report CS/EA/AP-5663-SR. Electric Power Research Institute, Palo Alto, California.

Flickinger, S., W. Hubert, and J. Johnson. 1995. Biological evaluation of a proposal to stock nonnative fishes into ponds within the 0- to 50-year floodplain of the upper Colorado River basin in critical habitat of endangered fishes. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins. 10 pp.

Fradkin, P.L. 1984. A river no more: The Colorado River and the West. The University of Arizona Press, Tucson. 360 pp.

Frankel , O.H. and M. E. Soulé. 1981. Conservation and evolution. Cambridge Universtiy Press. New York. 327 pp.

Gerhardt, D.R. and W.A. Hubert. 1991. Population dynamics of a lighly exploited channel catfish stock in the Powder River system, Wyoming-Montana. North American Journal of Fisheries Management 11:200-205.

Gilbert, , F.G. and D.G. Dodds. 1992. The philosophy and practice of wildlife management. Krieger Publishing Company, Malabar, Florida.313 pp.

Goodrich, J.M. and S.W. Buskirk. 1995. Control of abundant native vertebrates for conservation of endangered species. Conservation Biology 9(6):1357-1364.

Grabowski, S.J., and S.D. Hiebert. 1989. Some aspects of trophic interactions in selected backwaters and main channel of the Green River, Utah, 1987-1988. U.S. Bureau of Reclamation, Denver, Colorado..

Graf, W.L. 1978. Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region. Geological Society of America Bulletin 89:1491-1501.

Harvey, B.D. 1987. Susceptibility of young-of-the-year fishes to downstream displacement by flooding. Transactions of the American Fisehries Society 116:851-855.

Hawkins, J.A. and T.P. Nesler. 1991. Nonnative fishes of the upper Colorado River basin: an issue paper. Final Report. Colorado State University and Colorado Division of Wildlife. Fort Collins. 72 pp.

Hendrickson, D.A. and J.E. Brooks. 1987. Colorado squawfish reintroduction studies. Proceedings of the Desert Fishes Council 18 (1986):207-208.

Hesse, L.W. 1994. The status of Nebraska fishes in the Missouri River. 3. Channel catfish (Ictaluridae:*Ictalurus punctatus*). Transactions of the Nebraska Academy of Sciences 21:73-87.

Hill, T.D., W.G. Duffy, and M.R. Thompson. 1995. Food habits of channel catfish in Lake Oahe, South Dakota. Journal of Freshwater Ecology 10(4):319-323,

Holden, P.B. 1977. A study of habitat use and movement of rare fishes in the Green river. *In*: Habitat requirements of juvenile Colorado squawfish. U.S. Fish and Wildlife Service, Report FWS OBS/77/65..

Holden, P.B., and C.B. Stalnaker. 1975. Distribution of fishes in the Dolores and Yampa River systems of the upper Colorado Basin. Southwestern Naturalist 19:403-412.

Jacobi, J.E., and M.D. Jacobi. 1982. Fish stomach content analysis. Pages 285-321 *in*: U.S. Fish and Wildlife and Bureau of Reclamation. Colorado River Fisheries Project. Part 3. Salt Lake City, Utah.

Johnson, J.E., M.G. Pardew, and M.M. Lyttle. 1993. Predation recognition and avoidance by larval razorback sucker and northern hog sucker. Transactions of the American Fisheries Society 122:1139-1145.

Jonez, A. and R.C. Sumner. 1954. Lakes Mead and Mohave investigations: A comparative study of an established reservoir as related to a newly created impoundment. Federal Aid to Fisheries Restoration Project Completion Report, F-1-R, Nevada Fish and Game Commission, Reno. 186 pp.

Jordan, D.S. 1891. Report of explorations in Utah and Colorado during the summer of 1889, with an account of fishes found in each of the river basins examined. Bulletin of the U.S. Fish Commissioner 9:1-40.

Joseph, T.W., J.A. Sinning, R.J. Behnke, and P.B. Holden. 1977. An evaluation of the status, life history and habitat requirements of endangered and threatened fishes of the Upper Colorado River Basin. Report FWS/OBS-77/2, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Kaeding, L.R. and M.A. Zimmerman. 1983. Life history of the humpback chub in the Little Colorado and Colorado Rivers of the Grand Canyon. Transactions of the American Fisheries Society 112:577-594.

Karp, C.A. and H.M. Tyus. 1989. Behavior and interspecific interactions of Colorado squawfish *Ptychocheilus lucius*, and five other fish species. Copeia 1990:25-34.

Karp, C.A. and H.M. Tyus. 1990. Humpback chub (*Gila cypha*) in the Yampa and Green rivers, Dinosaur National Monument, with observations on roundtail chub (*G. Robusta*) and other sympatric fishes. Great Basin Naturalist 50(3):257-264.

Kohler, C.C. and W.R. Courtenay, Jr.. 1986. American Fisheries Society position paper on Introduction of aquatic species. Fisheries 11(2):29-42.

Kurdila, J. 1988. The introduction of exotic species into the United States: There goes the neighborhood. Boston College Environmental Affairs Law Review 16:95-118.

Langhorst, D.R. 1987. Larval razorback sucker, *Xyrauchen texanus*, in Lake Mohave, Arizona-Nevada. Proceedings of the Desert Fishes Council 17(1985):164-165 (Abstract).

Langhorst, D.R. 1989. A monitoring study of razorback sucker (*Xyrauchen texanus*) reintroduced into the lower Colorado River in 1988. Final Report. (Contract FC-9494). California Department of Fish and Game, Blythe.

Langhorst, D.R. and P.C. Marsh. 1986. Early life history of razorback sucker in Lake Mohave. Final Report to the U.S. Bureau of Reclamation, Order no.5-PG-30-06440. Arizona State University, Tempe. 34pp + App.

Larkin, P.A. 1956. Interspecific cometitin and population control in freshwater fish. Journal of the Fisheries Research Board of Canada 13(3):327-342.

Laycock, G. 1966. The alien animal. Ballentine Books edition, New York. 246 pp.

Lentsch, L.D., R. Muth, P.D. Thompson, T.A. Crowl, and B.G. Hoskins. 1995. Options for selectively controlling non-indigenous fish in the upper Colorado River basin. Draft Report. Utah Division of Wildlife Resources. Salt Lake City, Utah.

Leopold, A. 1949. A Sand County almanac and sketches here and there. Oxford University Press, New York..

Li, H.W. and P.B. Moyle. 1981. Ecological analysis of species introductions into aquatic systems. Transactions of the American Fisheries Society 110:772-781

Loudermilk, W.E. 1985. Aspects of razorback sucker (*Xyrauchen texanus*, Abbott) life history which help explain their decline. Proceedings of the Desert Fishes Council 13(1981):67-72.

Lydeard, C. and M.C. Belk. 1993. Management of indigenous fish species impacted by introduced mosquitofish: an experimental approach. The Southwestern Naturalist 38: 370-373.

MacArthur, R.H. and E.O Wilson. 1967. The theory of island biogeography. Prinction University Press, Princeton, N.J.

Maddux, H.R., L.A. Fitzpatrick, and W.R. Noonan. 1993. Colorado River endangered fishes critical habitat: Biological Support Document. U.S. Fish and Wildlife Service, Salt Lake City, Ut. 225 pp.

Marsh, P.C. and D.R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. Environmental Biology of Fishes 21:59-67.

Marsh, P.C. and J.L. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of introduced razorback suckers. The Southwestern Naturalist 34:188-195

Marsh, P.C. and W.L. Minckley. 1989. Observations on recruitment and ecology of razorback sucker: lower Colorado River, Arizona-California-Nevada. Great Basin Naturalist 49:71-78.

McAda, C.W. 1983. Colorado squawfish, *Ptychocheilus lucius* (Cyprinidae), with a channel catfish, *Ictalurus punctatus* (Ictaluridae), lodged in its throat. Southwestern Naturalist 28:119-120..

McAda, C.W. and H.M. Tyus. 1984. Resource overlap of Age-0 Colorado squawfish with other fish species in the Green River, 1980. Proceedings of the Bonneville Chapter, American Fisheries Society 1984:44-54.

Medel-Ulmer, L. 1983. Movement and reproduction of the razorback sucker (*Xyrauchen texanus*) inhabiting Senator Wash Reservoir, Imperial County, California. Proceedings of the Desert Fishes Council 12(1980):106(Abstract)

Meffe, G.K.. 1985. Predation and species replacement in American southwestern fishes: A case study. Southwestern Naturalist 30:173-187..

Meronek, T.G., P.M. Bouchard, E.R. Buckmen, T.M. Burri, K.D. Demmerly, D.C. Hatkeleli, R.A. Klumb, S.D. Schmidt, and D.W. Coble. 1996. A review of fish control projects. North American Journal of Fisheries Managemnt 16:63-74.

Miller, R.R. 1952. Bait fishes of the lower Colorado River from Lake Mead, Nevada to Yuma Arizona with a key for their identification. California Fish and Game

Miller, R.R. 1958. Origins and affinities of the freshwater fish fauna of western North America. Pages 187-222 *in*: C.L. Hubbs, Editor. Zoogeography . Publication 51, American Association for the Advancement of Science, Washington, D.C.

Miller, R. R. 1961. Man and the changing fish fauna of the American Southwest. Papers of Michigan Academy of Sciences, Arts, and Letters, 46:365-404.

Miller, R.R. 1972. Threatened freshwater fishes of the United States. Transactions of the American Fisheries Society 101:239-252).

Miller, W.H., H.M. Tyus, and C.A. Carlson (editors). 1982. Fishes of the upper Colorado River System: present and future. American Fisheries Society, Bethesda, MD. 131 pp.

Miner, J.G. and R.A. Stein. 1996. Detection of predators and habitat choice by small bluegills: Effects of turbidity and alternative prey. Transactions of the American Fisheries Society 125:97-103.

Minckley, W.L. 1982. Trophic interrelations among introduced fishes in the lower Colorado River, Southwestern United States. California Fish and Game 68(2):78-89.

Minckley, W.L. 1983. Status of the razorback sucker, Xyrauchen texanus (Abbott), in the lower Colorado River Basin. Southwestern Naturalist 28:165-187.

Minckley, W.L. and J.E. Deacon. 1991. Battle against extinction: native fish management in the American West. University of Arizona Press. Tucson. 517 pp.

Minckley, W.L., D.A. Hendrickson, and C.E. Bond. 1986. Geography of western North American freshwater fishes: Description and relationships to intracontinental tectonism. Pages 519-614, *In:* C.H. Hocutt and E.O. Wiley, (editors). The zoogeography of North American freshwater fishes. John Wiley and Sons, New York. 866 pp.

Minckley, W.L., P.C. Marsh, J.E. Brooks, J.E. Johnson, and B.L. Jensen. 1991. Management toward recovery of the razorback sucker. Pages 303-357, *In:* W.L. Minckley and J.E. Deacon (editors). Battle against extinction: native fish management in the American Southwest. University of Arizona Press. Tucson. 517 pp.

Modde, T. and G. Smith. 1995. Flow recommendations for endangered fishes in the Yampa River. Final Report. U.S. Fish and Wildlife Service, Denver, Colorado. 44 pp.

Molles, M. 1980. The impacts of habitat alterations and introduced species on the native fishes of the Upper Colorado River Basin. Pages 163-191 *in*: W.O. Spofford, Jr., A.K. Parker, and A.V. Kneese, Editors. Energy development in the Southwerst:. Problems of water, fish, and wildlife in the Upper Colorado River Basin, Volume 2. Resources for the Future, Washington, D.C.

Moyle, P.B. 1976. The inland fishes of California. University of California Press, Berkeley.

Moyle, P.B., H.W. Li, and B.A. Barton. 1986. The Frankenstein effect: Impact of introduced fishes on native fishes in North America. Pages 415-426, *in* R.H. Stroud, Editor. Fish culture in fisheries management. American Fisheries Society, Bethesda, Maryland. 481 pp.

Mueller, G. 1995. A program for maintaining the razorback sucker in Lake Mohave. American Fisheries Society Symposium 15:127-135.

Muth, R.T. and T.P. Nesler. 1993. Associations among flow and temperature regimes and spawning periods and abundance of young of selected fishes, lower Yampa River, Colorado, 1980-1984. Contribution 58, Colorado State University Fish Laboratory, Fort Collins. 50 pp.

Muth, R.T. and D.E. Snyder. 1995. Diets of young Colorado squawfish and other small fishes in backwaters of the Green River, Coloradi and Utah. Great Basin Naturalist 55:95-104.

Nalepa, T.F. and D.W. Schlosser, Editors. 1993. Zebra mussels, biology, impacts, and control. Lewis Publishers, Boca Raton, Florida. 810 pp.

Nesler, T.P. 1995. Interactions between endangered fishes and introduced gamefishes in the Yampa River, Colorado, 1987-1991. Draft Final Report. Colorado Division of Wildlife, Fort Collins.

Osmundson, D.B. 1987. Growth and survival of Colorado squawfish (*Ptychocheilus lucius*) stocked in riverside ponds, with reference to predation by largemouth bass (*Micropterus salmoides*). M.S. Thesis, Utah State University, Logan.

Osmundson, D.B. and L.R. Kaeding. 1989. Studies of Colorado squawfish and razorback sucker use of the 15-mile reach of the upper Colorado River as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. Final Report. U.S. Fish and Wildlife Service, Grand Junction, Colorado.

Papoulias, D. 1988. Survival and growth of larval razorback sucker, Xyrauchen texanus. M.S. Thesis, Arizona State University, Tempe.

Papoulias, D. and W.L. Minckley. 1990. Food limited survival of larval razorback suckers in the laboratory. Environmental Biology of Fishes 29:73-78.

Pimental, R., R.V. Bulkley, and H.M. Tyus. 1985. Choking of Colorado squawfish, *Ptychocheilus lucius* (Cyprinidae), on channel catfish, *Ictalurus punctatus* (Ictaluridae), as a cause of mortality. Southwestern Naturalist 30:154-158.

Propst, D.L. and K.R. Bestgen. 1991. Habitat and biology of the loack minnow *Tioroga cobitis*, in New Mexico. Copeia 1991(1):29-38.

Quartarone, F. 1993. Historical accounts of upper Colorado River basin endangered fish. Colorado Division of Wildlife, Denver. 66pp.

Raibley, P.T., K.D. Blodgett, and R.E. Sparks. 1995. Evidence of grass carp (*Ctenopharyngodon idella*) reproduction in the illinois and upper Mississippi rivers. Journal of Freshwater Ecology 10:65-74.

Raup, D.M. 1991. Extinction: Bad genes or bad luck? W.W. Norton and Company, New York.

Rinne, J.N. 1971. The life history of *Lepidomeda mollispinis mollispinis* (the Virgin River spinedace), a unique western cyprinid. M.S. Thesis. University of Nevada, Las Vegas. 109 pp.

Rinne, J.N. and W.L. Minckley. 1991. Native fishes of arid lands: a dwindling reource of the desert Southwest. U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station General Technical Report 206, Fort Collins, Colorado..

Rinne, J.N. 1991. Habitat use by spikedace, *Meda fulgida* (Pisces: Cyprinidae) in the southwestern streams with reference to probable habitat competition with red shiner, Notropis lutrensis (Pisces: Cyprinidae). Southwestern Naturalist 36:7-13.

Robs, S.T. 1991. Mechanisms structuring stream fish assemblages: Are there lessons from introduced species. Environmental biology of Fishes 30: 359-368.

Rose, S., and J. Hamill. 1988. Help is on the way for rare fishes of the upper Colorado River basin. Endangered Species Technical Bulletin 8(3):1-7. U.S. Fish and Wildlife Service, Washington, D.C.

Ruppert, J.B., R.T. Muth, and T.P. Nesler. 1993. Predation on fish larvae by adult red shiner, Yampa and Green rivers, Colorado. The Southwestern Naturalist 38:397-399.

Rutherford, D.A., W.E. Kelso, C.F. Bryan, and G.C. Constant. 1995. Influence of physiocochemical characteristics on annual growth increments of four fishes from the lower Mississippi River. Transactions of the American Fisheries Society 124:687-697.

Sabo, M.J., E.J. Pert, and K.O. Winemiller. 1996. Agonistic behavior of juvenile largemouth bass and smallmouth bass. Journal of Freshwater Ecology 11(1)115-118.

Schoenherr, A.A.. 1981. The role of competition and the replacement of native fishes by introduced species. Pages 173-203 *in* R.J. Naiman and D.L. Soltz (editors). Fishes in North American Deserts. Wiley-Interscience, John Wiley and Sons, New York.

Scoppertone, G.G. 1993. Intreractions between native and nonnative fishes of the upper Muddy River, Nevada. Transactions of the American Fisheries Society 599-608

Simberloff, D. 1974. Equilibrium theory of island biogeography and ecology. Annual Review of Ecology and Systematics 5:161-182.

Simberloff, D. 1986. Are we on the verge of a mass extinction in tropical rain forests? Pages 165-180 *in* D.K. Ellicott, Editor. Dynamics of extinction. Wiley Interscience, New York.

Smith, G.R. 1978. Biogeography of intermountain fishes. Pages 17-42 *in* K.T. Harper and J.L. Revel (editors). Intermountain Biogeography: A symposium. Great Basin Naturalist Memoirs 2.

Smith, M.L. 1981. Late Cenozoic fishes in warm deserts of North America: A reinterpretation of desert adaptations. pages 11-38 *in* R.J. Naiman and D.L. Soltz (editors). Fishes in North American Deserts. Wiley-Interscience, John Wiley and Sons, New York.

Soulé, M.E. 1983. What do we really know about extinction? Pages 111-124 *in* C.M. Schonewald-Cox, S.M. Chambers, B. MacBryde, and L. Thomas (editors). Genetics and conservation: A reference for managing wild animal and plant populations. The Benjamin/Cummings Publishing Company, Menlo Park, California. 722 pp.

Sport Fishing and Shooting Partnership Council. 1995. Position paper: Conserving federally thrreatened, endangerd, and proposed species while providing and enhancing recreational fishing programs.; U.S. Department of the Interior, Washington, D.C.

Stanford, J.A. and J.V. Ward. 1986a. The Colorado River system. Pages 353-374 *In* B.R. Davies and K.F. Walker (Editors). The ecology of river systems. Dr. W. Junk, Publishers , Dordrecht, The Netherlands.

Stanford, J.A. and J.V. Ward. 1986b. Fish of the Colorado system. Pages 385-402 *In* B.R. Davies and K.F. Walker (Editors). The ecology of river systems. Dr. W. Junk, Publishers , Dordrecht, The Netherlands.

Stanley, J.G., W.W. Wiley, and D.L. Sutton. 1978. Reproductive requirements and likelihood for naturaliaztion of escaped grass carp in the United States. Transactions of the American Fisheries Society 107:119-128.

Starnes, L.G., G. Compean-Jiminez, D. Dodge, G. Huntsman, P. Janck, J.N. Prosser, W. Royce, and W.M. Taylor. 1996. AFS Position Statement- North American Fisheries Policy. Fisheries 21(3): 26-29.

Stone and Webster Engineering Corporation. 1986. Assessment of downstream migrant fish protection technologies for hydroelectric application. Final Report AP-4711, Project 2694-1 to the Electric Power Research Institute. Palo Alto, California. 6 sections + App.

Taba, S.S., J.R. Murphy, and H.H. Frost. 1965. Notes on the fishes of the Colorado River near Moab, Utah. Proceedings of the Utah Academy of Science, Arts, Letters 42:280-283.

Taylor, J.N., W.R. Courtenay, Jr., and J.A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pages 323-373 *in* W.R. Courtenay, Jr, and J.R. Stauffor, Jr. Distribution, biology, and management of exotic fishes. Johns Hopkins University Press, Baltimore, Maryland. 430 pp.

Temple, S.A.. 1990. The nasty necessity: eradicating exotics. Conservation Biology. 4(2):113-115.

Trammel, M.A., E.P. Bergersen, and P.J. Martinez. 1993. Evaluation of an introduction of Colorado squawfish in a main stem impoundment on the White River, Colorado. Southwestern Naturalist 38:362-369.

Travnichek, V.H., M.G. Gain, and M.J. Maceina. 1995. Recovery of a warmwater fish assemblage after the initiation of a minimum-flow release downstream from a hydroeclctric dam. Transactions of the American Fisheries Society 124:836-844.

Tyus, H.M., B.D. Burdick, R.A. Valdez, C.M. Haynes, T.A. Lytle, and C.R. Berry. 1982. Fishes of the upper Colorado River Basin, distribution, abundance, and status. Pages 12-70, *In*: Miller, W.H., H.M. Tyus, and C.A. Carlson (editors). Fishes of the upper Colorado River System: present and future. American Fisheries Society, Bethesda, MD. 131 pp.

Tyus, H.M. and C.A. Karp. 1989. Habitat use and stream flow needs of rare and endangered fishes, Yampa River, Colorado. U.S. Fish and Wildlife Service Biological Report 89(14):1-27.

Tyus, H. M. and J. M. Beard. 1990. *Esox lucius* (Esocidae), and *Stizostedion vitreum* (Percidae) in the Green River basin, Colorado and Utah. Great Basin Naturalist 50(1):33-39.

Tyus, H.M. and G.B.Haines. 1991. Distribution, abundance, habitat use, and movements of young Colorado squawfish *Ptychocheilus lucius*. Transactions of the American Fisheries Society 120:79-89..

Tyus, H.M. and N.J. Nikirk. 1990. Growth, diet, and status of channel catfish, *Ictalurus punctatus*, in the Green and Yampa rivers, Colorado and Utah. Southwestern Naturalist 35(2):233-244.

USBR. 1985. Fact sheet: Tracy Fish Collecting Facility. U.S. Bureau of Reclamation, Central Valley Project, California. Sacramento, California. 3 pp.

USOTA. 1993. Harmful nonindigenous species in the United States. U.S. Congress Office of Technology Assessment, Publications OTA-F-565 (Report) and 566(Summary). U.S. Superintendent of Documents, Washington, D.C. 391 + 47 pp.

USOTA. 1995. Fish passage technologies : Protection at hydropower facilities. U.S. Congress Office of Technology Assessment. Publication OTA-ENV-641, U.S. Government Printing Office, Washington, D.C. 167 pp.

USFWS. 1987. Recovery implementation program for endangered fish species in the upper Colorado River Basin. U. S. Fish and Wildlife Service, Region 6, Denver, Colorado. 82 pp.

USFWS. 1994. Determination of Critical Habitat for four Colorado River Fishes; Final Rule. U.S. Fish and Wildlife Service, Federal Register 59(54):13374-13400.

USFWS. 1994. Endangered and threatened wildlife and plants; Animal candidate review for listing as endangered or threatened species; Proposed Rule; U.S. Fish and Wildlife Service, Federal Register 59(219)

USFWS and USBC. 1993. 1991 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Fish and Wildlife Service and U. S. Bureau of the Census, U.S. Government Printing Office, Washington, D.C. 176 pp.

USFWS and NMFS. 1995. Draft policy for conserving species listed or protected for listing under the Endangered Species Act while providing and enhancing recereational fisheries opportunities. U. S. Fish and Wildlife Service and U. S. National Marine Fisheries Service. Federal Register 60(239):64070-64073 (December 13, 1995).

Valdez, R.A. and R.J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha* in the Colorado River, Grand Canyon, Arizona. Executive summary to the Bureau of Reclamation, Salt Lake City, Utah. Contract No. 0.CS-40-09110. 23 pp.

Valdez, R.A., W.J. Masslich, R. Radant, and D. Knight. 1990. Status of the Virgin spinedace (*Lepidomeda mollispinis mollispinis*) in the Virgin River drainage, Utah. BioWest Report PR-197-1. 43 pp.

Vanicek, C. D. 1967. Ecological studies of native Green River fishes below Flaming Gorge Dam, 1964-1966. Ph.D. thesis, Utah State University, Logan. 125 pp.

Vanicek, C.D. and R.H. Kramer. 1969. Life history of the Colorado squawfish (*Ptychocheilus lucius*) and the Colorado chub (*Gila robusta*) in the Green River in Dinosaur National Monument 1964-1966. Transactions of the American Fisheries Society 98:193-208.

Vaske, J.J., M.P. Donnelly, and M.Lyon. 1995. Knowledge, beliefs and attitudes toward endangerd fish of the upper Colorado River basin. Human Dimensions in Natural Resources Unit Report 20, Colorado State University, Fort Collins. 91 pp.

Walburg, C.H. 1971. Loss of young fish in reservoir discharge and year class survival, Lewis and Clark Lake, Missouri River. Pages 4412-448 *in* G.E. Hall (Editor).

Reservoir fisheries and limnology. Special Publication 8, American Fisheries Society, Washington, D.C. 511 pp.

Wallis, O.L. 1951. The status of the fish fauna of the Lake Mead National Recreation Area, Arizona-Nevada. Transactions of the American Fisheries Society 80:84-92.

Ward, P. 1995. The end of evolution: A journey in search of clues to the third mass extinction facing planet Earth. Bantam Books edition, New York. 301 pp.

Wick, E.J., C.W. McAda, and R.V. Bulkley. 1982. Life history and prospects for recovery of the razorback sucker. Pages 120-126. *In:* W.H. Miller, H.M. Tyus, and C.A. Carlson (editors). Fishes of the upper Colorado River system: present and future. American Fisheries Society, Bethesda, Maryland.

Wigington, R. And D. Pontius. 1996. Toward range-wide integration of recovery implementation programs for the endangered fishes of the Colorado River. Proceedings of the Colorado River Workshop, Grand Canyon Trust, Flagstaff, Arizona.

Wilcox, B.A. 1980. Insular ecology and conservation. Pages 95-117 (Chapter 6) *in:* M.E. Soulé and B.A. Wilcox (editors). Conservation biology: An evolutionary-ecological perspective. Sinauer Associates, Inc. Sunderland, Massachusetts. 395 pp.

Wilcox, B.A. 1984. *In situ* conservation of genetic resources: determinants of minimum area requirements. pp. 639-647 *in* J.A. McNeeley and K.R. Miller (eds.). National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Proceedings of the World Congress on National Parks, Bali, Indonesia, 11-22 October 1982. Smithsonian Institution Press, Washington, DC.]

Wiley, R.W. 1996. Ecosystem integrity vs fisheries management. Fisheries 21(3):27-28.

Wiley, R.W. and R.W. Wydoski. 1993. Management of Undesirable fish species. Pages 335-354, *In:* C.C. Kohler and W.A. Hubert, Editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Wilson, E.O. 1992. The diversity of life. W.W. Norton Company, New York. 442 pp.

Williams, J.E., J.E. Johnson, D.A. Hendrickson, and six other authors. 1989. Fishes of North America, endangered, threatened, or of special concern. Fisheries 14(2): 2-20.

Wootton, R.J. 1990. Ecology of teleost fishes. Fiosh and Fisheries Series 1. Chapman and Hall, New York. 404 pp.

Wright, G.R. and J.A. Sorensen. 1995. Feasibility of developing and maintaining a sport fishery in the Salt River Project canals, Phoenix, Arizona. Final Report, Research Branch Technical Report 18, Arizona Game and Fish Department, Phoenix. 102 pp.

Zurlein, G. 1982. Food habits of channel catfish from the channellized Missouri River and the Niobrara River. Pages 20-20 *in*: Nebraska Game and Parks Commission. The Missouri River Channel Catfish. Nebraska Technical Series No. 11, Lincoln.

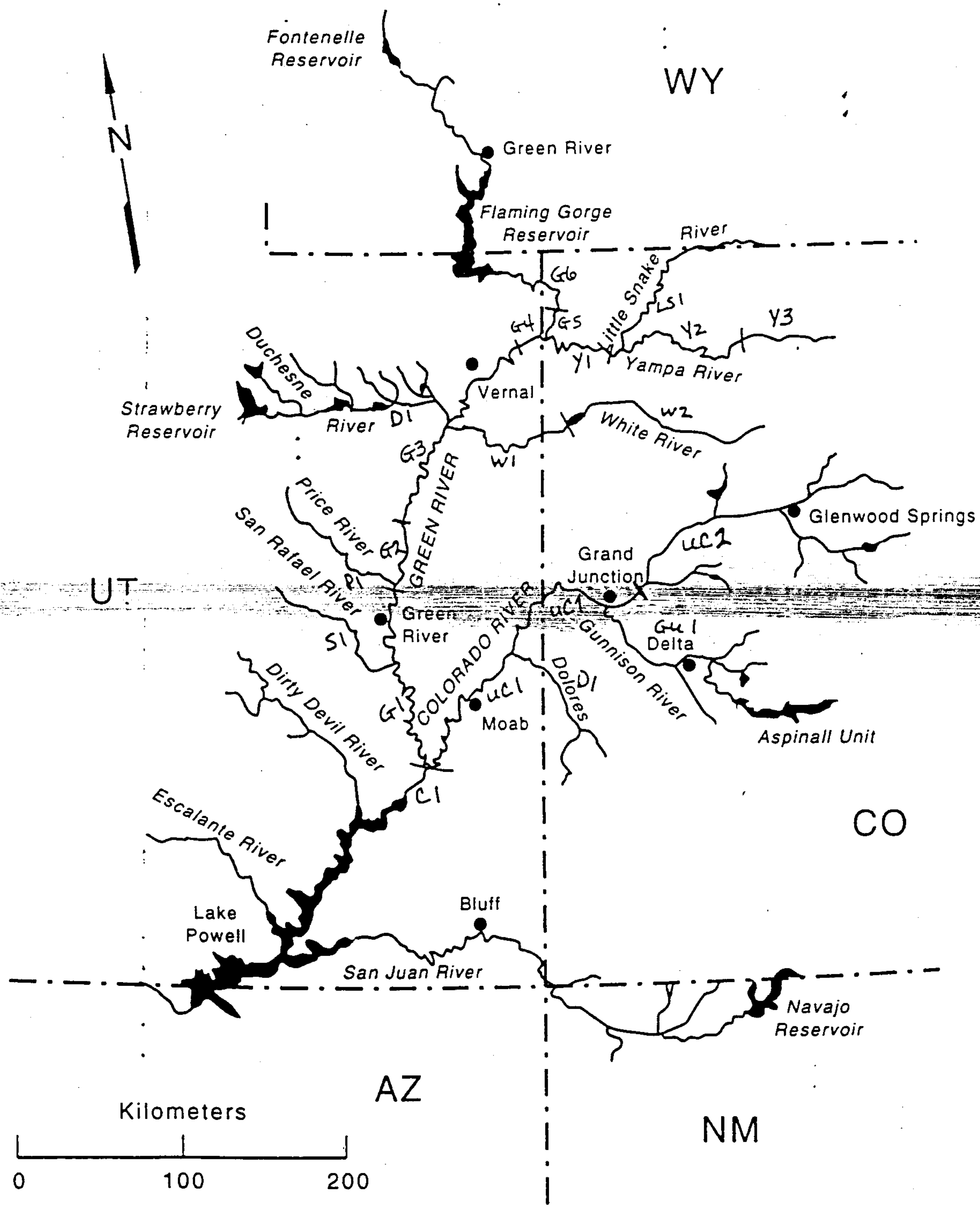


Figure 1. Map of the upper Colorado River basin with boundaries for reaches mentioned in text and tables.

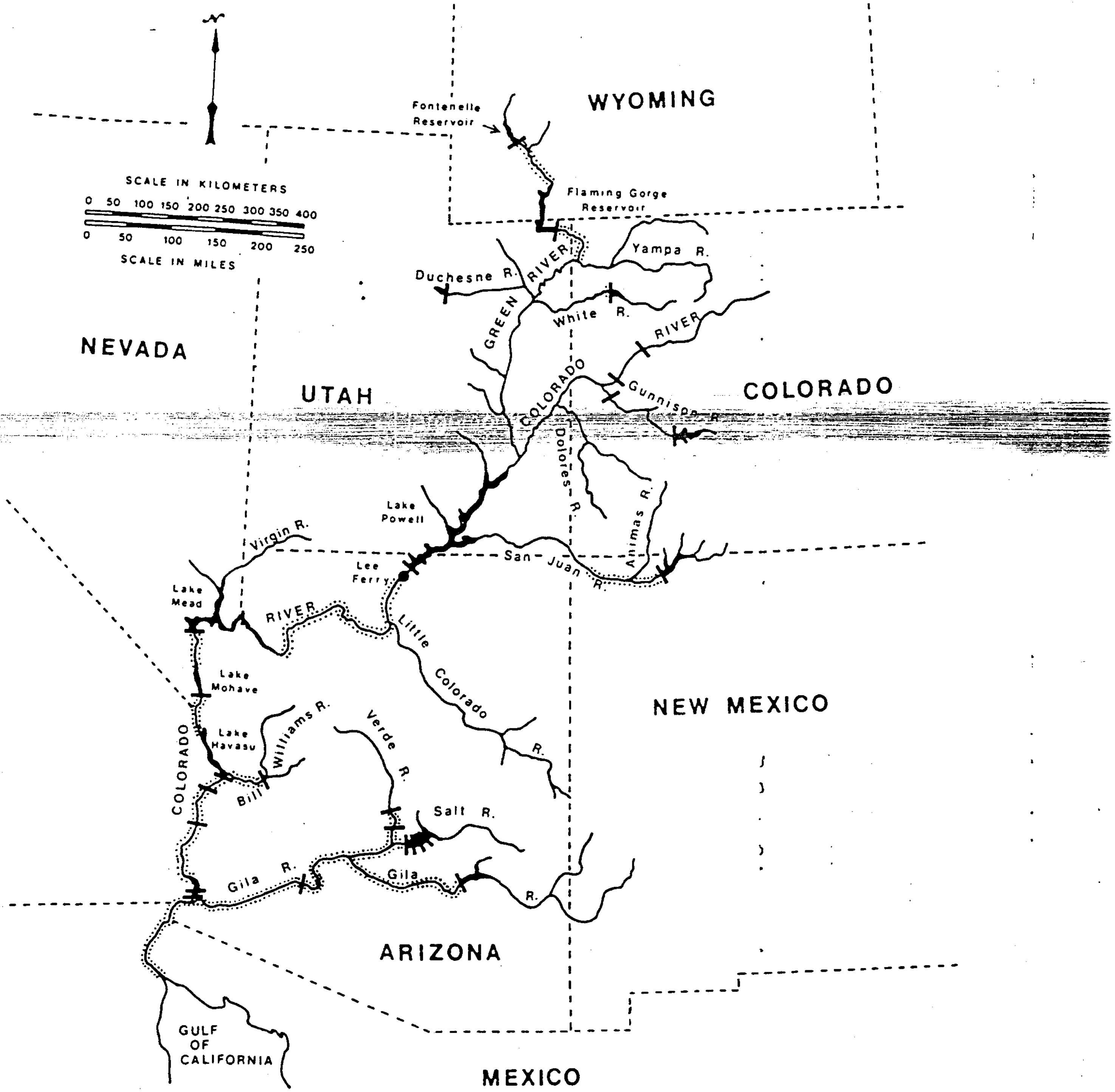


Fig. 2. Mainstream barriers and their impacts in the Colorado River basin (after Tyus 1984). || = location of barrier; ⋮⋮⋮ = downstream impact; and *blackened areas* = impoundments due to project completion.

Native Species	Introduced Predator	Reference
Razorback sucker	channel catfish	Medel-Ulmer 1983, Minckley 1983, Bozek et al. 1984, Brooks 1985, Langhorst 1987, Marsh and Langhorst 1988, Marsh and Brooks 1989, Marsh and Minckley 1989
	common carp	Jonez and Sumner 1954, Medel-Ulmer 1983, Minckley 1983, Bozek et al. 1984, Brooks 1985, Langhorst 1987, Marsh and Langhorst 1988, Marsh and Brooks 1989, Marsh and Minckley 1989
	green sunfish	Langhorst and Marsh 1986, Medel-Ulmer 1983, Minckley 1983, Bozek et al. 1984, Brooks 1985, Langhorst 1987, Marsh and Langhorst 1988, Marsh and Brooks 1989, Marsh and Minckley 1989, Muth and Beyers, in press
	sunfishes	Mueller 1995
	largemouth bass	Mueller 1995
	flathead catfish	Medel-Ulmer 1983, Minckley 1983, Bozek et al. 1984, Brooks 1985, Langhorst 1987, Marsh and Langhorst 1988, Marsh and Brooks 1989, Marsh and Minckley 1989
Colorado squawfish	channel catfish	Coon 1965, Muth and Beyers, in press
	green sunfish	Osmundson 1987, Muth and Beyers, in press
	largemouth bass	Osmundson 1987
	smallmouth bass	Hendrickson and Brooks 1987, Hendrickson 1993
	black crappie	Osmundson 1987
	bullheads	Taba 1964, Hendrickson and Brooks 1987, Osmundson 1987
	northern pike	Crowl and Lentsch 1995
	flathead catfish	Hendrickson 1993

Table 1 (beginning). Summary of citations for direct evidence of predation by nonnatives on native fishes of the Colorado River basin.

Humpback chub	channel catfish	Valdez and Ryel 1995
	bullheads	Taba 1964
	brown trout	Valdez and Ryel 1995
	rainbow trout	Valdez and Ryel 1995
Roundtail chub	northern pike	Nesler 1995
Bluehead sucker	northern pike	Nesler 1995
	red shiner	Ruppert et al. 1993
Flannelmouth sucker	northern pike	Nesler 1995
Speckled dace	northern pike	Nesler 1995
Sonoran topminnow	mosquitofish	Meffe 1985

Table 1 (concluded). Summary of citations for direct evidence of predation by nonnatives on native fishes of the Colorado River basin.

Geographical Distribution of Life History Stages

River Reach	Colorado Squawfish					Razorback Sucker					Humpback chub	
	Eggs	Larvae	Juve-nile	Adult	Migrant	Eggs	Larvae	Juve-nile	Adult	Migrant	Resident	Migrant
Y3			+	+								
Y2			+	+	+				+			
Y1	+	+	+	+	+	+	+	+	+	+	+	
LS1				+	+							+
G6				+								
G5				+					+			
G4		+	+	+	+	+	+	+	+	+	+	
G3		+	+	+	+	+	+	+	+	+		
G2	+	+	+	+	+		+	+	+		+	
G1		+	+	+	+	+	+	+	+			
W1			+	+	+				+			
W2				+								
D1			+	+	+				+			
P1			+	+								
S1				+								
UC2	+	+		+	+	+	+	+	+	+		
UC1	+	+	+	+	+				+		+	
C1		+	+	+	+				+		+	
GU1	+	+		+	+	+	+	+	+		+	
DO1				+	+							

Table 2. Important geographical areas for various life history stages of native Colorado River fishes.

	River Reach	Priority for Recovery			
		1	2	3	4
Y3	Steamboat to Craig	L	L/M	L	L
Y2	Craig to Yampa Canyon (Deerlodge)	H	H	H	H
Y1	Deerlodge to Echo Park (Yampa Canyon)	H	H	H	H
LS1	Baggs to Yampa River	M	L/M	M	M
G6	Flaming Gorge to Lodore	L	L	L	L
G5	Lodore to Echo	H	M	M	M
G4	Echo to Split Mt.	H	H	H	H
G3	Split Mt. to Desolation	H	H	H	H
G2	Desolation Canyon	H	M	H	H
G1	Gunnison Butte to confluence	H	H	H	H
W2	Meeker to Rangely	M	L	L	L
W1	Rangely to mouth	H	M/H	H	H
D1	Duchesne River	H	M	M	M
P1	Price River	M	L	L	L
S1	San Rafael River	H	L	L	L
UC2	Colorado River above Grand Diversion	M	H	H	H
UC1	Grand Diversion to confluence	H	H	H	H
C1	Confluence to Lake Powell (Cataract Canyon)	H	H	H	H
GU1	Gunnison River	H	M	H	H
DO1	Dolores River	M	L/M	L	L

Table 3. Recovery prospects ranking sheet from Nonnative Fish Control Workshop. Column number indicates small group; rankings indicate high (H), medium (M), or low (L) priority for recovery of endangered species in each river reach.

	River Reach	Concern for Interactions 1	2	3	4
Y3	Steamboat to Craig	M	M	L	L
Y2	Craig to Yampa Canyon (Deerlodge)	M	M	M	H
Y1	Deerlodge to Echo Park (Yampa Canyon)	H	M	M	H
LS1	Baggs to Yampa River	L	L/M	L	L
G6	Flaming Gorge to Lodore	L	L/M	L	L
G5	Lodore to Echo	M	M	L	M
G4	Echo to Split Mt.	H	H	M	H
G3	Split Mt. to Desolation	H	H	H	H
G2	Desolation Canyon	M	M	M	H
G1	Gunnison Butte to confluence	H	M/H	H	H
W2	Meeker to Rangely	L	M/H	L	L
W1	Rangely to mouth	H	M/H	L	H
D1	Duchesne River	H	H	M	M
P1	Price River	L/M	L	L	L
S1	San Rafael River	M	L	L	L
UC2	Colorado River above Grand Diversion	L	M	M	M
UC1	Grand Diversion to confluence	H	H	H	H
C1	Confluence to Lake Powell (Cataract Canyon)	H	H	M	H
GU1	Gunnison River	M	M	M	M
DO1	Dolores River	L/M	M	L	L

Table 4. Control Prospects Ranking Sheet from Nonnative Fish Control Workshop. Column number indicates small group; rankings indicate high (H), medium (M), or low (L) priority concern for interactions with endangered species in each river reach.

	River Reach	Recovery Priority	Nonnative Interactions	Number of Life History Stages
Y3	Steamboat to Craig	L	L/M	2
Y2	Craig to Yampa Canyon	H	M	4
Y1	Deerlodge to Echo Park	H	M/H	11
LS1	Baggs to Yamp River	M	L	3
G6	Flaming Gorge to Lodore	L	L	1
G5	Lodore to Echo Park	M	M	2
G4	Echo Park to Split Mountain	H	H	10
G3	Split Mountain to Desolation	H	H	9
G2	Desolation Canyon	H	M	9
G1	Gunnison Butte to Confluence	H	H	8
W2	Meeker to Rangely	L	M	4
W1	Rangely to Mouth	H	M/H	1
D1	Duchesne River	M	MH	4
P1	Price River	L	L	2
S1	San Rafael River	L	L	1
UC2	Colorado River above Grand Div.	H	M	9
UC1	Grand Diversion to Confluence	H	H	7
C1	Confluence Colo. River to L. Powell	H	H	6
GU1	Gunnison River	H	M	9
DO1	Dolores River	L	L	2

Table 5. Summary of Geographic Reach Rankings from Tables 2, 3, and 4.

Nonnative Species	Sources of River Population: river	ponds in flood-plain	reser-voir	stocking	Negative Interactions with Endangered Species: Predator on Juvenile and Adult	Predator on Egg/ Larvae	Compe-tition	Hybridi-zation
Channel catfish	+			+	+	+	+	
Red Shiner	+					+	+	
Northern Pike			+		+		+	
Common Carp	+					+	+	
Green Sunfish	+	+			+	+	+	
Fathead Minnow	+					+	+	
Sand Shiner	+					+	+	
Largemouth Bass		+	+		+		+	
Black bullhead	+				+	+		
Mosquitofish		+				+	+	
Striped Bass			+		+		+	
White Sucker	+						+	+
Redside Shiner	+					+	+	
Walleye	+		+		+		+	
White Crappie		+			+			
Bluegill		+				+	+	
Smallmouth Bass	+	+			+	+	+	
Black Crappie		+			+	+	+	
Trout (various)	+			+	+	+	+	
Plains topminnow		+				+	+	

Table 6. Overview of negative interactions between nonnative species and endangered species of the UCRB. Information was compiled from Hawkins and Nesler (1991) and Lentsch et al. (1995) and amended at the Nonnative Fish Control Workshop. The primary source of recruitment is also indicated for each nonnative species.

Species	egg 1	egg 2	egg 3	egg 4	larvae 1	larvae 2	larvae 3	larvae 4	juvenile 1	juvenile 2	juvenile 3	juvenile 4	adults 1	adults 2	adults 3	adults 4
Pike						H			M	H	M	H		M	L	L
Walleye									L	P		H		L		L
Largemouth					M	H		H	L			H		L		
Smallmouth					M	H		H	M	M	H	H		L		
Green sunfish					H	H	H	H		M	H	L				
Channel catfish		L			H	H	H	H	H	H	M	H				
Bluegill					L	L		M								
Black bullhead					L	L		M								
Common carp		L	L		L	L	L	M								
Sand shiner					L	L		M								
Redside shiner		P			L	L										
Red shiner		P			H	H	H	H								
Fathead minnow					H	H	H	H			M					
Black Crappie					M	H		H		M		M				
Striped Bass					L	H			M	H				L		
Plains Topminnow		P														
Mosquitofish		P				P		H								

Table 7A. Fish Interactions Ranking Sheet for the Colorado squawfish. Compiled by participants at the Nonnative Fish Control Workshop. Headers refer to small group numbers; rankings are high (H), medium (M), low (L), and potential (P). Blanks indicate no control action needed. See text for further explanation.

Species	egg				larvae				juvenile				adults			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Pike									L	H		H		M		L
Walleye									L	P		H		L		L
Largemouth					M			H	L			H		L		
Smallmouth					M			H	L	M	H	H		L		
Green sunfish					H	H		H		M	H	L				
Channel catfish		L	L		H	H	L	H	L	H	M	H				
Bluegill					L	L		M								
Black bullhead					L	M		M								
Common carp		L	L		L	H	H	M			H					
Sand shiner					L	L		M								
Redside shiner					L	L										
Red shiner					H	H	H	H								
Fathead minnow					H	H	H	H			H					
Black Crappie					M	H		H				M				
Striped Bass					L											
Plains Topminnow						H										
Mosquitofish								H								

Table 7B. Fish Interactions Ranking Sheet for the Razorback sucker. Compiled by participants at the Nonnative Fish Control Workshop. Headers refer to small group numbers; rankings are high (H), medium (M), low (L), and potential (P). Blanks indicate no control action needed. See text for further explanation.

	any stage			
Species	1	2	3	4
Pike	L	M		H
Walleye	L	L		H
Largemouth	L	L		H
Smallmouth	L	M	L	H
Green sunfish	L	M	L	H
Channel catfish	M/H	H	H	H
Bluegill				
Black bullhead				
Common carp		L		L
Sand shiner				
Redside shiner		L		
Red shiner		M		M
Fathead minnow				
Black Crappie		M		H
Striped Bass		L		
Plains Topminnow				
Mosquitofish				

Table 7C. Fish Interactions Ranking Sheet for the Humpback chub. Compiled by participants at the Nonnative Fish Control Workshop. Headers refer to small group numbers; rankings are high (H), medium (M), low (L), and potential (P). Blanks indicate no control action needed. See text for further explanation.

Species	Category of Control Technique			
	Mechanical	Chemical	Biological	Physico-chemical
Channel catfish	+		+	
Red Shiner	+	+	+	+
Northern Pike	+	+	+	+
Common Carp	+	+		
Green Sunfish	+	+	+	+
Fathead Minnow	+		+	+
Sand Shiner	+	+	+	+
Largemouth Bass	+	+	+	+
Black bullhead			+	
Mosquitofish			+	+
Striped Bass	+	+		
White Sucker	+	+		
Redside Shiner	+		+	+
White Crappie	+	+	+	+
Bluegill	+		+	
Smallmouth Bass	+	+	+	+
Black Crappie			+	
Plains topminnow				

Table 8. Control techniques applicable to nonnative fishes in the UCRB (from Lentsch et al. 1995). See text and original source for more detail.

Species	Seine @ low velocity				Net or Electrofishing				Commercial or recreational Harvest				Traps				Chemical			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1**	2	3	4
Channel catfish						H			L/M	H	H	H	H	H	H	H				
Red shiner				M												M				
Northern pike					M	H	M	H	L	H	M	H	M	H	H	H	M			H
Common carp					L			H	L/M	H	H	H	M*				H	H	?	H
Fathead minnow				M												M				
Sand shiner				M												M				
White sucker					L			L									H			L
Redside shiner				L																
Green sunfish					L	H		L									H	H		L
Smallmouth bass					L	H	M	L	L	H	?	L					M	H		L
Largemouth bass		H						L				L						H		
Black Crappie						H												H		
Bluegill						H												H		
Walleye												L								
Mosquitofish				M												M				

*off-channel entrapment (e.g., Old Charlie Wash)
**off-channel impoundments

Table 9. Control Measures Ranking Sheet as compiled by participants at the Nonnative Fish Control Workshop. Headers refer to small groups; rankings are high (H), medium (M), and low (L) according to the expected effectiveness of a control technique. Blanks indicate that a particualr technique is not thought to be feasible for control of a particular species.

	Stock squawfish				Discontinue stocking				Managed flow				Outlet con-trols	Sterili-zation	Exclu-sion	CCVD
Species	1	2	3	4	1	2	3	4***	1	2	3	4	2	2	3	4
Channel catfish							M					M	M	H		H
Red shiner	L	H							H	H	M	M			L	
Northern pike						H	N/A						M	H		
Common carp																
Fathead minnow	L								H		L	M				
Sand shiner	L								H	H	L	M				
White sucker																
Redside shiner	L								H	H		M				
Green sunfish							M					M				
Smallmouth bass					H	H	M					M	M			
Largemouth bass													M			
Black Crappie																
Bluegill																
Walleye																
Mosquitofish												M				

***technique rated "highly effective" but not ranked for each species.

Table 9 (concluded).

Location	Target Nonnative	Source Area	Control Technique	Beneficiary
basin-wide	any stocked	stocked sites	formal procedures	all
basin-wide	small cyprinids, centrarchids	channel	flow management	larval natives
basin-wide	pike	all habitats	catch & kill regulations	
critical habitat	all applicable	stocked sites	discontinue stocking	
nursery areas	channel catfish, carp	channel	bait & traps; other mechanical	all
High gradient HC habitat	channel catfish, carp	channel	bait & traps; winter electrofishing	YOY and juvenile humpback chub
Low gradient Csq & RZ habitat	channel catfish, carp, centrarchids, minnows	ponds	pond reclamation, levee removal	YOY & juv. CSq & RZ
G3	various	channel	screen from flooded bottomland	
G6	carp	channel	screen carp from spawning in NWR	
G1-4, UC1	various	channel	backwater exclusion	YOY Csq, RZ
G3 (Ouray)	channel catfish, carp	channel	commercial fishing & trapping	all
GU1	pike	channel	mechanical	
UC? (Govt Highline to Loma)	channel catfish, carp, centrarchids	channel	mechanical	
Green/Yampa	channel catfish, carp, centrarchids	channel	mechanical	
several	various	Elkhead, Kenney, Highline reservoirs	escapement control	Csq, RZ
Y3, UC2, UC1	various	large reservoirs	outlet controls/screens	Csq, RZ
UC2, UC1	various	floodplain ponds	screens	

Table 10. Suggested top priority strategies for control of nonnatives in the UCRB. Scenarios were developed during the Nonnative Fish Control Workshop. Each scenario is defined in terms of geographic location, target nonnative species, principal source of nonnatives at that location, control measure to be applied, and native species that benefit. Not all facets were defined for each scenario during the workshop. Abbreviations are defined as follows: CSq= Colorado squawfish; RZ= Razorback sucker, HC= humpback chub, YOY= young-of-year. For descriptions of river reaches (e.g., G1, UC1, etc.) see Table 2.

Section VIII. Appendix

Workshop Program, Participants, and Handouts

University of Colorado at Boulder

Environmental, Population, and Organismic Biology

N122 Ramaley
Campus Box 334
Boulder, Colorado 80309-0334
(303) 492-8981
FAX: (303) 492-8699

November 8, 1995

Announcing a Workshop on the Control of Nonnative Fishes in the Upper Colorado River Basin

---

Dear Workshop Participant:

The Center for Limnology at the University of Colorado welcomes you to its Nonnative Fish Control Workshop sponsored by the Colorado River Fishes Recovery Implementation Program. Workshop proceedings will be used to produce a draft strategic plan for nonnative fish control in the upper Colorado River basin. Because our mission is to produce a draft technical document, socio-political and institution constraints are not a major consideration at this point. In addition, our goal is to provide a plan containing enough detail to promote implementation planning for specific items of high priority.

The workshop will be held at the Clarion Harvest House, 1345 28th Street, Boulder. Airline travelers can obtain shuttle service at DIA. The hotel has many amenities and we have a special room rate of $79.00. A block of rooms has been reserved for workshop participants, but please reserve your room BEFORE November 20 by calling 1-800-545-6285. Please identify yourself as a "nonnative fish workshop" participant.

An agenda and list of invited guests are attached. Our sponsor has requested that we keep the number of attendees to about 30. However, please contact us if you think some individual should be added to the list.

The program includes a plenary session on the first day followed by discussion sessions that will provide opportunities for your participation. Please contact Dr. Harold Tyus, workshop organizer, with your comments, suggestions, or information that you believe pertinent to our endeavor. Dr. Tyus can be reached at: Voice 303-492-3947; Fax 492-0928; INTERNET> EMail: TyusH@Spot.Colorado.EDU; or at the above address.

Sincerely yours,

William M. Lewis Jr.

William M. Lewis, Professor and
Director, Center for Limnology

Attachments (2)

Interagency Workshop for Control of Nonnative Fishes
in the Upper Colorado River

Host: University of Colorado at Boulder
November 30 to December 1, 1995

AGENDA

Thursday, November 30:

8:00 am	Welcoming and Opening Remarks: Our charge	William Lewis
	Part 1. Program Module: The nonnative problem: What control is justified, what methods are applicable?	
8:15 am	Introduction to Program Module and Presenters	Harold Tyus
8:30 am	Instream flows: "Control" or native habitat? 9:00 - 9:15 Question/answer and discussion	Robert Muth
9:15 am	Non-native stocking: A prevention issue? 9:45 - 10:00 Question/answer and discussion	Dick Wydoski
10:00 am	------------------MORNING BREAK----------------	
10:15 am	Mechanical fish removal in main channel habitats 10:45 - 11:00 Question/answer and discussion	Larry Hesse
11:00 am	Fish exclusion structures in backwater habitats 11:30 - 11:45 Question/answer and discussion	Todd Crowl
11:45 am	-------------------LUNCH---------------------	
1:00 pm	Biotic interactions in non-evolved fish communities: Constraints on biological controls? 1:30 - 1:45 Question/answer and discussion.	Fran Gelwick
1:45 pm	Summary of program module. Integrated fish managment for nonnative fish and the Strategic Plan. 2:15-2:30 Question/answer and discussion,	Harold Tyus
	Part 2. Present Opportunities for Fish Control	
2:30 pm	Fish control opportunities in Colorado 3:00 - 3:15 Question/answer and discussion	Tom Nesler
3:15-3:30	------------------Afternoon Break------------------	
3:30 pm	Fish control opportunities in Utah 4:00-4:15 Question/answer and discussion	Leo Lentsch

Part 3. Developing the strategic plan

4:15 pm	How shall we proceed. What are the priorities? Fish control in designated recovery areas: Let us begin: A group discussion	Guy Burgess
5:30 pm	--------------Meeting adjourns for the day-----------	
7:00 pm	Workshop planning committee meets to condense material for the day.	

Friday, December 1

8:00 am	Summary of previous day	Guy Burgess
8:30 am	Conceptual framework for developing control options	Guy Burgess
9:00 am	Discussion Period	
10:00 am	---------------MORNING BREAK---------------	
10:15 am	Revisiting and ranking options in the conceptual framework.	Guy Burgess
11:45 am	-------------------LUNCH------------------	
1:00 pm	Where do we go from here? Perceptions of program needs for implementation. Concept of the Strategic Plan as a coordinated effort.	Harold Tyus
3:00 pm	Adjournment	

Invitees for the Nonnative Fish Control Workshop

Name	Representing	Phone
Leo Lentsch	Utah Division of Wildlife Resources	801-538-4756
Tom Pettingill	Utah Division of Wildlife Resources	801-538-4814
Tom Nesler	Colorado Division of Wildlife	303-291-7356 #357
Pat Martinez	Colorado Division of Wildlife	970-484-2836 #352
Mike Stone	Wyoming Fish and Game Department	307-777-4559
Christine Karas	U.S. Bureau of Reclamation	801-524-3273
Ron Sutton	U.S. Bureau of Reclamation	801-524-6292
Gary Burton	Western Area Power Administration	303-275-1725
Ray Tenney	Colorado River Water Conservation Dist.	970-945-8522
Tom Pitts	Water Users Representative	303-667-8690
Dan Luecke	Environmental Defense Fund	303-440-4901
Reed Kelly	Recovery Environmental Group	970-878-4666
John Hawkins	Colorado State University	970-491-5475
Henry Maddux	Recovery Implementation Program	970-248-0669
Frank Pfeifer	U.S. Fish and Wildlife Service	970-245-9319
John Hamill	Recovery Implementation Program	303-236-2985
Mike Stempel	U.S. Fish and Wildlife Service	303-236-8154
Bob Williams	U.S. Fish and Wildlife Service	801-524-5001
Todd Crowl	Utah State University	801-797-2498
Robert Muth	Colorado State University	970-291-1848

Workshop Planning Committee

Harold Tyus	University of Colorado at Boulder	303-492-3947
Jim Saunders	University of Colorado at Boulder	303-492-5191
Guy Burgess	University of Colorado at Boulder	303-492-1635
Fran Gelwick	Texas A & M University	409-862-4172
Larry Hesse	River Ecosystems, Incorporated	402-388-4276
Dick Wydoski	Colorado River Fishes Rec. Prog.	303-236-2985

Nonnative Fish Control Workshop
Major Issues

Issue Definition: Problems/Solutions/Outstanding Questions

I. **Scope:** Nonnative fishes, Element 4.4 of The Recovery Implementation Program (USFWS 1987): Further curtailment of stocking, reduction or elimination of some nonnative species are options to reduce some negative impacts to rare fish.

II. **Problem:** Competition and predation by nonnative fishes have contributed to decline of Colorado River fishes.

III. **Solution:** Remove or reduce nonnative fishes that are threats to listed fishes.

IV. **Outstanding Questions:** Control of nonnative fishes is hindered by many questions. The items below form a partial list that will serve as a basis for discussion during the workshop.

A. Geographic areas are not of equal importance.
   1. Critical habitat to 100 year flood plain.
   2. Entire range of listed species to 100 year flood plain.
   3. Entire basin to include upstream sources, offchannel areas.
   4. Identify high priority areas for relative importance.
      a. Emphasis on sensitive reaches (USFWS 1987).
      b. Emphasis on upstream areas as sources of nonnatives.
      c. Emphasis on problem nonnatives.
      d. Emphasis on areas/habitats conducive for control techniques.

B. Endangered fishes do not have same degree of vulnerability to nonnative fish interaction.
   1. Endangered fishes have different degree of vulnerability.
      a. Colorado squawfish are least vulnerable to predation, then humpback chub, then razorback sucker; bonytail unknown.
   2. Different life stages have different vulnerability.
      a. Larva most vulnerable; adults least vulnerable.

C. Nonnative fish species pose a range of threats.
   1. Nonnative fish threats vary by season: spring, summer, fall, winter.
   2. Nonnative fish threats vary by habitat: backwater, eddy, side channel, main channel.
   3. Nonnative fish threats vary by species: predators, direct competitors, indirect competitors.

D. Control methods are not equally effective (they are selective).
   1. Control methods differ by habitat.
   2. Control methods differ by species.
   3. Control methods differ by size of fish.
   4. Control methods differ by season (native fish behavior).

E. General lack of knowledge may require pilot studies.

V. Function of Strategic Plan.

A. Long-term framework = Define control strategies based on the literature and input from workshop.
   1. Develop long-term plan with specific goals and strategies for pursuing nonnative fish control objectives.
   2. Identify priority areas and control methods for further definition in implementation plans.

B. Intermediate framework = Development of implementation plans based on Part V-A (above) = considered out of our scope.
   1. Develop specific objectives for attaining the goals of the nonnative fish control program.
   2. Identify specific locations for implementation. Further definition of tasks, resources, schedules to be done in specific work plans.

Nonnative Fish Control Workshop
Recovery and Control Prospects Ranking Sheet

Map Code		River Reach	Priority for recovery	Level of concern for interactions with nonnatives
Y3	-	Steamboat to Craig	____	____
Y2	-	Craig to Yampa Canyon (Deerlodge)	____	____
Y1	-	Deerlodge to Echo Park (Yampa Canyon)	____	____
LS1	-	Baggs to Yampa River	____	____
G6	-	Flaming Gorge to Lodore	____	____
G5	-	Lodore to Echo	____	____
G4	-	Echo to Split Mt.	____	____
G3	-	Split Mt. to Desolation	____	____
G2	-	Desolation Canyon	____	____
G1	-	Gunnison Butte to confluence	____	____
W2	-	Meeker to Rangely	____	____
W1	-	Rangely to mouth	____	____
D1	-	Duchesne River	____	____
P1	-	Price River	____	____
S1	-	San Rafael River	____	____
UC2	-	Colorado River above Grand Diversion	____	____
UC1	-	Grand Diversion to confluence	____	____
C1	-	Confluence to Lake Powell (Cataract Canyon)	____	____
GU1	-	Gunnison River	____	____
DO1	-	Dolores River	____	____

River reaches proposed for evaluating recovery and control prospects. Assign a rank of high (H), medium (M), or low (L) to the priority for recovery of endangered species in each river reach. Do the same for the level of concern about negative interactions with nonnative species in each river reach. It is possible to indicate high priority for recovery without there being concerns about nonnatives. Add river reaches as needed.

Nonnative Fish Control Workshop
Geographical Distribution of Life History Stages

iver each	Colorado Squawfish					Razorback Sucker					Humpback chub	
	Eggs	Larvae	Juve- nile	Adult	Migrant	Eggs	Larvae	Juve- nile	Adult	Migrant	All Stages	Migrant
Y3												
Y2			+	+	+				+			
Y1	+	+	+	+	+	+	+	+	+	+	+	
LS1												+
G6												
G5				+					+			
G4		+	+	+	+	+	+	+	+	+	+	
G3		+	+	+	+	+	+	+	+	+		
G2	+	+	+	+	+				+		+	
G1		+	+	+	+				+			
W1				+	+				+			
W2									+			
D1												
P1												
S1												
UC2												
UC1	+	+	+	+	+				+		+	
C1			+	+					+			
GU1				+					+			
DO1												

mportant geographical areas for various life history stages of native Colorado River fishes. This table is ntended as a basis for discussion. Feel free to amend or expand as needed.

Nonnative Fish Control Workshop
Negative Interactions

Nonnative Species	Source of Recruitment to Riverine Population	Negative Interactions with Endangered Species: Predator on Juvenile and Adult	Predator on Egg/ Larvae	Direct Competition	Indirect Competition
Channel catfish	self-sustaining	+	+		+
Red Shiner	self-sustaining		+	+	+
Northern Pike	upper Yampa	+		+	+
Common Carp	self-sustaining		+	+	
Green Sunfish	self-sustaining	+	+	+	+
Fathead Minnow	self-sustaining		+	+	+
Sand Shiner	self-sustaining		+	+	
Largemouth	Colo. River floodplain	+		+	
Black bullhead	self-sustaining	+	+		
Mosquitofish	?		+		
Striped Bass	Lake Powell	+			+
White Sucker	self-sustaining				+
Redside Shiner	self-sustaining		+	+	
Walleye	self-sustaining	+			+
White Crappie	small impoundments	+			
Bluegill	small impoundments				+
Additional					

Overview of negative interactions between nonnative species and endangered species of the UCRB. Information was compiled from Hawkins and Nesler (1991) and Lentsch et al. (1995). The primary source of recruitment is also indicated for each nonnative species. This table is intended as a basis for discussion. Feel free to amend or expand it as needed.

Nonnative Fish Control Workshop
Fish Interactions Ranking Sheet

Nonnative Species	Colorado Squawfish Egg	Colorado Squawfish Larvae	Colorado Squawfish Juvenile	Colorado Squawfish Adult	Razorback Sucker Egg	Razorback Sucker Larvae	Razorback Sucker Juvenile	Razorback Sucker Adult	Humpback Chub All stages
Northern Pike			( )	( )			( )	( )	( )
Walleye			( )	( )			( )	( )	( )
Largemouth Bass			( )	( )			( )	( )	( )
Smallmouth Bass			( )	( )			( )	( )	( )
Green Sunfish		( )	( )			( )	( )		( )
Channel Catfish	( )	( )	( )		( )	( )	( )		( )
Bluegill		( )				( )			
Black Bullhead		( )				( )			
Common Carp	( )	( )			( )	( )			( )
Sand Shiner	( )	( )			( )	( )			
Redside Shiner	( )	( )			( )	( )			( )
Red Shiner	( )	( )			( )	( )			
Fathead Minnow			( )				( )		
White Sucker	( )				( )				
Additions									

Nonnative-endangered fish interactions. Nonnative species ranked according to mouth gape and/or type of food eaten. For each interaction, assign a rank of high (H), medium (M), or low (L) according to the need for control measures. Feel free to amend or expand the table as needed.

Nonnative Fish Control Workshop
Control Measures by Species and River

Nonnative Species	River or River Drainage					
	Colorado	Gunnison	Dolores	Green	Yampa	White
Channel Catfish	M,B,P		M,B,P	M,B,P	M,B,P	
Red Shiner	M,C,B,P	M,C,B,P	M,C,B,P	M,C,B,P	M,C,B,P	M,C,B,P
Northern Pike					M,C,B,P	
Common Carp	M,C	M,C	M,C	M,C	M,C	
Fathead Minnow	M,B,P	M,B,P	M,B,P	M,B,P	M,B,P	
Sand Shiner	M,C,B,P				M,C,B,P	
White Sucker		M,C			M,C	
Red Shiner					M,B,P	

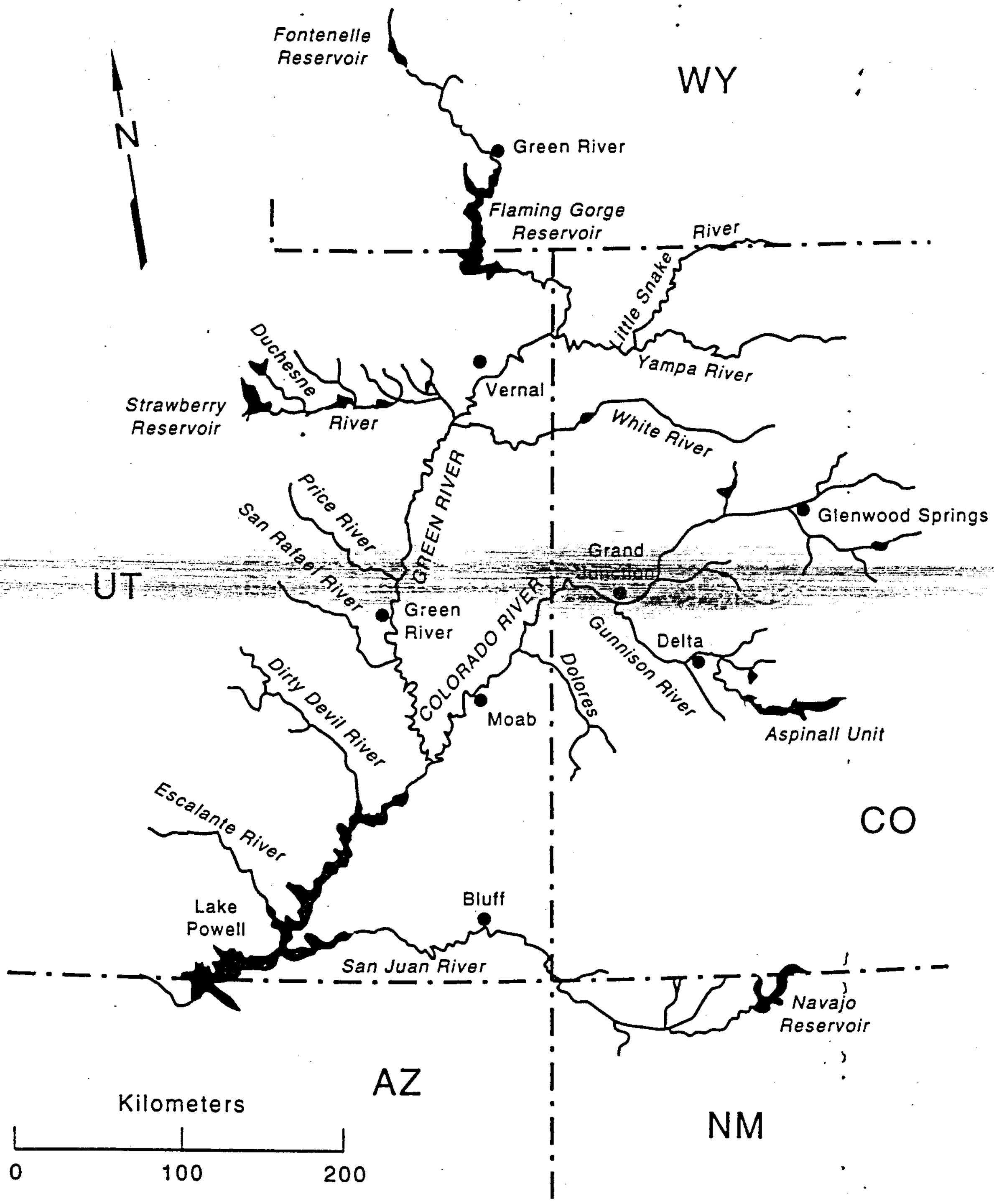
General categories of control measures recommended for nonnative fish species considered a threat to endangered species and common or abundant in riverine environments of the seven major drainages of the UCRB. M = mechanical, C = chemical, B = biological, P = physicochemical. Based on Lentsch et al. 1995. Blanks indicate that a given species is not common or abundant in a particular river; the species may be rare, incidental or absent. This table is intended as a basis for discussion. Feel free to amend or expand it as needed.

Nonnative Fish Control Workshop
Control Measures Ranking Sheet

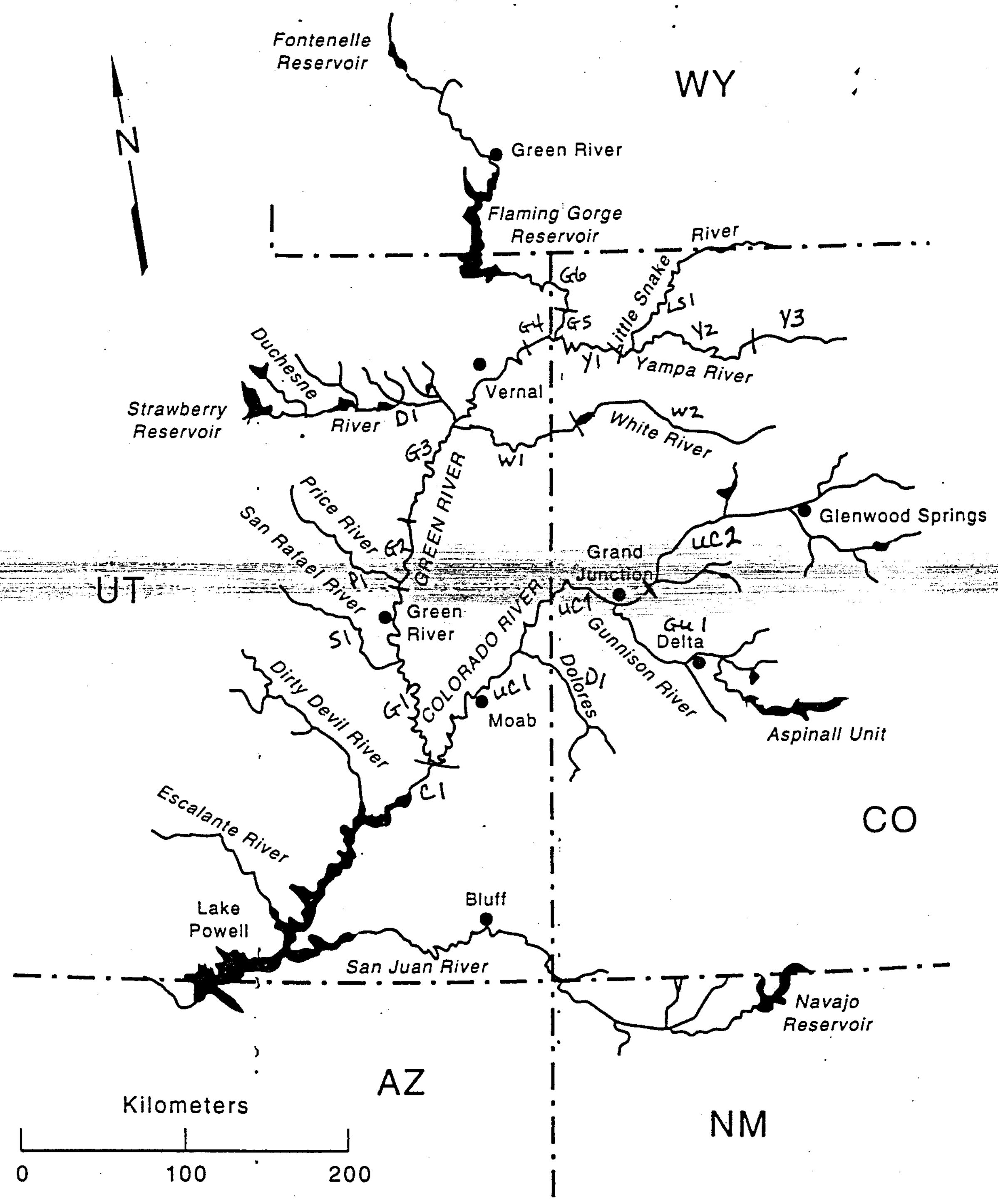
Species	Control Techniques							
	Seine at low velocity	Net or electrofishing[1]	Commercial or recreational harvesting	Traps	Chemical[1]	Stock Squawfish	Discontinue Stocking	Managed Flow
Channel catfish			( )	( )				
Red shiner	( )					( )		( )
Northern pike		( )	( )	( )	( )		( )	
Common carp		( )	( )		( )			
Fathead minnow	( )					( )		( )
Sand shiner	( )					( )		( )
White sucker		( )			( )			
Redside shiner	( )					( )		( )
Green sunfish		( )			( )		( )	
Smallmouth bass		( )	( )		( )		( )	
Additional								

[1] Target spawning aggregations or other isolated assemblages.

Control techniques applicable for target nonnative fish species. Based on Lentsch et al. 1995. For each combination, assign a rank of high (H), medium (M), or low (L) according to the expected effectiveness of the control technique. Blanks indicate that a particular technique is not thought to be feasible for control of a particular species. This table is intended as a basis for discussion. Feel free to amend or expand it as needed.



Base map of UCRB.



Base map of UCRB with proposed boundaries of reaches. See "Recovery and Control Prospects Ranking Sheet" for details.

Nonnative Fish Control Workshop Identification and Prioritization of Control Options

This worksheet seeks participant views on which nonnative fish control scenarios should be implemented. You should feel free to add additional scenarios if you think that they merit consideration.

Each scenario could include some or all of the following:

- Endangered species to be protected.
- Nonnative species to be controlled.
- Geographical areas in which the control efforts would take place.
- Control method used.

Please indicate the importance you attach to each scenario using the following scale:

- A = Absolutely essential
- B = Desirable but not essential
- C = Inappropriate for this scenario.

In addition, please mark the level of effort you consider appropriate for the implementation of this scenario:

- **Pilot Test Program** to determine the feasibility and effectiveness of some fish control strategies prior to full implementation.
- **Limited Program** with implementation of only the highest priority nonnative fish control options.
- **Full Program with Sport Fishery Protection** - the maximum degree of nonnative fish control with no *net* negative impact on sport fisheries. (Sport fishery enhancements may, however, be used to offset adverse impacts from nonnative control efforts.)
- **Full Program** - implementation of a nonnative fish control program sufficient for the full recovery of all endangered fishes in appropriate geographic locations.

Examples of scenarios might include:

1) Control of channel catfish by trapping in all humpback chub areas.

2) Poison all ponds within the 20-year floodplain of river section UC1 to protect young Colorado squawfish.

3) Restrict stocking of nonnative fishes in critical habitat.

Nonnative Fish Control Workshop
Scenario Worksheet

Scenario	Importance	Effort

Nonnative Fish Control Workshop
Small Group Assignments

1	2	3	4
Burton	Davis	Hamill	Crist
Crowl	Karas	Hayse	Gelwick
Hesse	Lentsch	Maddux	Hawkins
Luecke	Miller	Modde	Hlohowskyj
Martinez	Muth	Nesler	Pettingill
Thompson	Stempel	Stone	Pfeifer
Williams	Wydoski	Sutton	Tenney