

# ***Interactions and Management of Alien Fishes in the Grand Canyon.***

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## **ABSTRACT**

Many changes have occurred in the Grand Canyon over the past 100 hundred years. Some of these changes include the closure of Glen Canyon Dam in 1963 and the continuous introduction of alien fishes since the late part of the 19<sup>th</sup> century. These changes have caused the decline of native fishes. As a result, managers have attempted to promote native fishes by regulating floods, mechanically removing alien fishes and have even investigated use of thermal regulation. The purpose of this paper is to describe the alien fishes of the Grand Canyon, investigate their interactions with native fishes and explore the adaptive management techniques being used to decrease their populations in order to promote native fishes. I conclude the paper by giving my recommendations for suppressing alien fishes to promote native fishes in the Grand Canyon.

## **INTRODUCTION**

The Colorado River Basin is home at to a unique group of eight endemic native fishes: the Colorado pikeminnow (*Ptychocheilus luscious*), bonytail chub (*Gila elegans*), roundtail chub (*Gila robusta*) and razorback sucker (*Xyrauchen texanus*), humpback chub (*Gila cypha*), flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*C. discobolus*) and speckled dace (*Rhinichthys osculus*). These fish are unique because of a combination of isolation and extreme conditions that existed in the pre-regulated Colorado River. These fish were adapted to extreme conditions such as spring runoff flows that averaged about 84,000 cfs in addition to late-summer thunderstorms that were known to produce flows that of were similar size (Haden 1992). These flows were critical for the movement of sediment which creates sandbars and backwaters suitable for juvenile and larval native fishes. They were also adapted to very low flows in the late summer through winter (Minkley 1991). Temperature was also a significant variable, as temperature varied from near freezing temperatures in January to highs of 27°C through July and August (Webb et al. 2002).

For the past one hundred years, these native fish have faced problems which have led to their decrease in abundance. The regulation of the Colorado River (e.g. Glen Canyon dam) has caused native fish fauna to cope with reduced flows, reduced sediments, and colder summer temperatures. Alien fishes, which have been introduced in the system, compete with and prey upon native fish, thus leading further to their demise (Minckley 1991). For the past 100 years, alien fish have been introduced either as game fish or through bait buckets used by fishermen. Since the construction of the Glen Canyon Dam and the introduction of alien fishes, four native fishes have been placed on the federal endangered species list and three of the four have been extirpated from the Grand Canyon. Native fish which have been extirpated from the Grand Canyon include: Colorado pikeminnow, bonytail chub, and razorback sucker (Minkley 1991). The fish that are listed as endangered include: Colorado pikeminnow, humpback chub, bonytail chub and the razorback sucker.

Attempts are currently being made to suppress alien fishes through protocols that regulate flows from Glen Canyon Dam. These flows are meant to decrease alien fish populations and create habitat for native fish (Hoffnagle et al. 1999). The purpose of this paper is to describe the alien fishes of the Grand Canyon, investigate their interactions with native fishes and explore the adaptive management techniques being used to decrease their populations in order to promote native fishes.

## **HISTORY OF NON-NATIVE INTRODUCTIONS**

The introduction of alien species into the Colorado River basin has occurred since Euro-American settlers first explored the river basin. John Westley Powell first brought public attention to the Grand Canyon with his exploration of the river in 1869 (Webb et al. 2002). Since his exploration of the river, there have been continuous invasions of alien fishes beginning with the common carp in 1890 (Haden 1992). Since then, 25 fish species have been introduced into the lower Colorado River (Hoffnagle et al. 1999). Currently, there are 15 freshwater species in the Grand Canyon in which only 4 are native and 11 are alien (Valdez et al. 2001). There are only seven alien fishes commonly found in the Grand Canyon. (see figure 1). Figure one shows some of the common alien fishes found in the Grand Canyon, their habitat and the year and reason for their introduction.

## Rainbow Trout

Rainbow trout are a prized catch among sport fishermen. Rainbow trout support “blue ribbon fishery” below Glen Canyon Dam, which draws in large sums of money for the local economy. More information regarding the fishery, management and life history of rainbow trout is further explained in Epstein (2005) in this volume.

They have been continuously stocked in the mainstem and tributaries since their first introduction in Tapeats creek in 1923 (Haden 1992, Stricklin 1950, Arizona Game and Fish Department 1950). The continuous stocking, reproduction and recruitment of rainbow trout have allowed them to be successful in spreading its distribution from Lee’s Ferry area to the Little Colorado river inflow (Valdez et al. 2001).

Species	Status	Year introduced	Reason for introduction
Rainbow Trout <i>Oncorhynchus mykiss</i>	Dam tailwaters and tributaries <sup>1</sup>	1923 <sup>3</sup>	Sport Fishing <sup>3</sup>
Brown Trout <i>Salmo trutta</i>	Mainstem and tributary inflow <sup>1</sup>	1926 <sup>3</sup>	Sport Fishing <sup>3</sup> and Bait Bucket <sup>5</sup>
Common Carp <i>Cyprinus carpio</i>	Mainstem <sup>1</sup>	1890 <sup>3</sup>	Sport Fishing <sup>3</sup>
Channel Catfish <i>Ictalurus punctatus</i>	Mainstem <sup>1</sup> and tributaries <sup>4</sup>	1890s <sup>3</sup>	Sport Fishing <sup>3</sup>
Fathead minnow <i>Pimephales promelas</i>	Backwaters and tributaries <sup>1</sup>	Late 1800s <sup>2</sup>	Bait bucket <sup>3</sup>
Plains Killifish <i>Fundulus zebrinus</i>	Backwaters and tributaries <sup>1</sup>	1950 <sup>5</sup>	Bait bucket <sup>5</sup>
Red Shiner <i>Cyprinella lutrensis</i>	Backwaters near Lake Mead <sup>1</sup>	Late 1940s <sup>3</sup>	Bait bucket <sup>3</sup>

**Figure 1:** list of the common alien fishes in the Grand Canyon.

1: Valdez et al 2001

2: approximation from Valdez 2002 table in Webb et al 2002.

3: Haden 1992

4: Marsh and Douglas 1997

5: Miller 1951

## **Brown Trout**

First introduced into Shinumo Creek in 1926, brown trout were also introduced in Bright Angle Creek and Garden Creek until 1934 (Stricklin 1950, Haden 1992, Arizona Game and Fish Department 1950). Relative to rainbow trout, brown trout do not support a popular fishery because of the lack of abundance and brown trout are more difficult for fisherman to catch. They are most abundant in the mainstem but have been reported in some tributaries (Haden 1992).

The presence of brown trout in the system without further introduction since 1934 suggests that they are successfully reproducing in the system. Brown trout are known to spawn in the fall and winter in water temperatures ranging from 6.7°C to 8.9°C (Scott and Crossman 1973). Reports have shown that brown trout make spawning runs up Bright Angel Creek during late November through January (Haden 1992).

Stomach contents of brown trout suggest that they are omnivorous. They are known to eat terrestrial invertebrates, fish eggs and variety of native and alien fishes (Marsh and Douglas 1997). In a personal interview with Timothy Hoffnagle (2005), brown trout may be a ferocious predator on native fishes especially humpback chub.

## **Common Carp**

Common carp were one of the first alien fishes introduced into the system. Originally from Asia, carp were introduced in the 1890s as a game and bait fish (Haden 1992, Miller 1951). Personal accounts in Miller (1951), show that carp was a popular bait sold in bait shops for \$1.25 a dozen. It was also used as a forage fish for the poor locals, who would purposely fish for carp using cane poles and anything available for bait (Dill 1944). Miller (1951) also reported that carp were abundant throughout the system. It seems that 54 years later, their abundance has changed little (Haden 1992.).

Carp are known to reproduce beginning in spring to early summer and can even continue in autumn and late winter (Sivakumaran et al. 2003). They seem to prefer water temperatures ranging from 19°C to 22°C. These temperatures are most commonly found in the Little Colorado River and Kanab Creek (Haden 1992). Carp are found in the mainstem of the Grand Canyon; however, it is most likely a result of inflow from Lake Mead (Valdez et al. 2001).

Carp are known to be successful omnivores around the world. Its diet primarily consists of detritus, algae, plant debris, various invertebrates and fish eggs (Scott and Crossman 1973). It has not been documented that carp are active predators among other fish in the system; it would be safe to speculate that carp would prey upon larval or juvenile native fishes given the opportunity.

### **Channel Catfish**

Much like carp, channel catfish were introduced into the Grand Canyon during the 1890s. According to Dill (1944), they were introduced as a game fish for three reasons: their fight, good taste, and susceptibility to artificial lures. Introductions have been very successful in the system, and can be demonstrated by the simple fact that every fish survey since their introduction has found channel catfish (Haden 1992). They have been found in some tributaries like the Little Colorado River and Kanab Creek where they are known to get quite large. Timothy Hoffnagle has caught channel catfish in the Little Colorado River weighing up to 22 pounds (Hoffnagle, T.L., personal communication, 2005). These fish are also abundant further downstream near Hells Hollow, Spencer Creek and the Lake Mead area (Valdez et al. 2001).

Channel catfish are known to spawn at temperatures ranging from 23.9°C to 29.5°C, which are locally found in Little Colorado River and near Lake Mead (Haden 1992). Reports by Carothers and Minckley (1981), have confirmed channel catfish reproduction by finding young of year fish in the Little Colorado River. However they do require periods of cool water and short day lengths during the winter months for proper egg development. They are known to be fierce nest guards that produce egg masses up to 20,000 eggs (Riehl and Baensch 1991, Yamamoto and Tagawa 2000).

Stomach contents show that Channel catfish are opportunistic omnivores. Channel catfish are known to eat detritus, vegetation, algae, variety of invertebrates, native and alien fishes, and fish eggs (Marsh and Douglas 1997).

### **Fathead minnow**

Fathead minnow was first introduced in the late 1800s (Webb et al. 2002). Since its introduction it has become widespread throughout the system especially in the backwaters (Valdez et al. 2001, Hoffnagle et al. 1999). It was originally introduced as a bait fish, and was

sold in the local bait shops. Records show that bait shops were supplied with fathead minnow from bait tanks in Truth or Consequence, New Mexico (Miller 1951). Fathead minnow are known to be rather aggressive fish and may influence the use of backwater habitat by native fishes (Hoffnagle, T.L., personal communication, 2005)

Fathead minnow are known to spawn at temperatures around 15°C. Fathead minnow are known to inhabit muddy waters. Hoffnagle and Tuegal (2001) found that there is some food overlap with native fishes. As a result, Hoffnagle and Tuegal (2001) concluded that fathead minnow may influence habitat use by native fishes. To what degree fathead minnow influences native fishes is still unknown.

### **Plains Killifish**

Plains killifish was commonly sold in bait shops around the area. It was first reported on March 23, 1950, being sold at a bait shop in Yuma (Miller 1951). It was predicted that plains killifish would eventually disappear from the system during pre-dam conditions (Miller 1951). However since the construction of Glen Canyon Dam in 1963, plains killifish have become established in the back waters of the mainstem and tributaries throughout the Grand Canyon (Hoffnagle et al. 1999).

Known to spawn at temperatures around 27°C (Koster 1948), plains killifish are known to mature and reproduce by the second summer, but usually doesn't survive past the third summer (Minckley and Klassen 1969).

Plains killifish are known to survive harsh conditions that other fish aren't known to inhabit such as high alkaline and saline waters. It is known to bury itself in sand with only its eyes and mouth visible. Supposedly this behavior allows for plains killifish to avoid predators, detect prey or stream desiccation (Page and Burr 1991).

### **Red Shiner**

The introduction was probably a result of bait buckets. It was first found in the lower Colorado River basin in January of 1953 (Hubbs 1954). Since then it has been successful in backwater habitats near the Lake Mead inflow (Valdez et al. 2001).

Red shiner are known to spawn at temperatures between 15°C to 30°C. They are quick maturing and usually mature within the first year of life but usually do not live past three years (Scott and Crossman 1973).

Much like fathead minnow, red shiner are relatively aggressive fish. In a aquaculture study by Gido et al. (1999), the presence of red shiner reduced the recruitment of juvenile pupfish. They documented that predation by red shiner was a factor in limiting the abundance of pupfish. Events like this, maybe occurring in the backwaters where larval and juvenile native fishes encounter red shiners.

### **Other Fishes**

The fishes previously described are not the only alien fishes in the Grand Canyon; they are some of the most common fishes found in the Colorado River and in the tributaries. Other fish have been found in the Grand Canyon from Lake Mead, Lake Powell and some tributaries. These fish include, but are not limited to: striped bass, threadfin shad, yellow bullhead, redbelt shiner, large mouth bass, black crappie, bluegill, green sunfish and walleye. Many other fish have been introduced into the system but were not successful such as coho salmon (Haden 1992).

## **INTERACTIONS WITH NATIVE FISHES**

Native fish have negative interactions with alien fishes at every stage of their life cycle. As a result, populations of native fishes have declined with increasing alien populations and with the regulation of the river (Webb et al 2001.). Throughout North America, introductions of alien fishes have had similar impacts on native fishes. Moyle et al. (1987), says that some of the impacts that alien fishes have on native fishes include the following: elimination of native species, reduced growth and survival, changes in community structure and no effect. The alien fishes in the Grand Canyon have certainly impacted native fishes in the ways predicted by Moyle et al. (1987).

Native fishes have also been displaced by alien fishes. According to Moyle et al. (1987), there are six mechanisms which allow introduced species succeed in displacing native fishes. These mechanisms are: competition, predation, inhibition of reproduction, environmental modification, transfer of new parasites or diseases and hybridization. These interactions, some more than others, have helped in the decline of native fishes in the Grand Canyon.

## **Elimination of Species**

In the Grand Canyon, elimination has occurred locally with two species of native fishes: Colorado pikeminnow and bonytail chub. The last documented occurrence of these fish was in 1975 (Haden 1992). The exact cause for their extirpation from the river is unknown, but one can safely speculate that their extirpation is a direct result of alien fishes and the closure of Glen Canyon Dam. Colorado pikeminnow was the only known native predator it may have faced with competition with other alien predators that currently dominate the system like channel catfish and brown trout. In fact, Colorado pikeminnow were faced with mortality even when they preyed upon some alien fishes. There is one documented case of a Colorado pikeminnow which attempted to eat a channel catfish but in the attempt Colorado pikeminnow choked itself on the spines of the channel catfish (McAda 1983). Elimination of humpback chub is still a very real threat, especially if further introductions of alien fish are successful. If predacious fish such as smallmouth bass become established in the Grand Canyon the humpback chub will surely go extinct (Hoffnagle, T.L., personal communication, 2005).

## **Reduced Growth and Survival**

Reduced growth and survival is prevalent in the Grand Canyon. The cool hypolimnetic water released from Glen Canyon is a factor that not only reduces growth but also may reduce survival. Lupper and Clarkson (1994) found that growth rates of humpback chub, as with most fish, vary with temperature. They found the growth rate for humpback chub was 10.63 mm/day at 20°C compared to 2.30 mm/day at 10°C. The current temperature of the river is about 8°-10°C. Furthermore, the largest population of reproducing humpback chub occurs in the Little Colorado River (LCR) (Haden 1992). The LCR has a relatively warmer temperature than that of the Colorado River (Robinson and Childs 2001). As a result, when juvenile and larval humpback chub are displaced from the LCR, they fall victim to thermal shock which very well may reduce survival (refer to Campos (2005) this volume).

Predation is also a factor that reduces survival. There may be significant predation by alien fishes not only on juvenile native fishes but also adult native fishes (Marsh and Douglas 1997). I discuss predation in more detail later in the paper.



## **Changing of Community Structure**

The change of community structure of the fish assemblage in the Grand Canyon is hard to quantify since the community structure was not well defined prior to the introduction of alien fishes. There are some unexplained occurrences with native fishes that may result from a change in community structure. Interestingly enough, humpback chub primarily spawns in the Little Colorado River (LCR) even when there are suitable temperatures for spawning in other tributaries. This may suggest some physical and biological parameters that prevent humpback chub spawning in tributaries besides the LCR (Haden 1992). Humpback chub populations are mostly limited to the LCR even when downstream tributaries such as Kanub Creek have similarities with the LCR (Haden 1992). Some reasons why humpback chub are not dispersed successfully from the LCR are predation and thermal shock. If they were able to overcome these obstacles would they be successfully be dispersed? Is there sufficient food for them to live in the lower parts of the river? Would they exist in the lower parts in the face of competition and predation by the alien fishes that live there? Are there enough backwater habitats for to provide for the rearing of juveniles and larvae humpback chub? All of these questions may lead to some answers in suggesting a change in community structure.

## **No Effect**

It is possible for alien fishes to have no effect on native fishes. However Moyle et al. (1987), warns that if no effect is suggested further investigation should be done.

## **Competition**

Competition is hard to quantify, but with a basic understanding of ecology it can be easily speculated. Hoffnagle and Tuegal (2001) showed that in the backwaters there is some food overlap between native and alien fishes. Since food, wasn't considered a limiting resource, competition of resources was not occurring. However, in low productive tributaries like the Little Colorado River (Hoffnagle, T.L., personal communication, 2005) competition may be occurring for food or even habitat.

## **Predation**

Predation on native fishes by alien fishes is prevalent within the river. Results from a study by Marsh and Douglas (1997), show that there is significant predation by alien fishes on native fishes in both juvenile and adult stages in the Little Colorado River (LCR). They identified the local predators to be: rainbow trout, channel catfish, yellow bullhead, black bullhead and brown trout. Out of the 219 stomachs the examined, 14% of them had remains of native fishes. Native fishes that were eaten varied in size dramatically, ranging from 43-250mm (see figure 2). This variation in size implies that predation not only reduces recruitment among native juveniles but also adults (Marsh and Douglas 1997). An interesting example Marsh and Douglas (1997) used in their conclusions which helped quantify the predation pressure alien fishes had on natives is as follows: “Data indicates that on average about 3% of rainbow trout and channel catfish ate an average of 2.3 humpback chubs. If 2.3 prey is taken once a week, a predator population of 1000 would annually consume 3,588 humpback chubs.” The number of humpback chub consumed is a very large number when compared to estimated populations of 4,000 to 10,000 humpback chub in the LCR (Marsh and Douglas 1997)

<b>Native Fish Consumed</b>	<b>Size Range (mm)</b>	<b>Size of Juvenile Fish*<sup>1</sup></b>	<b>Size of Adult Fish</b>
Humpback chub	43-200	30-120	>120
Speckled Dace	45-77	30-120	>120
Flannelmouth Sucker	78-200	30-120	>120
Bluehead Sucker	150-250	30-120	>120

**Figure 2.** Various sizes of native fishes eaten by alien fishes. Data from Marsh and Douglas (1997).

1: Sizes of Juvenile fish in millimeters defined by Hoffnagle and Tuegal (2001).

### **Inhibition of Reproduction and Environmental Modification**

Inhibition of reproduction and environmental modification is a result of human regulation of the river. The closure of the Glen Canyon Dam has reduced both temperatures and flows relative to pre-dam conditions. These variables were crucial in cueing native fishes to spawn (Minckley 1991). Ideal spawning temperature for native fishes is approximately 20°C while the current temperature of the river ranges from 8°C to 12°C, see table 1 (Yard and Collins 2003). As a result, native fish spawning are mostly limited to warm water tributaries like the Little

Colorado River (Hoffnagle, T.L., personal communication, 2005). More information regarding spawning behavior of native fishes can be found in Campos (2005) in this volume.

### **Transfer of Parasites**

It has been documented that parasites from alien fishes have infected native fishes. Choudhury et al. reports that 17 species of parasites were found in the Little Colorado River (LCR) of which only one was native. During their study, the only native parasite reported was *Rhabdochona* sp. They believed the other 16 alien parasites were introduced into the system with their respective host fish. Native fishes were found to have had 11 different parasites on them (see table 2 for complete list) (Choudhury et al. 2004). Pathogenic parasites such as the Asian tapeworm *Bothriocephalus acheilognathi* and the anchor worm *Lernaea cyprinacea* were also found on some native fishes. Asian tape worms were found in all four native fishes (Choudhury et al. 2004). In earlier sampling by Clarkson et al. (1997) Asian tapeworm was found in two native fishes, humpback chub and speckled dace.

The presence of Asian tapeworm is alarming (Clarkson et al. 1997). According to Clarkson et al. (1997), Asian tapeworms are known to cause intestinal abrasion and disintegration, loss or separation of gut microvilli and enterocytes (Hoole and Nisan 1994), or blockage and perforation of the GI tract (Hoffman 1980, Mitchell 1994) in host fishes. Other possible effects may include emaciation and anemia (Scott and Grizzle 1979); decreases in intestinal, liver, and pancreatic enzymes (Hoole 1994); reduced growth and reproductive capacity, poor swimming performance as a result of muscle fatigue and other impairing influences (Heckmann et al. 1986, Hoole 1994). Clarkson et al. (1997), believes that biotic interactions that result from the transferring of parasites must be considered one of the most serious threats to conservation and recovery of native fish populations.

### **Hybridization**

Hybridization between native and alien fishes has not been documented in the lower Colorado River. As of now, there are no alien fishes that have the potential of hybridizing with native fishes.

## **MANAGEMENT OF NON-NATIVES**

Alien fishes are one of the major causes for the decline of native fishes. Unfortunately, many alien fishes are now well established within the system which makes removing them from the system impractical and near impossible. Management of the Glen Canyon Dam and the lower Colorado River system should be focused on promoting native fishes and suppressing alien fishes. In a letter written from the Grand Canyon Trust to the Superintendent of the Grand Canyon National Park, they recommended several tools in suppressing alien fishes including fluctuating flows, temperature changes, sediment augmentation, and mechanical removal of alien fishes (Barnard 2002). Past experiments, such as the flood of 1996, and mechanical removal of alien fishes in the Grand Canyon show that these methods may work in suppressing some alien fishes.

### **Test flood of 1996**

Seasonal floods were common occurrences in the pre-dam Colorado River (Minckley 1991). They reshaped channels and created a dynamic environment, which made native fish highly specialized and unique. The test flood of 1996 was an experimental flood that was intended to rebuild sandbars, deposit nutrients, restore backwater channels and mimic the dynamics of a natural system (Valdez et al. 2001). It was believed that the flood would promote native fishes and disadvantage alien fishes. The Bureau of Reclamation released a 1274 m<sup>3</sup>/s flood for seven days followed by a low release of 226 m<sup>3</sup>/s for 4 days. Valdez et al. (2001) studied the impacts of the flood on native and alien fishes. By surveying populations before, after and in some places during the flood; they showed that the test flood temporarily affected some alien fishes. The flood significantly impacted juvenile rainbow trout, plains killifish, and fathead minnow.

#### *Rainbow trout*

Initially the flood had some impact on rainbow trout, but they recovered shortly thereafter. Rainbow trout were most affected in the tailwaters below Glen Canyon Dam and in some sample reaches downstream from the dam. Valdez et al. (2001) found an 8% reduction of

juvenile trout (152mm TL) in the tail waters of the dam and an increase in juvenile trout in sample reaches down stream from the dam. Surveys eight months after the flood showed a 20% increase from pre-flood surveys of juvenile trout in the tailwaters. This increase may have resulted from the recruitment from remnant eggs after the flood, or by reinvasion from trout in the Paria River. Furthermore, they found that the flood had virtually no impact on the diet of the adult rainbow trout. They found that there was little difference in stomach contents to the fish prior to the flood.

#### *Fathead Minnow*

Fathead minnow populations significantly reduced immediately after the flood. Nevertheless, populations recovered to pre-flood conditions eight months later (Hoffnagle et al. 1999). They were mostly found in the backwater habitat during the pre-flood sampling. The flood inundated backwaters; as a result they were displaced from the backwaters during the flood. Sampling eight months after the flood, showed that fathead minnow recovered to pre-flood levels (Hoffnagle et al. 1999). Valdez et al. (2001) believed that the flood's magnitude was inadequate to scour the channel, leaving potential refuges for fathead minnow. As a result, some minnows resisted displacement and were able to reinvade the backwater habitats. They concluded that the flood was not powerful enough to have a permanent impact on fathead minnow.

#### *Plains Killifish*

The flood had similar effects on plains killifish as it did on fathead minnow. Pre-flood sampling found that the plains killifish was commonly found through the backwaters. Sampling eight months later showed that plains killifish was decimated by the flood (Hoffnagle et al. 1999). Plains killifish were unable to find suitable habitat and were either killed by the flood or displaced entirely from the mainstem of the river. Populations of plains killifish were able to grow to pre-flood levels shortly after the flood via reinvasion from other populations in the Grand Canyon. Valdez et al. (2001) concluded that the flood of 1996 only caused short term reductions in some alien fishes and that managed floods are unlikely to permanently reduce alien fishes. They believe that if regulated floods are properly designed and timed; they can be used as an effective tool in reducing alien populations.

## **Temperature Control Device**

Water temperature is an important factor in the life cycle for native fishes. Water released from the Glen Canyon Dam comes from the hypolimnetic layer of Lake Powell. This water is usually much colder than the other limnetic layers in the reservoir. The current temperature of the mainstem water varies between 8°C -12°C. These temperatures are too cold for native fish spawning and favor alien fishes such as rainbow trout and brown trout (Epstein this volume). In an attempt to create temperatures more suitable for native fishes, specifically humpback chub, the Grand Canyon Monitoring and Research Center drafted a plan to create a temperature controlling device in the Glen Canyon Dam (GCMRC 1999). Submitted in 1999, the theory of the plan was to warm main stem waters by drawing water from the mesolimnetic and epilimnetic layers of Lake Powell (GCMRC 1999). Selectively withdrawing water from Lake Powell could benefit humpback chub by increasing recruitment. Warmer waters would increase recruitment by increasing hatching success of eggs (Hamman 1982), and increasing growth rates (Lupher and Clarkson 1994). Some concerns of temperature regulation are increased recruitment of aggressive alien fishes, introduction of more alien fishes from Lake Powell, and increased recruitment of parasites (GCMRC 1999, Hoffnagle, T.L., personal communication, 2005)

## **Mechanical Removal**

The mechanical removal of rainbow trout and brown trout has taken place recently at the Little Colorado River confluence. Originating from recommendations from the Grand Canyon Monitoring and Research Center, the mechanical removal of alien fishes from RM 56.2-65.7 began in January of 2003. Success in removing rainbow trout and brown trout has been high. In the first three depletion trips, abundance of rainbow trout (RBT) and brown trout (BNT) decreased by greater than 80% (Yard and Collins 2003). This level of success in removing RBT and BNT was unexpected. As a result, with less than half of the scheduled depletion trips completed drafts were made to extend the removal area to RM 72.7. The goal of the experiment was to better understand interactions between native and alien fishes, especially that of salmoids and humpback chub. Removal was focused at the Little Colorado River confluence with the Colorado River. This area was specifically chosen because young of year native fish are known

to spawn in the Little Colorado River (Yard and Collins 2003). As a result, high runoff flows in the spring and summer displace juvenile humpback chub into the mainstem of the Colorado River. It is thought that since abundance of juvenile humpback chub declines with downstream distance from the Little Colorado River, many of these individuals fall victim to predation by RBT and BNT. Therefore by removing RBT and BNT in this area may increase recruitment of juvenile humpback chub. Based on success of the first three trips, scientists now want to extend the removal area to further decrease the abundance of alien fishes. A goal is to better understand the level of non-native reduction which would result in an increase in humpback chub recruitment (Yard and Collins 2003).

## **MANAGEMENT RECCOMENDATIONS**

Complete restoration of the Grand Canyon is impractical without removing Glen Canyon Dam. The removal of Glen Canyon Dam is not an option since millions of people require it as a source of power, water and revenue. However, it is vital to the livelihood of the native fishes that Glen Canyon dam be used as management tool in promoting native fishes and suppressing alien fishes. Managers can use Glen Canyon Dam to modify flows, temperature and sediment. All of these are tools that can be used to suppress some alien fishes. In addition to using Glen Canyon Dam as a tool, managers should continue programs to remove alien fishes not only in the Colorado River but also in the tributaries. Furthermore, the “blue ribbon trout fishery” compromises the promotion of native fishes and therefore should cease. The long term goal should be focused on replacing the blue ribbon trout fishery with the world’s first Colorado white salmon fishery, also known as the Colorado pikeminnow fishery. Below I outline my management recommendations in the Grand Canyon for suppressing alien fishes in attempts to promote native fishes.

### **Management of Flows**

Glen Canyon Dam should begin releasing flows that mimic the natural flow regime. The test flood of 1996 showed that alien fishes can be temporarily suppressed with large floods (Valdez et al. 2001, Hoffnagle et al. 1999). However, these floods should be sufficient in

magnitude and properly timed. Floods should have enough magnitude to redistribute sediment to create sandbars and disperse alien fishes. These floods should also be timed during the appropriate season to mimic the pre-dam conditions. Floods during the spring and early summer should be high, in addition to having low flows during mid summer through winter.

Low flows, during the summer, would also result in warmer mainstem temperatures because of the reduced thermal budget of a lower water volume (Valdez et al. unpublished). Native fishes would benefit by having increased growth, survival, recruitment and these flows would provide ideal conditions in the backwaters for the rearing of juveniles. Furthermore, low flows would provide increased light penetration and photosynthesis which would increase primary and secondary production of food resources for fish (Valdez et al. unpublished). However, native and alien fishes should be closely monitored during low summer flows. Alien fish might benefit resulting in increased predation and competition pressures on native fishes (Valdez et al. unpublished). In addition, parasites could further benefit from the warmer temperatures.

Some floods should also be spontaneous floods timed with seasonal floods that come from downstream tributaries such as the Paria River and Little Colorado River. These spontaneous floods may be effective in dispersing alien fishes from the backwaters in the mainstem (Valdez et al. unpublished), in addition to distributing more sediment into the mainstem. Lastly, these floods should be of shorter duration than the test flood of 1996. The erosion of sandbars in the latter part of the test flood of 1996 may have been caused by the duration of the flood but also the lack of sediment in the river.

### **Sediment Transportation Program**

In order to ensure that there is enough sediment for these managed floods, engineers should research ways in removing sediment that is blocked by Glen Canyon Dam. This sediment should be transported to the other side of the dam so that it can be dispersed. This would allow for plenty of sediment for building backwater habitat for native fishes, sand bars for campers and may even extend the life of Glen Canyon Dam. I'm sure campers and tourists would not mind paying an additional fee for camping along the river so that programs like this can be implemented.



## **Mechanical Removal**

Mechanical removal programs should continue at the Little Colorado River (LCR) confluence in addition to beginning removal programs throughout the LCR. Predation by brown trout, rainbow trout and among other predators may be a major factor in the unsuccessful dispersal of humpback chub. Removal of alien fishes throughout the LCR may reduce competition and predation pressures on native fishes. Removal techniques should vary by using gill nets, trammel nets, fyke nets, hoop nets, seines, electrofishing, weirs, setlines, angling, and spear guns. Angling is an effective method at removing large methods and can be widely used at little cost. The National Park Service or Arizona Department of Game and Fish should reward fishermen for removing alien fishes. Special awards should be given to fishermen who remove brown trout, rainbow trout, channel catfish, yellow bullhead and black bullhead which are known predators of native fishes (Marsh and Douglas 1997). If removal of alien fishes is successful in increasing populations of native fishes, removal programs should be implemented downstream of LCR.

## **Prioritize the Little Colorado River**

The focus of these projects is to allow for successful dispersal of native fishes beginning with the native fishes in the Little Colorado River. The goals of these programs should be to reduce predation and competition pressures and promote habitat formation in the Colorado River immediately below the LCR confluence so that native fishes can expand their range. In time, and if these programs are successful, the stocking of more native fishes would be appropriate.

## **Temperature Regulation**

Temperature regulation should be one of the last priorities in promoting native fishes. The use of a temperature control device has consequences such as promoting some alien fishes and some parasites. Before implementing the temperature regulation managers should find ways to prevent or reduce the threat of warm water fishes migrating into the Grand Canyon from not only Lake Mead but also Lake Powell. Some of these warm water fish such as smallmouth bass can handle the cold waters during the winter time. If these fish were to establish themselves the system, humpback chub would surely go extinct (Hoffnagle, T.L., personal communication, 2005). Therefore precautionary steps should be taken in preventing migration before any use of

a temperature regulation. In addition to alien fishes, parasites may also be promoted. If a temperature control device were put in the dam, the health of native fish should be closely monitored.

### **Creation of a Native Fishery**

After significant progress has been made in suppressing alien fishes and increasing native fish populations, the promotion of the rainbow trout fishery should be replaced with a native fishery. The aura of sport fishing in much of North America is to catch the “big beautiful game fish.” It is unfortunate that some government agencies support this mentality by stocking alien fishes in river systems and reservoirs for sport fishing. This mentality is partly responsible for the demise of native fishes in the Grand Canyon. Native fishes may be promoted if sport fishermen change the way they view fishing and begin fishing for the “big indigenous fish.” As populations of native fishes increase, trout stocking should be stopped and attempts should be made to reduce populations of rainbow trout in the river. Programs should then be made to create a native fishery by reintroducing the Colorado pikeminnow into the Grand Canyon, beginning with in the Little Colorado River. Promotion of a native fishery may be a useful mechanism in gaining funding for programs that would promote other native fishes. In order for the native fishery to succeed, sport fishermen must change the way they view fishing. Sport fishermen should ultimately become conservationists. If sport fishermen were to support the native fishery, government agencies which cater to their needs will follow. I believe if anything will save native fishes, this will.

### **Summary of Recommendations**

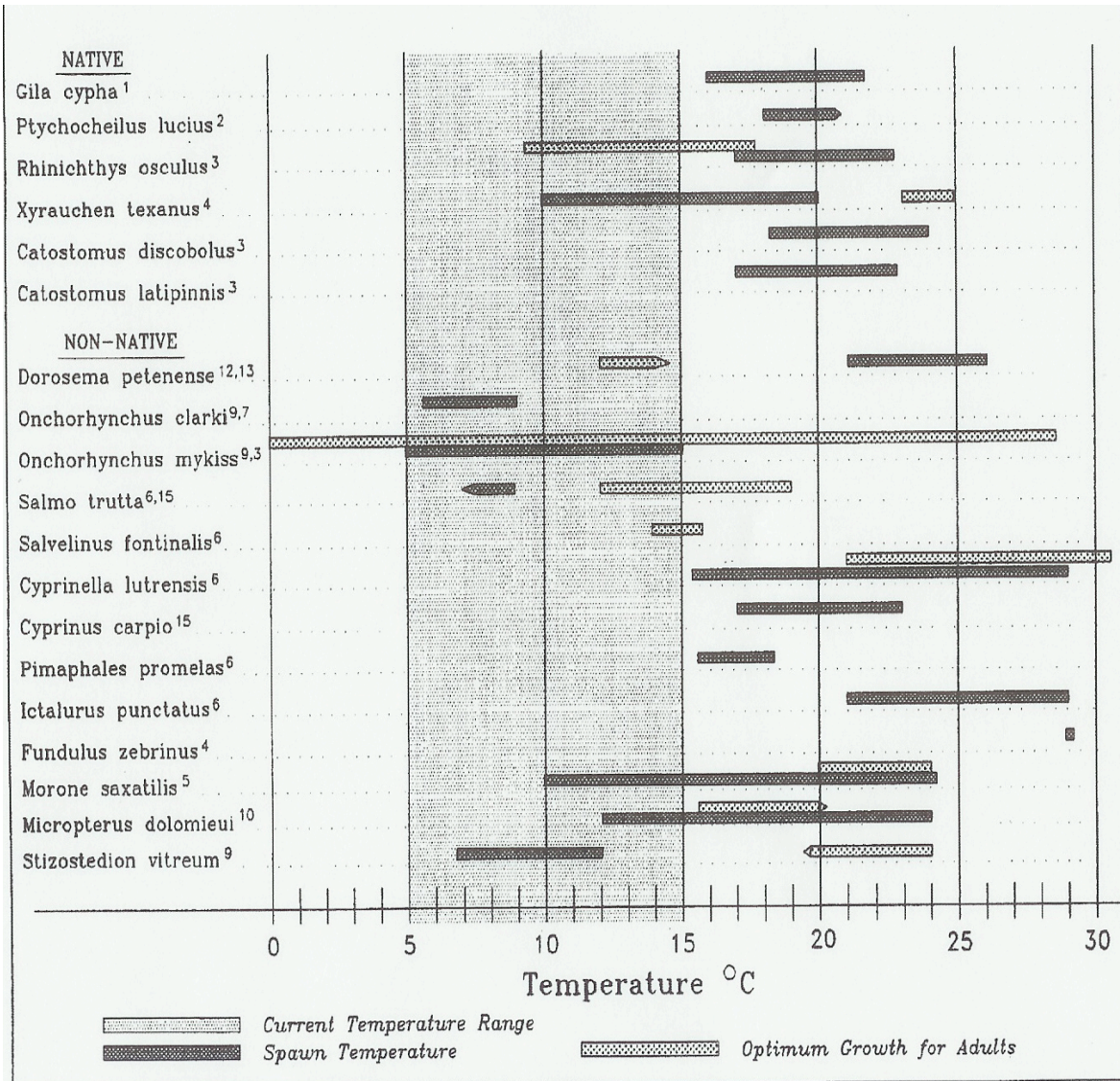
Flows coming from Glen Canyon Dam should mimic the historic flow regime. Sediment transportation devices should be investigated in order to ensure that the lower Colorado River has an adequate supply of sediment to create ideal habitat for native fishes. Focus for suppressing alien fishes and restoring native fishes should begin in the Little Colorado River (LCR) and its confluence with the Colorado River. The removal of alien fishes using a variety of techniques should focus in the LCR area in order to reduce predation and competition pressures on native fishes. Temperature regulation should be considered, however its use and affects

should be closely monitored. Promotion of the blue ribbon trout fishery should stop and be replaced with a native fishery by reintroducing the Colorado pikeminnow.

## **CONCLUSION**

The Grand Canyon fish assemblage is dominated by alien fishes. It is impractical if not impossible to completely extirpate them. However it is important that we attempt with the best of our ability to suppress alien fishes and promote native fishes. In order to create a naturalized system for the well-being of native fishes requires the collaboration of the public, sport fisherman, private industry and government agencies.

**Table 1. Temperature Requirements for Colorado River Fishes (Haden 1992)**



**REFERENCES**

1. Kaeding & Zimmerman, 198
2. Vanicek & Kramer, 1969
3. Carothers & Minkley, 1981
4. Bestgen, 1990
5. Allan & Roden, 1978
6. Scott & Crossman, 1973
7. Cross, 1967
8. Koster, 1948
9. Sublet et al, 1990
10. Clark, 1967
11. Jenkin, 1975
12. Griffith, 1978
13. Johnson, 1971
14. Deacon et al, 1987
15. Lubinski et al, 1984
16. Stanford & Ward, 1990

## REFERENCES

- Arizona Game and Fish. 1950. Stocking report on fishes stocked in the Grand Canyon. Museum of Northern Arizona Library.
- Barnard, G. 2002. Letter to the Superintendent of Grand Canyon National Park about the Colorado River Management Plan Scoping Comments. Grand Canyon Trust.
- Clarkson, R.W., A.T. Robinson, and T.L. Hoffnagle. 1997. Asian Tapeworm (*Bothriocephalus acheilognathi*) in Native Fishes from the Little Colorado River, Grand Canyon, Arizona. *Great Basin Naturalist* 57: 66-69.
- Choudhury, A., T.L.Hoffnagle, and R.A. Cole. 2001. Parasites of Native and non-native fishes of the Little Colorado River, Grand Canyon, Arizona. *Journal of Parasitology* 90: 1042-1053.
- Dill, W. A. 1944. The Fishery of the lower Colorado River. *Calif. Fish Game* 30: 109-211.
- Gido K.B., J.F. Schaefer, K. Work , P.W. Lienesch, E. Marsh-Matthews, and W.J. Matthews. 1999., Effects of Red Shiner (*Cyprinella lutrensis*) on Red River Pupfish (*Cyprinodon rubrofluviatilis*). *Southwestern Naturalist* 44:287-295.
- Grand Canyon Monitoring and research Center. 1999. Draft Science Plan to accompany environmental assessment for a temperature control device for Glen Canyon Dam for Bureau for Reclamation, 1999
- Haden, Allen. 1992. Nonnative fishes of the Grand Canyon: A review with regards to their effects on native fishes. Glen Canyon Environmental Studies.
- Hamman, R.L. 1982. Culture of endangered Colorado River Fishes, report 3 section IV, spawning and culture of humpback chub. Pg 158-167 in Colorado River Fishery project, part 3, final report. Fish and Wildlife Service and Bureau of Reclamation, Salt Lake City.
- Heckman, R.A., P.D. Greger, and R.C. Furtek. 1983. The Asian tapeworm, *Borthriocephalus acheilognathi*, in fishes of Nevada. *Journal of Helminthological Society of Washington* 60: 127-128.
- Hoffman, G.L. 1980. Asian tapeworm, *Borthriocephalus acheilognathi* Yamaguti, 1934, in North America. *Fisch und Umwelt* 8: 69-75
- Hoffnagle, T.L. and M.A. Tuegel. 2001. Diet preference and overlap among larval and juvenile natives and non-native fishes in backwaters of the Colorado River in the Grand Canyon. *American Fisheries Society Annual Meeting* 131: 165-166

- Hoffangle, T.L., R.A. Valdez, and D. W. Speas. 1999. Fish Abundance, Distribution, and Habitat Use in The Controlled Flood in Grand Canyon. American Geophysical Union. 1999
- Hoole, D. 1994. Tapeworm infections in fish: past and future problems. Pages 119-140 in A. W. Pike and J. W. Lewis, Parasitic diseases of fish. U.K. Samara Publishing Limited.
- Hoole, D., and H. Nisan. 1994. Ultrastructural studies on intestinal response of carp, *Cyprinus carpio*, to the pseudophyllidean tapeworm, *Borthriocephalus acheilognathi* Yamaguti, 1934. *Journal of Fish Disease* 17:623-629.
- Hubbs, C.L. 1954. Establishment of a Forage fish, the Red Shiner (*Notropis lutrensis*) in the Lower Colorado River System. *California Fish and Game* 40: 287-294
- Koster, W. F. 1948. Notes on the spawning activities of *Plancterus kansae*. *Copeia* 1948: pg. 25-33
- Lupher, M.L., Clarkson R.W., 1994. Temperature tolerance of humpback chub (*Gila cypha*) and Colorado Squawfish (*Ptychocheilus lucius*). *Proc. Desert Fishes Council*. 25: 38
- Marsh, P.C. and M.E. Douglas. 1997. Predation by Introduced Fishes on Endangered Humpback Chub and Other Native Species in the Little Colorado River, Arizona *Transactions of the American Fisheries Society*, 126: 343-346.
- 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.
- Miller R. R. Bait Fishes of the lower Colorado River, from Lake Mead to Yuma, Arizona, with a key for their identification. *Calif. Fish Game* 38 (1) pg 7-42.
- Minckely C.O. and H.E. Klaassen. 1969. Burying behavior of the plains killifish, *Fundulus kansae*. *Copeia*, 1969: 200-201.
- Minckely, W. L. 1991. Native Fishes of the Grand Canyon Region: an Obituary? Pages 124-177 in Colorado River Ecology and Dam Management-Proceedings of a Symposium, May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington D.C. 1991.
- Moyle, P.B., H.W. Li., and B.A. Barton. 1987. The Frankenstein Effect: Impact of Introduced Fishes on Native Fishes in North America. 415-426 in R.H. Shroud. ed. The role of fish culture in fisheries management. Bethesda, Md. Amer. Fish. Soc.
- Page, L.M. and B.M. Burr, 1991. A field guide to freshwater fishes of North America north of Mexico. Boston. Houghton Mifflin Company

- Robinson A. T., and Childs M.R.; 2001. Juvenile Growth of Native Fishes in the Little Colorado River and in a Thermally Modified Portion of the Colorado River. *North American Journal of Fisheries Management*: 21: 809-815.
- Reihl, R. and H. A. Baensch, 1991, Aquarien Atla. Band 1.10<sup>th</sup> edition. Mergus Verlag GmbH, Melle, Germany. 992: 485
- Scott, A.L and J. M. Grizzle. 1979. Pathology of cyprind fishes caused by *Borthriocephalus gowkongenesis* Yea, 1955 (Cestoda: Pseudophyllidea). *Journal of Fish Diseases* 2:69-73
- Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin No. 1984. Fisheries Research Board of Canada, Ottawa.
- Sivakumaran, K. P.; Brown, P.; Stoessel, D.; Giles, A. Maturation and reproductive biology of female wild carp, *Cyprinus carpio*, in Victoria, Australia. *Environmental Biology of Fishes* 68: 321-332
- Striklin, H. B. 1950. Letter to superintendent, Grand Canyon National Park describing Bright Angel Creek fish plant.
- Valdez, R.A., T.L. Hoffnagle, C.C. McIvor, T. McKinney, and W.C. Leibfried. 2001 Effects of the Test Flood on Fishes of the Colorado River in Grand Canyon, Arizona. *Ecological Applications* 11: 686-700.
- Valdez, R.A., B. Persons, T.L. Hoffnagle. Unpublished. Non-native Fish Control Strategy for Grand Canyon, Arizona.
- Webb, R. H., T.S. Melis, and R.A. Valdez with Grand Canyon Monitoring and Research Center. 2002. Observations of Environmental change in Grand Canyon, Arizona. in USGS Water-Resources Investigations report 02-4080. Tuscon, Az. 2002.
- Yard, M. and Coggins, L. 2003. Non-native Fish Removal Efforts in Grand Canyon: A Proposed Modification to Ongoing Activities. USGS. Southwest Biological Science Center. Grand Canyon Monitoring and Research Center. June 6, 2003
- Yamamoto, M.N. and A.W. Tagawa, 2000. Hawaii's native and exotic freshwater animals. Honolulu, Hawaii. Mutual Publishing

