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Effect of Common Carp (*Cyprinus carpio*) on Aquatic Restorations

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Photo by Konrad Schmidt

Introduction

Cyprinus carpio (common carp) are regarded as one of the most important freshwater fish in the world, considered prized food in Asia, Europe and the Middle East. When introduced into ponds in Washington D.C. in the 1870's, they were believed to be so valuable that the ponds had to be guarded (Eddy and Underhill 1974). What happened over the past century to change its status from one of high regard to ill repute with U.S. fishery and waterfowl managers?

Introduction of common carp into U.S. waters has proven to be a nuisance to fishery managers because of its negative effects on native fish, ecosystems, and water quality in wetlands and lakes (Hill 1999). Deterioration of wetland water quality reduces aquatic vegetation, which waterfowl rely on during migration. The impact on waterfowl is evident in Minnesota where duck populations have declined despite national high populations in the past two years. The deteriorating habitat of wetlands and shallow lakes is due in part to the proliferation of carp that have spread through ditches and channels. Recent mild winters have perpetuated the problem by preventing shallow waters from freezing deep enough to kill undesirable fish (Smith 2000).

Natural History of Common Carp

While common carp are native to Asia, they are also widespread and abundant in Europe where they were introduced in the 11^{th} or 12^{th} century (Eddy and Underhill 1974). With pressure from European immigrants to bring the fish to U.S freshwaters, carp were first introduced into the Hudson River in New York in 1831. Massive stocking occurred before fishery administrators realized that U.S. anglers preferred the native fishes and were not harvesting the carp. This realization led to the first attempt to control carp in 1891 in Lake Merced, California (Wydoski and Wiley 1999).

The common carp is very adaptable and despite initial theories that cold waters would prevent its spread northward, carp have spread throughout most of the stream systems in the U.S. and into Canada. They thrive in shallow mud-bottom lakes and large streams, avoiding swift, rocky streams characteristic of trout streams (Eddy and Underhill 1974).

Common carp dominate wetlands and lakes because of their long life spans and large size (Bonneau 1999). They are the largest of the *Cyprinidae* (minnow) family and can weigh well over 9 kg and span more than 60 cm. Highly prolific, they crowd into shallow bays or headwater sloughs to spawn in April and May. Eggs hatch in 10 to 20 days and grow rapidly, reaching lengths of 20 cm or more in the first year. Adult carp have no natural predators and are not sought by anglers so they have a low mortality rate and often comprise the majority of fish mass in a water body. Fertile lakes can support up to 1125 kg of carp per hectare, which is three times the mass of game fish that can be supported in the same area (Eddy and Underhill 1974).

The effect of common carp domination on wetland and lake ecosystems is complex. Carp uproot aquatic macrophytes when spawning and feeding. These activities also suspend bottom sediments and nutrients, limiting light penetration needed for macrophyte growth. Carp also reduce zooplankton and macroinvertebrate populations by predation and by eliminating macrophytes that provide cover. Phytoplankton populations increase due to increased release of nutrients and reduced predation by zooplankton. Fish and wildlife are adversely affected by the loss of zooplankton and macroinvertebrate food sources, and loss of aquatic macrophytes that provide cover for larval and juvenile fish and substrate for eggs and invertebrates (Kahl 1991).

Once carp are removed, algal production declines due to reduced nutrients, macrophytes increase due to decreased turbidity, and zooplankton increase due to increased cover of macrophytes (Meijer et al. 1990). However, the change from a turbid state dominated by phytoplankton to a clear state dominated by macrophytes may be temporary. To sustain the new state, the resilience mechanisms that maintained the turbid state must shift to those that favor the clear state (Carpenter and Cottingham 1997).

Impacted Ecosystems

Examples of restored systems affected by common carp include Swan Lake located in Carroll County, Iowa. The shallow manmade lake was restored in 1982 as part of the U.S. EPA Clean Lakes Program. Swan Lake was deepened, an aeration system was installed to prevent winterkills, two new water sources were added to maintain the water level, and it was chemically treated with rotenone to remove all existing fish for subsequent restocking. Carp entered the lake between June 1990 and July 1993 when the lake overflowed and carp adults were able to jump from a stilling basin into the lake. The carp population increased from 27 kg/ha in 1990 to 230 kg/ha by 1996. *Micropterus salmoides* (largemouth bass) and *Lepomis macrochirus* (bluegill) standing stock decreased significantly over that same period (Hill 1999).

After carp entered the lake, the water became more turbid and algal blooms increased, resulting in decreased growth of aquatic macrophytes. Excess nutrients were most likely entering the lake from the watershed and the feeding habits of the carp resulted in suspension of sediment and nutrients. The nutrients fueled the algal blooms, which reduced water quality and ultimately eliminated the submerged aquatic vegetation. With the loss of submerged vegetation, the lake's water quality continued to deteriorate and fishing quality declined (Hill 1999).

Another example is Metzger Marsh, a coastal wetland on the south shore of western Lake Erie. The marsh provides spawning, nursery, and feeding habitat for Lake Erie's native fishes. The area was degraded in the late 1800's with the draining and filling, diking, and increased nutrient loading that resulted from urbanization and industrialization. *Esox lucius* (northern pike) populations, which had been abundant in Lake Erie, declined with coastal wetland loss. In the 1920's most of the remaining coastal wetlands in western Lake Erie were diked to enhance managed production of aquatic vegetation and waterfowl. Northern pike populations were further diminished because they could not access the remaining wetlands for spawning and feeding (French et al. 1999).

Metzger Marsh further degraded when carp were introduced. Carp entered the wetlands as fry through the pumps and gates when the wetlands were filled and could not return to Lake Erie after they increased in size. The carp disrupted the wetlands through their spawning, uprooting, and sediment-stirring activities (French et al. 1999). The marsh was protected from storm activity by a heavily vegetated barrier beach until 1940 when the beach partially eroded. The barrier beach was totally lost by 1973, increasing the marsh water level and greatly reducing the emergent marsh area. By 1990 it was an open water bay with scattered islands of *Typha* and *Phragmites*. In 1994 the Metzger Marsh Wetland Restoration project was initiated to restore fish habitat. Since the wetland is connected to Lake Erie through a protective barrier, one of the challenges is to control the passage of carp from the main body of Lake Erie (French et al. 1999).

A third example is Lake Christina, a shallow eutrophic lake in central Minnesota. Prior to restoration, the lake had become highly turbid, suffered from high chlorophyll-a levels, and had lost nearly all of its submergent macrophytes, greatly reducing its suitability for migrating waterfowl. In the fall of 1987, virtually all of the lake's fish were eliminated, with subsequent restocking in the spring of 1988 with piscivores to establish a more favorable ratio of piscivores to benthivores and planktivores. For the first few months following restoration, the chlorophyll-a concentration dramatically declined and water transparency, macrophytes, and zooplankton populations significantly increased. The result was increased waterfowl feeding on macrophytes in 1988 (Hanson and Butler 1990).

Management Techniques

Fish removal projects have been practiced for hundreds of years, evolving from control of a single species to an approach that considers entire fish communities (McComas 1993, Wydoski and Wiley 1999). To be successful, control methods need to be cost-effective and have minimal impact to other fish (Bonneau 1999). Other factors that need to be considered in selecting a method include size of the water body, water temperature and quality, public opinion, ownership of water, and environmental concerns (Wydoski and Wiley 1999).

The basic methods of control are chemical, mechanical, and biological. Chemical methods are preferred because of ease of application, short time period required to achieve results, and lower cost when compared to other controls. The majority of projects focus on complete removal as partial treatment has varying success. Biological methods consist of using predatory fish, pathogens, and biomanipulation. With biomanipulation, various chemical and mechanical methods are used to adjust the interrelationships among plants, animals, and their environment to achieve a balanced food-web structure. In general, the ratio of piscivorous to planktivorous fish species is the key to stabilizing an aquatic system. Mechanical methods include barriers, commercial fishing, water level manipulation, and traps. Barriers are the most commonly used mechanical method because of their one-time expense and potential effectiveness over several years, whereas most other mechanical methods are considered labor intensive with limited effectiveness from 1 to 5 years (Wydoski and Wiley 1999). Following are the most frequently used methods for controlling common carp.

Rotenone

Rotenone was first used in North America in 1934 and is the most commonly used fish toxicant (Wydoski and Wiley 1999). It is a natural chemical extracted from stems and roots of several tropical plants and is non-selective when applied at dose rates necessary to eliminate carp (Fajt and Grizzle 1993). Absorbed through gills, it inhibits oxygen transfer at the cellular level resulting in suffocation. Rotenone is available as a powder or liquid and can be applied by pump sprayer, boat, aircraft, and constant-flow drip stations in streams. The powder form is less expensive and can be mixed with sand, gelatin, and water to form a paste to use in harder to reach areas such as heavily vegetated shorelines and deep waters. Rotenone is thought to be nontoxic to waterfowl and humans and is also environmentally non-persistent (Wydoski and Wiley 1999). Restocking of fish can occur in the same season of treatment. However, effectiveness only lasts for about ten years unless other steps are taken to prevent return of the lake or wetland to previous conditions (McComas 1993).

Rotenone should be applied at water temperatures greater than 20°C for optimum fish kill and detoxification. Natural detoxification occurs within 2 days to 2 weeks in late summer. Warm water temperatures, high alkalinity, and sunlight in clear waters will accelerate detoxification while turbidity and decreased light penetration in deep water will inhibit the process. Rotenone can remain toxic up to 3 months at low temperatures such as immediately before ice forms on a lake. Fall applications before ice formation eliminate the odor from decomposing fish, reduce the disposal of dead fish, and detoxify by the time the ice breaks up so that restocking can occur in the spring (Wydoski and Wiley 1999).

Effectiveness of the treatment depends on several factors including clarity of the water, dose, fish exposure time, repeated exposure, and life stage. Turbid water reduces effectiveness as does repeated treatments which can cause some fish species to develop a tolerance to the chemical. Dosages and exposure times selected will vary depending on the water chemistry. Carp at different life stages will exhibit different resistances to rotenone, with eyed carp eggs having 50 times as much resistance as larvae (Wydoski and Wiley 1999).

Rotenone applied in the form of treated bait has been less successful for use with carp as they do not readily eat the treated bait. Baiting with corn has been used to concentrate the carp which can then be spot treated with the rotenone (Wydoski and Wiley 1999). For spot eradications to be acceptable, carp need to be concentrated in areas with few non-target fish. This can be accomplished by applying treatment during spawning in areas where the carp’s presence is obvious, either through visual observation of spawning activity or high water turbidity (Bonneau 1999).

Rotenone has been successful at eradicating carp as well as all the other fish from lakes in efforts to restock with a more favorable fish community. However, as the Swan Lake restoration demonstrated, eradication is not permanent and additional steps must be taken to ensure that carp populations remain under control. Recommendations made from the study at Swan Lake include installation of a barrier so that carp cannot reenter the lake (Hanson and Butler 1990).

Spot rotenone treatments and rotenone-impregnated baits were tested during restoration of the Bowman-Haley Reservoir in southwestern North Dakota. The reservoir was constructed in 1968 at the confluence of three streams, with construction of a dam for flood control. The shallow, wind-swept reservoir was often turbid and dominated by large common carp (Bonneau 1999). Spot eradication with rotenone applied in the tributaries during spawning periods was the most effective method tested, with 70% of the carp removed between 1994 and 1995. Barriers were set up in the areas treated with rotenone so that remaining carp could not enter these areas. After treatment, water clarity increased, total suspended solids decreased, zooplankton populations increased, and there were no blue-green algal blooms (Bonneau 1999). Rotenone-impregnated bait was fed to carp through automatic feeders installed in the tributaries. The carp were initially fed non-impregnated bait to attract them to the feeding stations. However, when the impregnated bait was introduced, they immediately stopped feeding and there was virtually no fish kill, rendering the method ineffective (Bonneau 1999).

The greatest adverse impact from rotenone control is its high toxicity to many invertebrates and fish. Zooplankton communities can be drastically reduced and usually recover within two to twelve months. With spot treatment, recolonization from adjacent untreated water can occur in as little as one week. At the other extreme, zooplankton communities in cold alpine waters may not recover for two to three years. Reduction in benthic macroinvertebrates varies in response to tolerance, ranging from 0 to 70 percent when rotenone is applied at a rate from 1 to 2 mg/L in freshwater. Typical recovery for benthic macroinvertebrate communities is within two months. Phytoplankton and rooted aquatic plants are not affected by the rotenone (Wydoski and Wiley 1999). In addition to public opposition to the use of toxic chemicals, complete eradication can be costly for large water bodies since it results in elimination of non-target species that will need to be replaced. Complete eradication is, however, the quickest way to achieve dramatic improvements in water clarity, natural revegetation, and desirable fish populations. Combined with other techniques, it could be used to achieve long-term results (Kahl 1991).

Spot treatment is a less costly alternative that receives less opposition and can also be effective when combined with other techniques. However, it produces results more slowly and requires a continued annual effort. It may not be effective in situations where spawning or feeding concentrations are erratic and difficult to isolate (Kahl 1991).

Barriers

When carp are absent from a wetland or lake, barriers such as metal grates can be placed over culverts and streams to prevent future entry of adult carp. Other types of barriers include electrical barriers and velocity culverts that channel outgoing water to produce high velocities that prevent carp from swimming into the water body. Barriers have the disadvantage that initial cost is high compared to other methods because they require construction and installation, as well as future operation and maintenance costs. Adverse effects include interference with spawning runs of desirable fish species and restriction of boats (Kahl 1991). Complete success of metal grates is unlikely since small carp fry can pass through to the water body.

The restoration project at Metzger Marsh included design of a fish control system consisting of five 2-meter wide channels that can be closed individually. It allows native fish access to the diked wetlands while restricting access by common carp. Vertical bar grates with 5-cm wide spacing were placed across three of the channels. The other two channels were fitted with experimental grates that accommodated larger fish. The larger fish were retrieved in a lift basket where they were identified, counted, and measured. The native fish were released into the wetland or Lake Erie and the carp were released into Lake Erie or harvested. The size and shape of the openings were optimized to maximize the passage of native fish into lift baskets and minimize the number of carp handled. Grates used in the initial field-testing in 1999 resulted in the handling of 15% carp biomass. Effectiveness is yet to be determined as testing is ongoing and a final determination of grate size will depend on trade-offs between access by larger native fish and the practicality of handling larger numbers of common carp (French et al. 1999).

While results are not as widely published regarding the use of carp barriers for inland wetlands, projects such as the Middle Bear River Wetland Restoration in southeastern Idaho are underway. The restoration is sponsored by the U.S. Fish and Wildlife Service, Ducks Unlimited, and PacifiCorp and seeks to improve the waterfowl habitat and water quality of the carp-infested wetlands. A five-mile long earthen dike will be constructed to isolate a section of the wetland for carp and sediment control. The dike will have four 48-inch water control structures with rotary fish screens in addition to a 72-inch culvert. The wetlands will be drawn down to concentrate the carp, followed by treatment with rotenone to eradicate the existing carp population (Bear River Resource Conservation and Development 2000).

Harvesting

Harvesting is achieved through seining or trapping. To increase harvesting success in the northern states, long seines are used under the ice in late winter while the fish are schooled. Corn or other bait can be spread in the area to further concentrate the fish. However, seining is not always successful, as carp will dive to deeper water when disturbed (Eddy and Underhill 1974). Another optimum time for harvest is spawning in May. Carp move into sloughs or shallow lakes and are easily found flopping in the weeds. Removal at this time has the additional bonus of interruption of spawning. Once harvested, carp can be sold, used as fertilizer, or ground up for animal feed. Use of trapnets in tributaries is another harvesting technique but is labor intensive and has limited effectiveness (McComas 1993). Trapnetting was evaluated during the restoration of the Bowman-Haley Reservoir and found to be inefficient since only 15% of the fish caught were carp (Bonneau 1999).

Commercial fishing has few adverse effects as there is little impact on non-target species and the cost to agencies and the public is modest. It does, however, require an annual effort and the fish market can be unpredictable (Kahl 1991).

Water clarity improvements

The most ecologically sound method to reduce common carp populations is to improve the water clarity. Sight-feeding game fish such as *Esox lucius* (northern pike) or *Stizostedion viteum* (walleye) can more easily capture carp minnows in clear water. Removing adult carp will also help improve water clarity but other steps need to be taken to sustain the system. The first step is to determine through a lab analysis if algae or suspended mud causes the reduction in water clarity. If the particles settle out, fish, wind, waves, or an incoming stream may be the cause. Options for controlling the turbidity include controls on outboard motors, establishing vegetation beds, shoreline stabilization, erosion control in the watershed, and employment of commercial fishers to harvest the carp (McComas 1993). Once water quality and habitat improvements are implemented, long-term control might be achieved with stocking of appropriate predator species so that populations can be maintained. (Kahl 1991).

Conclusion

The fact that carp control has been carried out for over 100 years indicates the difficulty of completely eradicating it from aquatic systems. While rotenone can eliminate all of the existing carp from a water body, carp can still enter after treatment. Metal grates exclude adult carp from an aquatic system but do little to control the entry of smaller carp. Combined methods such as rotenone treatment followed by stocking with carp predators succeeded at restoring clear waters for a year or two, but there is little information indicating success in the long term.

As mentioned previously, to achieve long-term success, the resilience mechanisms that maintain the turbid water state must shift to those that favor the clear water state. The mechanisms that maintain a clear water state include restoration of riparian, wetland, and macrophyte vegetation; reduction of external phosphorus loading; and reduction in game fish harvesting (Carpenter and Cottingham 1997). In the restorations discussed, two primary goals for undertaking aquatic restoration were to increase waterfowl usage of wetlands (i.e. consumption of macrophytes) and increase angling usage of lakes (i.e. increased fish harvesting). These goals conflict with the changes needed to maintain the clear water state and may cause aquatic systems to shift back and forth between turbid and clear states. Reconciliation of goals with the required changes would be necessary to maintain the clear state.

Another reason for the lack of success in controlling carp can be explained by the absence of barriers to impede its spread. Geography was the initial barrier that was breached when carp were introduced into U.S. waters. Another barrier is clear water since carp are more susceptible to predation by sight-feeding fish. This barrier was removed over time with land disturbances associated with agriculture, industry, and urbanization. As long as these barriers are absent or until new ones are in place, opportunities for carp to spread will continue and periodic control measures will also need to continue.

References

Bear River Resource Conservation and Development. A river runs through us. <http://www.bearriverrcd.org/bearriver/field/MB5a.html> (Accessed 11/25/00).

Bonneau, J.L. 1999. Ecology of a fish biomanipulation in a great plains reservoir. Dissertation. University of Idaho.

Carpenter, S.R. and K.L. Cottingham. 1997. Resilience and restoration of lakes. Conservation Ecology [online]1(1):2. <http://www.consecol.org/vol1/iss1/art2> (Accessed 7/16/99).

Eddy, S. and J.C. Underhill. 1974. Northern fishes with special reference to the upper Mississippi Valley. Third Edition. University of Minnesota Press.

Fajt, J.R. and J.M. Grizzle. 1993. Oral toxicity of rotenone for common carp. Transactions of the American Fisheries Society 122:302-304.

French, J.R.P.III, D.A. Wilcox, and S.J. Nichols. 1999. Passing of northern pike and common carp through experimental barriers designed for use in wetland restoration. Wetlands 19:883-888.

Hanson, M.A. and M.G. Butler. 1990. Early responses of plankton and turbidity to biomanipulation in a shallow prairie lake. Hydrobiologia 200/201:317-327.

Hill, K.R. 1999. Evaluation of the impact of common carp on an intensively managed largemouth bass, channel catfish, and panfish fishery. Federal aid to fish restoration completion report: small reservoir investigations, project no. F-160-R. Iowa Department of Natural Resources.

Kahl, R. 1991. Restoration of canvasback migrational staging habitat in Wisconsin: a research plan with implications for shallow lake management. Technical Bulletin No. 172. Department of Natural Resources, Madison, WI.

McComas, S. 1993. Lake smarts: The first lake maintenance handbook. Terrene Institute.

Meijer, M.L., M.W. deHaan, AW. Breukelaar, and H. Buiteveld. 1990. Is the reduction of the benthivorous fish an important cause of high transparency following biomanipulation in shallow lakes? Hydrobiologia 200/201:303-315. 1990.

Smith, D. September 27, 2000. Fowl waters. Minneapolis StarTribune.

Wydoski, R.S. and R.W, Wiley. 1999. Management of undesirable fish species. Pages 403-430 in C.C. Kohler and W.A. Hubert, Editors. Fisheries management in North America. Second Edition. American Fisheries Society, Bethesda, MD.