Chapter 10: Grass Carp for Biocontrol of Aquatic Weeds

Mark Hoyer: University of Florida, Gainesville FL; mvhoyer@ufl.edu

The grass carp (*Ctenopharyngodon idella* Cuvier and Valenciennes), is native to rivers in eastern Russia and China that feed into the Pacific Ocean, but the fish has been introduced to approximately 70 countries including the U.S.A., Taiwan, Japan, Mexico, India, Malaysia, and several European countries. It has been introduced for use as a food fish and for biological control of aquatic weeds. Although the grass carp is highly adaptable and can survive in a variety of conditions, the natural grass carp life cycle has not been observed to occur many times outside of the native range. The restriction is related to reproduction, as the fish requires large and long low gradient, turbid rivers and cannot reproduce in confined water bodies. Of all the countries where the fish were introduced, they have established populations in only few countries, primarily Asia and Europe. However, there have been reports of breeding populations including the Atchafalaya, Mississippi (and major tributaries), and the Trinity rivers in the U.S.

Grass carp were imported to the U.S.A. in 1963 as a biological control agent for hydrilla (*Hydrilla verticilliata*) and other aquatic plants. Their arrival caused an explosion of research on their use as an aquatic plant management tool. Efficacy experiments were conducted in Florida in the 1970s by the United States Department of Agriculture and the University of Florida. Use of the "diploid" fish was limited from 1970 until 1984 due to tight regulations surrounding concerns of escape and reproduction, which could potentially impact native flora and fauna. These concerns led to research that developed a non-reproductive "triploid" fish, which was equally effective in controlling hydrilla. Sterile fish were developed by subjecting fertilized eggs to stress, such as heat (hot or cold) or pressure. The stress causes each egg to retain an extra set of chromosomes and become triploid instead of diploid. Although triploid fish are virtually sterile, this does not affect their aquatic plant herbivory.

Grass carp are so effective at controlling aquatic plants that in 2009 the use of grass carp was recorded in 45 states, all states except Alaska, Maine, Montana, Rhode Island, and Vermont. Most states currently require that only artificially produced sterile triploid grass carp be stocked to prevent further natural reproduction in our large river systems. The use of grass carp for aquatic weed control is governed by individual states; some require permits, site inspections and use of sterile fish, whereas others have no restrictions. Several states in the northern US actually prohibit the possession, sale or transportation of grass carp. As a result, you must consult the appropriate state agencies before considering grass carp for weed control to determine whether their use is restricted or prohibited in your state

Consumption rates and aquatic plant preferences

Grass carp consumption rates (measured as the daily percentage of body weight eaten) are affected by size of the fish and by environmental characteristics such as temperature, salinity and oxygen content of the water. Also, grass carp consumption rates decrease as fish become larger and reach sexual maturity (which occurs even in sterile fish) at 2 or 3 years of age. Large grass carp (over 15 pounds) consume up to 30% of their body weight daily, whereas smaller fish (less than 10 pounds) can consume as much as 150% of their body weight a day. Maximum consumption occurs when water temperatures range from 78 and 90 °F and is greatly reduced at temperatures below 55 F°. Consumption is reduced by 45% when oxygen levels in the water drop to 4 ppm and fish stop feeding completely if the oxygen level drops below 2 ppm. Although grass carp can tolerate salinities up to 10 parts per thousand, they will not feed if salinity levels are higher than 6 parts per thousand.

The grass carp is a general herbivores, feeding on vegetation mostly near the surface waters. Many plant palatability studies have been conducted to determine grass carp plant preferences. Recent studies have shown that the preference lists are determined primarily by the aquatic plant's structural firmness as well as the secondary metabolites individual plant species produce (Sun et al. 2017). However, the grass carp is a generalist, and in the absence of the preferred plant, will feed on most other types of aquatic vegetation. Grass carp even have been observed to feed on terrestrial plants that are hanging over the water. In general, the five most-preferred species in order of preference are hydrilla, musk grass (*Chara* spp.), pondweeds (*Potamogeton* spp.), southern naiad (*Najas guadalupensis*), and Brazillian elodea (*Egeria densa*). Grass carp is not a good control method for filamentous algae, Eurasian watermilfoil (*Myriophyllum spicatum*), spatterdock (*Nuphar advena*), fragrant waterlily (*Nymphaea odorata*), sedge (*Cladium spp*.), cattail (*Typha spp*.), or other firm structured aquatic plants.

Stocking rates and duration of aquatic plant control

Symposia held during 1979 and 1994 (Grass Carp Symposia), 2004 (Hydrilla Management in Florida), and 2008 (Triploid Grass Carp Risk Analysis) summarized hydrilla management strategies as well as the potential of using Grass Carp as a management tool (Shireman 1979, Haller 1994; Hoyer et al. 2005, Zajicek et al. 2009). Additional studies that evaluated methodologies, impacts, or controversies associated with Grass Carp were conducted in Lake Conroe, Texas, Lake Guntersville, Alabama, and the Santee Cooper reservoirs, South Carolina. Most of these studies determined that introducing triploid Grass Carp is the most cost-effective method for long-term control of hydrilla but with a major limitation: triploid Grass Carp are best used where loss of all palatable submersed vegetation is an acceptable outcome for an extended period of time.

Grass carp should not be stocked in open systems that are connected to a stream or river because they migrate with moving water and will leave the stocked water body thus not supplying any plant control. Grass carp stocking rates in closed systems typically range from 2 to 50 fish per acre. Most biologists agree that there is no "magic stocking number" of grass carp to achieve a specific percentage of submersed weed control. Both growth rate of aquatic plants and consumption rate of grass carp are moving targets that are dependent on many factors including but not limited to: the type and quantity of aquatic plants present, water temperature, oxygen content nutrient concentration of water. If the consumption rate of the grass carp exceeds the growth rate of the aquatic plants then plant control can be achieved, otherwise plant abundance generally remains a problem.

Nationally, because grass carp feeding rates are less in cooler water, stocking rates in more northern temperate climates may need to be higher than more sub-tropical climates to achieve similar plant control. The mortality rate of the grass carp immediately after stocking ranges tremendously and can impact the success or failure of the plant management action. Once grass carp are stocked, predation by fish-eating predators can be a problem because grass carp typically feed near the water surface and are commonly preyed upon by osprey, otters and other fish. For example, studies in research ponds in Florida revealed that the number of grass carp lost to predation ranged from 7 to 70% one year after stocking. Predation can be especially problematic in water bodies with large fish predators such as striped bass or largemouth bass. Grass carp that are larger than 12 inches should be used in these systems to avoid losing the majority of the stocked grass carp to predation and to ensure adequate aquatic weed control. Overstocking or excellent survival of stocked grass carp generally results in removal of almost all submersed aquatic plants, whereas understocking or excessive mortality of grass carp results in no noticeable plant control. The proper balance of grass carp and weed growth is difficult/impossible to achieve and only a few cases of this type of success have been reported (Zajieck et al. 2009).

If complete elimination of aquatic plants by grass carp is an outcome, it can last for as long as 10 to 15 years. It is important to understand that the use of grass carp as biocontrol agents is a long-term strategy because grass carp grow to an extremely large size, live up to 20 years and cannot easily be removed from a water body once they are stocked. It is almost impossible to remove significant numbers of grass carp (approximately 90% of population) from large lakes to allow the growth rate of aquatic plants to exceed the consumption rate of the carp thus allowing an increase in aquatic plant abundance. Many studies have examined dozens of grass carp removal methods from lakes and none were efficient enough to remove significant number from a lake and/or canal (Hoyer et al. 2005). However, a few management agencies are still experimenting with removal techniques and in some cases bowfishing tournaments show promise as a means of removing grass carp from lakes (https://fishgame.com/2016/10/bowfishing-grass-carp-solving-overpopulation-problem/). Additionally, it may take five to 20 grass carp per acre to achieve aquatic plant control but it only takes approximately one carp per acre to maintain control.

Effects on water quality and fish populations

Most changes in water quality and plankton abundance associated with grass carp are not caused directly by the fish, but are due to the removal of aquatic plants and associated periphyton (algae attached to the plant material). When aquatic plants are controlled in a lake with grass carp, herbicides and/or mechanical cutting leaving material in the lake, nutrient and algal abundance tends to increase and water clarity tends to decrease. These whole-lake changes in water quality only occur when large amounts of plants (greater than 15% to 30 % percent coverage of aquatic plants) are controlled and the changes are related to three primary mechanisms: 1) by ingesting plant material and associated periphyton, nutrients incorporated into plant tissue are released increasing ambient nutrient concentrations, which causes more algal growth and filling the water column with algal cells decreases water clarity as measured by Secchi depth readings, 2) aquatic plants also tend to stabilize the water column not allowing wind to resuspend sediments and nutrients, and 3) finally the stabilized water also allow the sedimentation of algal cells and other detritus maintaining a low nutrient and clearwater state (Scheffer 1998).

Similar to water quality, changes in fish population characteristics associated with grass carp are not caused directly by the fish, but are due to the removal of aquatic plants. Canfield and Hoyer (1992) examined fish populations in 60 Florida lakes ranging in lake trophic status and abundance of aquatic macrophytes with the goal of determining what was the optimum abundance of aquatic macrophytes for a healthy fish population. The main conclusion was that fish populations in lakes with greater than 15% and less than 85% area covered with aquatic plants were functioning normally and that populations in lakes with less than 15% and greater than 85% plant coverage had an increased probability of having depressed fish populations. Thus, when grass carp take aquatic plant abundances to zero there is an increase probability of having a depressed fish population. However, there are many emergent and floating leaved aquatic plants that grass carp cannot consume so most lakes with grass carp always maintains some habitat that may be sufficient for some sportfish, especially in smaller lakes (approximately 500 acres or less).

Each individual fish species has its own life history and that history has a relationship to the abundance of aquatic plants. Because of these individual relationships, Canfield and Hoyer (1992) found fish species that tended to increase in the presence of abundant aquatic plants (e.g., bluefin killifish *Lucania goodei*, taillight shiner *Notropis maculatus*, golden topminnow *Fundulus chrysotus*, bluespotted sunfish *Enneacanthus gloriosus*, Everglades pygmy sunfish *Elassoma evergladei*, warmouth *Lepomis gulosus*, and others), those that decreased in the presence of abundant aquatic plants (e.g., gizzard shad *Dorosoma cepedianum*, threadfin shad *Dorosoma petenense* and others) and those that remained relatively stable with or without abundant aquatic plants (e.g., largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, redear sunfish *Lepomis microlophus* and others). It is important to note, that while the relative abundances of many fish species change with the control of abundant aquatic plants, individual species are not eliminated from the system.

Summary

This brief description of using grass carp for control of aquatic plants could not hope to cover all of the aspects and extensive research that has been conducted on grass carp and there are many good summaries available for further information (Shireman 1979, Haller 1994; Hoyer et al. 2005, Zajicek et al. 2009). The take home message of this description is that grass carp can be an effective, cost-efficient tool for long-term aquatic plant removal in closed systems. However, management agencies and stakeholders using the lake to be stock with grass carp must be willing to accept the probability that all submersed aquatic vegetation may be eliminated and with the elimination of the submersed aquatic vegetation will also come changes in water quality and fish populations. Additionally, until new removal techniques are developed the users must accept that there is no way to affectively remove the carp once they are stocked.

For more information:

Canfield, D. E., Jr., and M. V. Hoyer. 1992. Relations between aquatic macrophytes and the limnology and fisheries of Florida lakes. Final Report. Bureau of Aquatic Plant Management, Florida Department of Natural Resources, Tallahassee, Florida. (http://lakewatch.ifas.ufl.edu/pubs/historical/Canfield%20and%20Hoyer%201992.PDF).

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•Proceedings of the grass carp symposium. Shireman J. V 1979, Haller B. 1994. Gainesville, Florida. (http://plants.ifas.ufl.edu/manage/control-methods/biological-control/chinese-grass-carp/proceedings-of-grass-carp-conferences-1979-and-1994/).

Scheffer M.1998. Ecology of Shallow Lakes. Chapman and Hall, London.

Sun J., L. Wang, L. Ma, F. Min, T. Huang, Y. Zhang Z. Wu, F He. 2017. Factors affecting palatability of four submersed macrophytes for grass carp *Ctenopharyngodon idella*. Environmental Science and Pollution Research. 24: 28046-28054.

Zajicek P. W., T. Weier, S. Hardin, J. R. Cassani , V. Mudrak. 2009. A triploid grass carp risk analysis specific to Florida. Journal Aquatic Plant Manmagement. 47:15-20. (Additional information can be found in the Final Report: https://www.freshfromflorida.com/content/download/5661/97358/A-Risk-Analysis-Triploid-Grass-Carp.pdf).