

State of Michigan's Status and Strategy for Grass Carp Management

Scope

Invasive grass carp (*Ctenopharyngodon idella*), native to eastern China and eastern Russia, threaten the waters of the State of Michigan. The goals of this document are to summarize the:

- Current level of understanding on the biology and ecology of grass carp.
- Current management options for grass carp in Michigan.
- Possible future directions of grass carp management in Michigan.

Biology and Ecology

I. Identification

Grass carp, also known as white amur, is the only member of genus *Ctenopharyngodon* within Cyprinidae (Chilton and Muoneke 1992). Adapted to break

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down plant material, their serrated double-rowed pharyngeal bones are a distinguishing trait (Hickling 1965, Cross 1969, Shireman and Smith 1983). Grass carp are a relatively large member of Cyprinidae with elongated, laterally compressed bodies with the potential to reach approximately 60-100 pounds and over 3 feet in length (Chilton and Muoneke 1992, Pflieger 1997). The grass carp has a terminal mouth, a short caudal peduncle, and a dorsal fin origin anterior to the pelvic fin origin (Jenkins and Burkhead 1994, Ross 2001). The body is covered with cycloid scales with dark edges giving the fish a crosshatched appearance (Pflieger 1997). Coloration on the dorsal surface is olive-brown and fades to silvery-white on the lower body (Pflieger 1997). The grass carp's dark edged scales and lack of barbels distinguish the species from goldfish (*Carassius auratus*) and common carp (*Cyprinus carpio*), respectively (Page and Burr 1991). Grass carp also have a shorter dorsal fin (7-8 rays) when compared to goldfish (17 rays) and common carp (19-22 rays) (Ross 2001). Grass carp have fewer anal rays (9 or less) when compared to silver (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*) (19-22 rays) (Ross 2001).

II. Life History

Even before reaching sexual maturity at variable ages from 1-11 years or ~20-33 inches, grass carp grow rapidly; with the potential to weigh approximately 2 pounds after 1 year and continue to grow approximately 4-7 pounds each year in temperate regions (Shireman and Smith 1983). In its native range, grass carp can reach approximately 400 pounds, 3 feet in length, and live over 20 years (Shireman and Smith 1983, Ross 2001). Water, temperature, and diet are important factors in age of maturity while length, weight, and age directly influence fecundity (Cudmore and Mandrak 2004, Shireman and Smith 1983). Spring and summer spawning, primarily in the upper water column of main river channels over rapids or sand bars, occurs in high velocity, turbid waters ranging in temperatures from 59-86°F (Cudmore and Mandrak 2004, Shireman and Smith 1983). Typically, movement to spawning areas begins at ~59-63°F and spawning occurs at temperatures above ~64°F (Stanley et al. 1978). During spawning, 2-3 males in open water follow a female; the males rub against the females to stimulate release of eggs near the water's surface (Shireman and Smith 1983). Females are broadcast spawners releasing copious amounts of eggs. Their eggs are semi-pelagic and must remain suspended until they hatch, which happens approximately one day after spawning (Stanley 1976, 1978). Temperature plays a large role in the timing of hatching and temperatures below 68°F during egg incubation increases the chances of mortality and deformities (Chilton and Muoneke 1992).

III. Diet

Grass carp feed voraciously on aquatic plants and can consume large quantities in a relatively short time. Food sources within the first two weeks of hatching mainly include rotifers, protozoans, cladocerans, insect larvae, and other zooplankton species. Grass carp transition to filamentous algae before feeding exclusively on macrophytes starting approximately at 1 month of age (Opuszynski and Shireman 1995). Adult grass carp will consume preferred plant species to scarcity before moving to those less desired (Bain 1993). Soft-leaved submerged plants such as, Curly leaf pondweed or American waterweed, are most preferred, while filamentous algae, floating vegetation, and firmer-leaved submerged plants, like Eurasian water milfoil or Watershield, are less preferred (Pine and Anderson 1991, Opuszynski and Shireman 1995). If vegetation is low, grass carp will utilize animal food sources such as crayfish, detritus, and zooplankton (Conover 2007).

IV. Habitat

Long networks of warm, flowing water are important for grass carp egg incubation, while larvae and juveniles develop in quieter backwater habitats such as floodplains (Verigin et al. 1978). Grass carp in general are a temperature (~32-90°F), oxygen, and salinity tolerant species (Meyer et al. 1975, Fedorenko and Fraser 1978, Shireman and Smith 1983). They may be able to inhabit brackish water (~10 ppt) during migration (Shireman and Smith 1983). Adult grass carp prefer the slow flowing, near shore, highly vegetated backwaters of large rivers, pools, ponds, and lakes (Shireman and Smith 1983, Page

and Burr 1991). These areas range approximately 3-10 feet in depth (Shireman and Smith 1983). In the winter, grass carp retreat to deep depths of the riverbeds (Shireman and Smith 1983).

V. Effects from Grass Carp

Introduced to the United States to control aquatic vegetation, grass carp deplete preferred macrophytes to a point of compromised water quality and ecosystem structure (Page and Burr 1991, Nico et al. 2006). The effects are often so severe that it has become a widely held view that grass carp are an all or nothing control method. When grass carp are introduced to or invade a new area, a reduction in native non-targeted species of plants is usually seen through selective feeding (Taylor et al. 1984). An increase in turbidity is a consistent consequence of grass carp establishment; the attributed source of the turbidity, whether from sediment disturbance or increased algae abundance, varies (Maceina et al. 1992). Numerous studies have found other water quality consequences such as reduced dissolved oxygen and varying increases in alkalinity and nutrients like phosphorus, manganese, and iron (Lembi et al. 1978, Van Zon et al. 1977, Bernstein 2001). However, grass carp's direct effect on water quality is still in question (Chilton and Muoneke 1992).

Grass carp can lead to the decline of plankton, zooplankton, and benthic macro-invertebrates, such as snails and crayfish, thus altering the trophic structure of invaded systems (Bettoli et al. 1993, Chilton and Muoneke 1992). They also have potential negative impacts on native amphibians by removing required cover (Murphy et al. 2002). Grass carp predate on, compete with, and deplete the habitat/shelter of benthic invertebrates and, therefore, influence fish species abundance and composition (Bettoli 1990, Nico et al. 2006). Impacts in the fish community vary by location (Bailey 1978), but given grass carp's potential to deplete food sources and shelter/spawning habitat, native fish species should be considered at risk (Taylor et al. 1984). The fish waste left behind by grass carp can fuel excessive algal growth, speeding eutrophication of invaded systems. They also compete directly with other herbivorous fish, such as catfish and sunfish, and the depletion of macrophytes increases the predation of organisms dependent on the plant habitat as shelter (Shireman and Smith 1983, Chilton and Muoneke 1992). Sport fishes, such as centrarchids, can benefit from this increased predation but can also be negatively affected by the degraded reproductive habitat important in their life cycle (Chilton and Muoneke 1992). This typically leads to a decline in fish numbers and can translate into economic losses, as sport fishermen are a significant source of income for Great Lakes businesses. Other species, like catfish, have shown increases in abundance (Chilton and Mueoneke 1992, Opuszynski and Shireman 1995) and cohabitation of these species is not uncommon in their native range. Grass carp also have the potential to carry the Asian tapeworm that can infect native cyprinids (Hoole et al. 2001). Waterfowl can be negatively affected by the invasion of grass carp due to the competition for aquatic plants and near shore habitat (Chilton and Muoneke 1992).

Current status and distribution in Michigan

Although introduced to control aquatic vegetation, grass carp have proven only moderately effective – they often overfeed and remove all submerged vegetation including native species. In the 1970s, grass carp escaped the confines of private hatcheries and dispersed throughout the central United States (Kelley et al. 2011). Today, grass carp can be found from the Texas Gulf Coast region to the Mississippi River Basin and have been caught in the Lake Erie watershed (Figure 1, Baerwaldt et al. 2013). While Michigan does not allow the stocking of any grass carp, most states permit the stocking of triploid or sterile grass carp, and seven Mississippi River basin states allow diploid or fertile fish to be stocked (Zajicek et al. 2011). Five counties in Michigan reported grass carp observations to the Midwest Invasive Species Information Network (MISIN); these counties include Clinton (2 reports), Sanilac (2 reports), Saginaw (2 reports), Newaygo (2 reports), and Allegan (1 report) (Figure 2). According to the United States Geological Survey (USGS), grass carp have been found in Lake Michigan, Lake Erie, Mays Lake, Saginaw and St. Clair-Detroit drainages, Little Muskegon, Kalamazoo and St. Joseph Rivers (Figure 1 and 2).

It is not unusual for grass carp to be found in Michigan tributaries; most of these fish are likely triploid releases or escapes from other states. However, grass carp recruitment has recently been documented in the Sandusky River, Ohio – a Lake Erie tributary (Chapman et al. 2013). Grass carp is listed in Michigan as a “prohibited fish species” in the Natural Resources and Environmental Protection Public Act 451 of 1994.

Management of Grass Carp

Management of other aquatic invasive species in the past, such as sea lamprey and zebra mussels, has proven difficult, long-term, and expensive. With this experience, efforts in Michigan should be focused on preventing grass carp introductions and range expansions. For grass carp populations that may become established in Michigan, measures to extirpate or reduce the population in order to promote native species need to be taken. An integrated management framework, likely using a combination of management methods to minimize damages while keeping grass carp at insignificant levels, should be adopted (Hart et al. 2000). More information on the management strategies in this report can be found in the Asian Carp Working Group’s management plan for Asian carp in 2007 (Conover et al. 2007).

I. Prevention

Prevention of accidental or deliberate introductions and further establishment of the current grass carp population should be a top priority for Michigan. In response to the growing threat grass carp present to Michigan, along with 31 other states, Michigan has outlawed the possession of this species within its borders. Posting informative signage at infested or high-risk waterbodies could help to raise awareness among recreational users. Increased inspection and monitoring, possibly using environmental DNA (eDNA) technology to detect low abundances (Jerde et al. 2011), will be important in prevention efforts. Electroshocking and fish tagging are alternative monitoring methods that can be used in addition to eDNA and in conjunction with citizen monitoring to track the spread

and distribution of Grass carp. For low-density surveillance, eDNA is generally the best option; this method can detect individual fish other methods miss, allowing for an earlier response. Yet it is important to understand that eDNA only provides presence/absence information and does not give estimates of population size.

Education and outreach about the damaging effects of grass carp would help to raise awareness and discourage illegal, deliberate introductions by private citizens whether introduced for sport or vegetation control. Unfortunately, improper or illegal stocking practices, stocking of fertile fish in other states, and illegal sale of diploid fish as triploid fish will continue to put the state of Michigan at constant risk. Because of the constant risks, monitoring and quick response are key to preventing the spread of grass carp.

II. Management/Control

Since negative effects caused by grass carp are likely directly proportional to their abundance, management efforts need to be effective in keeping the populations at levels that mitigate damage to the natural ecosystem and minimize the potential of further invasion into new habitats.

a. Physical

Harvest enhancement could be used as a primary tool to control an established population of grass carp in Michigan. The promotion of commercial harvesting in the future could prove effective in reducing population numbers. If commercial harvesting is to be used, a determination of the most effective gear and harvest methods would be useful. Also, contracting experienced commercial fisherman or changes in the market and regulation are needed to increase the number of commercial fishers. Recreational fishing could be promoted, but probably with less success. In order to promote recreational fishing of grass carp, harvest regulations will need to be modified and informative materials on harvest and preparation could be dispersed. In conjunction with harvest, natural resource agencies and others that regularly sample aquatic environments could also physically remove and destroy grass carp when encountered. Some common harvest methods include: angling, pop-nets, lift nets, baited traps, and herding for removal with gill nets or seines. Although harvesting is unlikely to remove all individuals, it is useful for keeping populations in check.

Habitat and hydrological manipulation could be another option, in some locations, to prevent invasion, create undesirable conditions for grass carp, and/or more favorable habitat for native species. More understanding on the grass carp's life history could make this method more effective. Potential impacts of this type of manipulation on native species and the system as a whole should be considered.

Electrofishing or trapping could also be used to shock and physically remove stunned grass carp from infested waters, but are limited to relatively shallow waters and is impractical for use on the Great Lakes. Electric barriers or nets can be placed along invasion corridors and rivers to prevent the further spread of the species but may face

problems in rivers with high traffic or seasonal fish migrations (i.e. Salmon migrations). One such electric barrier has been put built in the Chicago Sanitary and Ship Canal to prevent Asian carp from entering Lake Michigan and plans for a permanent physical barrier are in development. Bubble, light, and acoustic walls have been investigated by Minnesota but are not 100% effective.

b. Biological

The introduction of sterile males or monosex tetraploids could be an effective measure taken to reduce the reproductive success of grass carp and is common practice in many states. Transgenic manipulation of grass carp genes could also be used; transgenic fish would express deleterious characteristics that could aid in population control. Captured reproductively viable fish could be sterilized and returned as an alternative to removal or disposal. However, more research on effective sterilization methods is needed before this kind of practice can be used (Kapusinski and Patronski 2005).

The use of viruses or diseases such as grass carp reovirus could mitigate the impacts of invasion, but is not recommended. The reovirus and other viruses are deadly to non-target species and may have lasting effects. In recent years the use of reovirus has had severe, long term, impacts on Chinese aquaculture (Su et al. 2009).

c. Chemical

Once developed for use, sex and alarm pheromones could produce desired management results. Almost a dozen pheromones have already been identified for the common carp and sea lamprey pheromones are being tested as a control. Pheromones are natural chemicals, but research on their use in the field and specific life stages needs to be evaluated. Once developed and approved, pheromones can be used in conjunction with other management methods to increase efficacy or as a stand-alone method to limit grass carp spread. They can greatly influence recruitment rates, deter fish, interrupt spawning, alter development, or lure fish into trapping areas, potentially from great distances (Lim and Sorensen 2010).

Piscicides, specifically rotenone and antimycin, could be utilized to control grass carp if made available to appropriate users. Research into the contact time required to kill grass carp and the environmental conditions in which these chemicals could be used needs to be determined. The use of piscicide bait is a promising method; although this method does not completely eliminate carp populations, it can be useful in reducing their numbers to manageable levels. Fish Management Bait (FMB) is a floating rotenone poison that has been tested in several flavors and forms. Alfalfa pellets were most extensively tested and removed an average of 79% of grass carp with only minor ingestion by non-target species, several similar poison baits are available. Research into the most effective form of bait is warranted, but poison baits could provide relief for overstocked or infested water bodies. In isolated ponds and lakes or ponds and lakes with high potential to spread grass carp (i.e. those on floodplains of major rivers) rotenone could be applied to the whole system, but restocking or removal of native

species prior to treatments would be required and it could take several years for the system to fully recover.

Future Directions for Michigan and Grass Carp management

Prevention is the most cost-effective approach in management and should be top priority in any management plan. A prevention strategy that identifies and targets areas that are most at risk to invasion should be the first goal in grass carp management. However, new infestations are inevitable and, therefore, a cohesive monitoring and reporting system needs to be created or current systems must be updated. This will increase knowledge of aquatic invasive species locations and possibly enable early detection responses to new occurrences.

Grass carp management techniques have the potential to be very effective management tools. However, there are critical knowledge gaps in which scientific research is warranted, but with the development of a regional or national network to communicate research results, these gaps can likely be filled in the near future. Topics of research include, but are not limited to harvest practices, life history in North American waters, disease, pheromones, invasion dynamics, and piscicides. Dependent on the populations that are already established, states currently manage grass carp based on policy; grass carp are either prohibited, require triploid verification, or have no restrictions at all. While Michigan already prohibits grass carp from the state, further exploratory steps could be taken to create an effective management strategy for more established populations in the future. Random inspection of live fish shipments, best management practices for suppliers and purchasers, and restriction of water use from infested water bodies should be implemented as soon as possible with additional regulations to follow.

Although there is no silver bullet for grass carp, as with many other invasive species, several effective management methods do exist. Each lake or stream will likely require a response or management plan tailored to meet its specific needs and none of these methods should be considered blanket treatments. Careful observation and planning is required for a safe and effective management effort, but as always prevention should be top priority in future AIS planning.

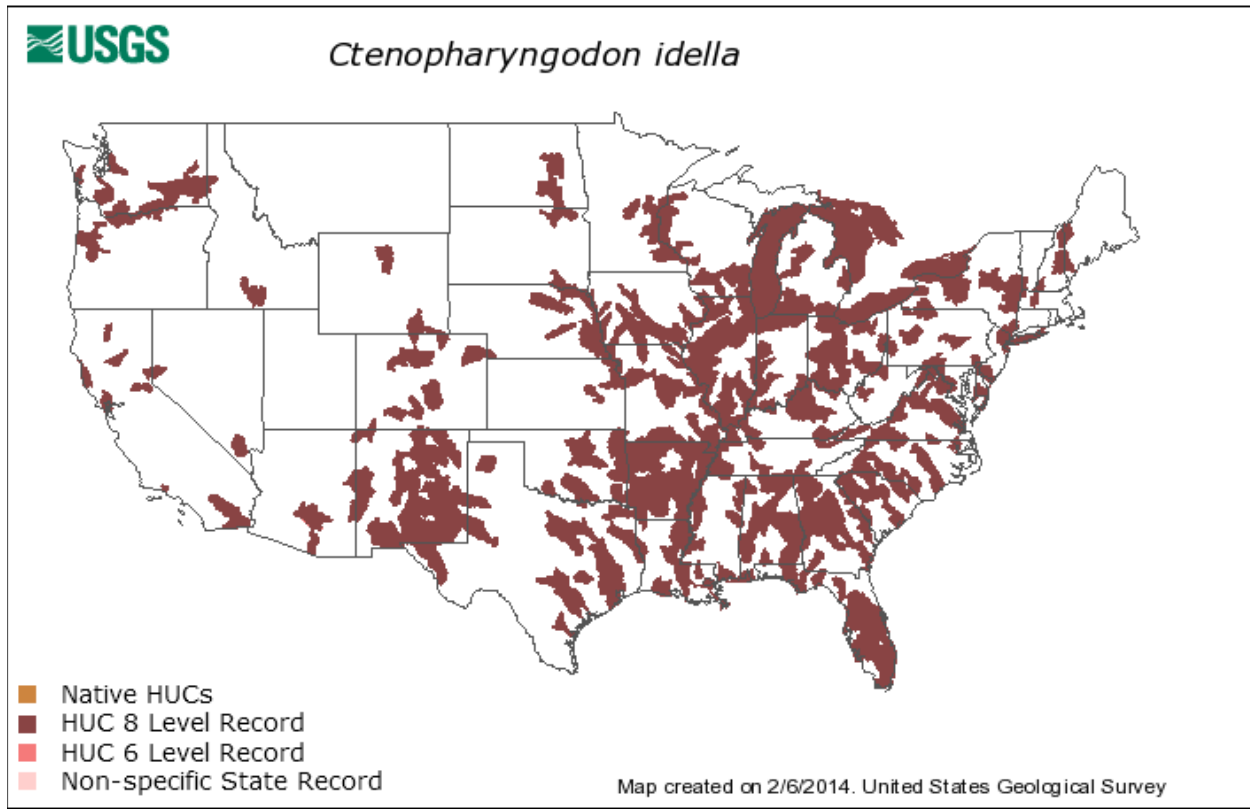


Figure 1. Distribution of grass carp in the United States (Nico et al. 2014). Accessed January 25, 2014

Michigan Counties with Grass Carp Detections

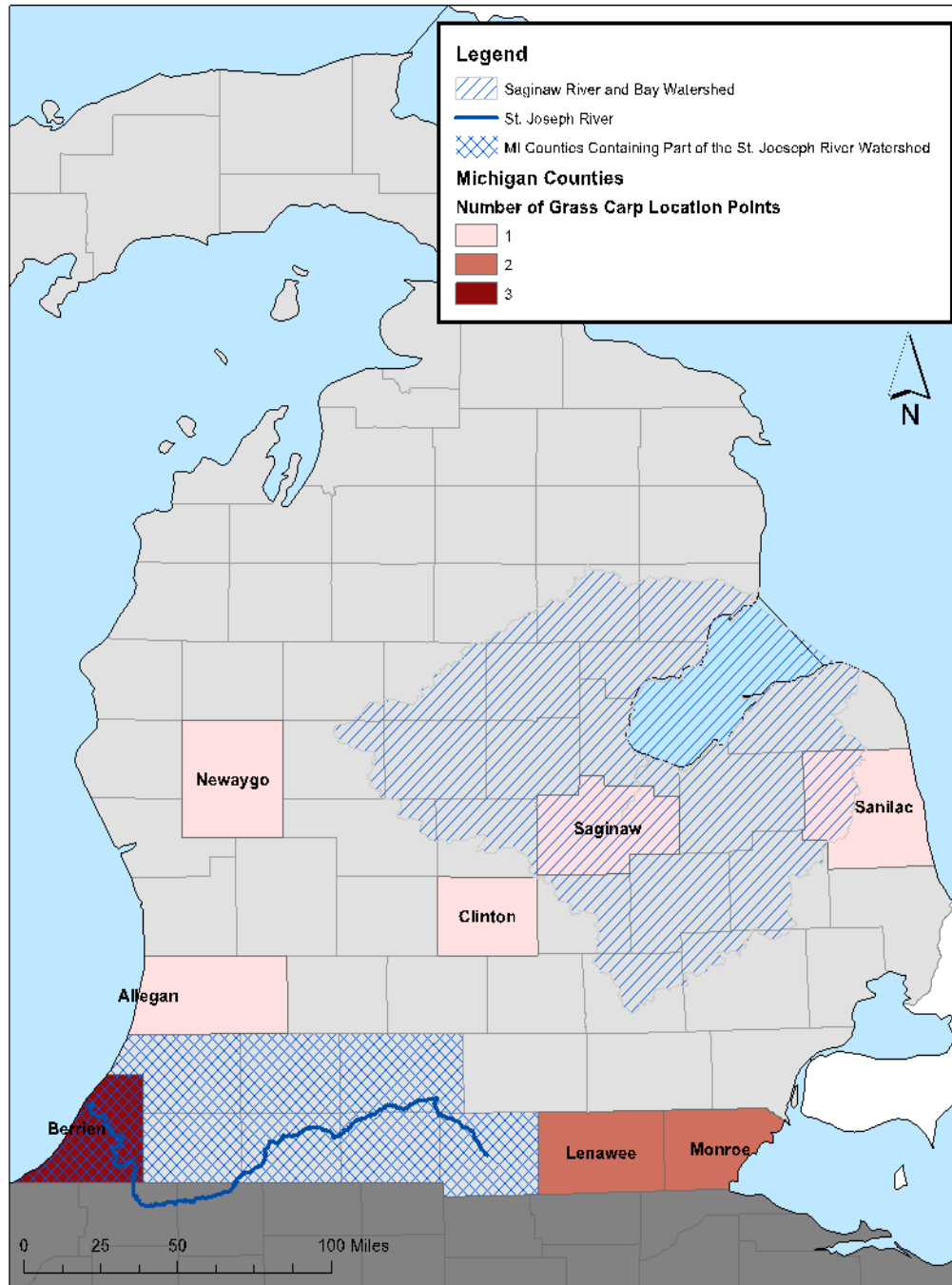


Figure 2. Number of unique coordinate location points within Michigan counties at which grass carp were detected. This data is from the United States Geological Survey (USGS), Midwest Invasive Species Information Network (MISIN), Biodiversity Information Serving Our Nation (BISON), and the State of Michigan fishery databases. Grass carp have been detected in Lake Erie, the Saginaw and Lake Michigan drainages, and the St. Joseph River.

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