The Potential Effects of Asian Carp on the Gizzard Shad and the Overall Ecosystem of the North Branch of the Chicago River

Natural Systems Ecology (BIO 5010 01)
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February 18, 2013

Citation Note: I have chosen to follow APA style. I'm using Purdue University's Online Writing Guide for reference.

Introduction

Prior to the Clean Water Act of 1972, the Chicago River was a veritable dumping ground for industrial, agricultural and residential pollutants; including raw sewage, chemicals from agricultural runoff, industrial byproducts and heavy metals. For most of the 20th century the Chicago Waterway System (CAWS) was too polluted to support most aquatic life, but better sewage treatment and river cleanup efforts have resulted in a revitalization of the habitat (Egan 2006). Typical surveys in the 1970s in the North Branch would find only ten species of fish. In recent years over sixty native fish species have been identified including large-mouth bass, yellow perch, and bluegill, along with a number of non-native species. Beyond fish, frogs, crayfish and turtles are returning. The beaver population is growing, and an increasing number of birds have been spotted flying overhead (Kibel 2007). The recent discovery of several species of native fresh water mussels is a particularly good sign that the river is becoming a healthier ecosystem. The threeridge, threehorn wartyback, pimpleback and the mapleleaf mussels are intolerant of pollutants and their presence bodes well for the river (Klocek & Krueger 2004). .

One species of fish making a rapid resurgence is the gizzard shad. This fairly pollution tolerant species was one of the first to reestablish itself after the cleanup of the river. Although the shad is native to Illinois, in Wisconsin, Iowa and Michigan many label the fast-spreading fish as an invasive. Using them as live bait is illegal in many public lakes and other bodies of water (Ohio Department of Natural Resources [ODNR] 2012). This is particularly ironic, because here in Illinois the gizzard shad is about to embark on the epic battle of competition against the infamous invading Asian carp.

The pollution of the river had been tantamount to a biological seal, and the cleanup enabled carp and other aquatic invasive species to begin invading the CAWS. Three separate samples of DNA evidence of the presence of carp were found in October of 2011, but so far the silver or bighead carp have yet to establish themselves (Egan 2012). There has been no evidence of live fish. “Asian carp” is actually a generic name for three species of carp including bighead, silver and grass. The most pernicious, the bighead and silver carp can grow to up to 110 pounds and eat between 20-40% of their body weight each day. (Alexander 2011). The Great Lakes Commission (GLC), a panel of scientific and technical experts, political leaders and stakeholders from Chicago, Northwest Indiana, and other areas of the Great Lakes region are suggesting a radical solution. They recommend that permanent barriers be constructed at key points to prevent all invasive species from passing through the CAWS—effectively undoing the work of generations (GLC 2012). Proponents of the barrier say it is critical that we prevent the imminent invasion of the carp into the inland sea of the Great Lakes, where they will grow to unmanageable levels and seriously impact the ecosystem by consuming the nutrients native species depend on. Bighead carp eat zooplankton detritus, and blue-green algae; and silver carp eat zooplankton, phytoplankton, bacteria, and detritus. These are food sources shared by many native species of fish and omnivorous invertebrates. The gizzard shad, for example, also depends on these sources and is in turn an important food source to game-fish like yellow perch and largemouth bass (ODNR 2012). Although catfish, walleye and northern pike have been known to be prey upon young Asian carp, they quickly outgrow a size conducive to predation

(Sigurson 2010). The gizzard shad shares this feature, but does not attain the size or voracious appetite of its potential competitor.

If established in the CAWS would the Asian carp eat the shad out of the proverbial house and home? Would their presence in the already fragile North Branch ecosystem limit the population density of the gizzard shad? How would the presence of a ravenous competitor affect the growth and fecundity of the gizzard shad and other planktivores? Would the nutrient transport role of the gizzard shad be expanded as its preferential forage of plankton is compromised by the carp forcing it to resort to detritus? A close examination of the North Branch of the Chicago River ecosystem will help determine whether the fears of the Great Lakes Commission are founded.

Geographic Description of the Ecosystem

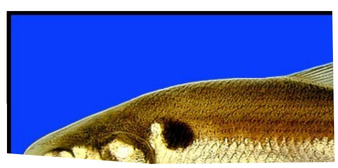
The North Branch is a section of the Chicago River, approximately 24 miles long. Its source is in the northern suburbs, west of the city of Waukegan, IL. It runs southward, parallel to the Lake Michigan shoreline and the East and West forks. On its way south, it passes through wetland, forest preserves, golf courses and the Chicago Botanic Gardens. Around the town of Highland Park, IL the river meanders through the former marshlands known as the Skokie Lagoons. The North Branch and the East Fork merge at Watersmeet Woods west of the city of Wilmette, IL, continuing to flow southward until the West Fork joins the river at Morton Grove, IL. The river continues to flow southward, entering the city of Chicago near the intersection of Milwaukee Avenue and Devon Avenue. Here the river bends slightly, curving southeasterly as it passes through more forest preserve land and residential areas around Foster Avenue. In the neighborhood of West River Park the North Branch joins with the North Shore Channel. This drainage canal was built in the late 1900s to accommodate water traffic and to flush pollution into the Chicago Sanitary and Ship Canal—and away from Lake Michigan. Unlike the upper sections of the North Branch, this stretch of the river contains built-up banks and is unnaturally deep and straight. The river continues to pass through residential corridors south of Belmont Avenue until it reaches the industrial area known as the Clybourn Corridor. Continuing under a string of historic bridges it reaches the Main Stem in downtown Chicago (Hill 2000).

Habitats

According to a biological survey done by the Illinois Department of Natural Resources in 1999, the North Branch (especially in the sections north of the city) displays a habitat typical of a slow flowing stream, which is composed primarily of submerged roots, logs and brush. The riparian corridors vary; some of the most prominent are Mesic woodland, floodplain forest, disturbed savannah and urban. In the northern most sections of the North Branch near the town of Glenview, IL, there is an abundance of lizards tail, an emergent aquatic plant that provides a suitable habitat for aquatic organisms (Pescitelli & Rung 1999). However due to the engineering interventions of Chicagoans over the years the southern sections of the North Branch lack many of the natural features that make for good wildlife habitat such as bends, riffle zones (stretches of choppy water where water becomes oxygenated) and gently sloping banks that allow plants to grow and fish to spawn. In the urbanized sections, the North Branch is a straight channel with reinforced concrete walls where there should be banks (Brandel 2012). This has negatively affected population growth of organisms at all levels of the food chain.

Model Organism the Gizzard Shad

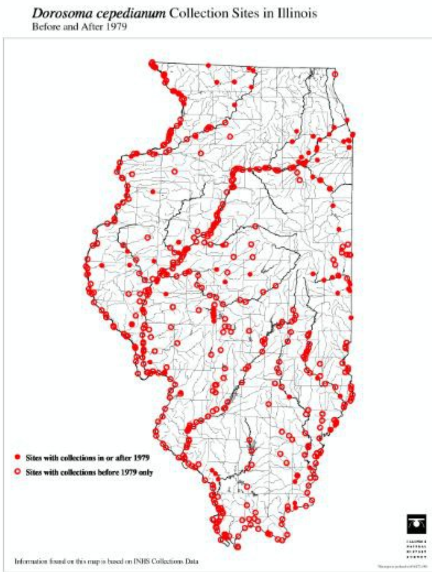
The unassuming gizzard shad is considered too bony and slimy to be a good game fish. Except in historic references and the rare sushi recipe it does not appeal to the gastronomical ideals of most cooks. However it is one of the main food sources for the beloved largemouth bass and thus has gained begrudging acceptance as important to anglers.

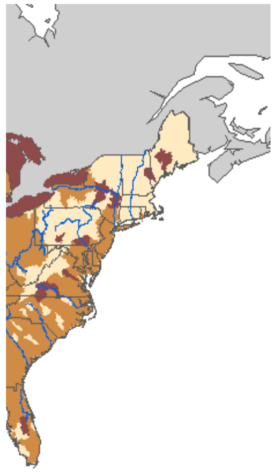


Its Latin name is *Dorosoma cepedianum* and it is a member of the herring family. The shad is a deep bodied fish that is laterally compressed. Its body is silver and its fins slate gray. Behind the gill openings on the upper sides is a dark spot. The dorsal fins are positioned above the pelvic fins and like other members of the herring family; the shad has a rear dorsal ray that extends as far back as its anal fins. Gizzard shad bellies have a sharp saw-like edge due to a row of folded scales. They differ from threadfin shad in their coloring and shorter dorsal ray.

Distribution and Dispersal

The gizzard shad is native to North America. Its range extends from the Great Lakes and the St. Lawrence River to Eastern South Dakota and central New Mexico. It has even been found in the Gulf of Mexico and as far south Rio Panuco, Mexico.





3. United States Geological Survey

The North Branch of the Chicago River has been the home to the gizzard shad for thousands of years. Archaeologists speculate that gizzard shad may have constituted 50% of the total fish yield for consumption by pre-European societies in the Midwest. However due to the fragility of the shad's skeleton, little evidence remains (Limp & Reidhead 1979).

As indicated in Chart 1, biological surveys have noted ample numbers of shad in the North Branch, and the numbers seem to be growing. During surveys by the Illinois Department of Natural Resources, 17 shad were observed in 2001 and 88 were observed in 2006 at the same testing station (Prescitelli, Burns & Rung 2001; Prescitelli & Rung 2009).

Chart 1: Number of gizzard shad collected from North Branch testing stations during biological surveys from 1974-2006 (Dennison, Sedita, Tata, Zenz, Lue-hing 1998; Pescitelli & Rung 1999; Pescitelli et al. 2001, Pescitelli & Rung 2009)

Fecundity and Spawning of the Gizzard Shad

The gizzard shad can live up to 6 years (Hassan-Williams & Bonner 2007). They grow and multiply rapidly which is one of the reasons they are found to be a species of concern in non-native locations (Illinois State Museum 2012). Female shads can begin breeding their second year. Each year as the water warms, spawning occurs between April and June (Hassan-Williams & Bonner 2007). Female shads produce as many as 500,000 eggs annually (ODNR 2012). They do not build nests but instead weave in and out of near-shore vegetation depositing eggs that adhere to the plants. A male shad follows in her wake fertilizing the eggs. This method reduces predation and results in large hatches. Females may spawn on more than one occasion during the breeding season (Bodola 1966). Depending on the temperature of water the eggs will hatch anywhere between 36 hours at 27.6°C and 95 hours at 16.1°C hours (Hassan-Williams & Bonner 2007).

Although shad spawn in the shallow vegetated water close to the shore, most shad prefer deeper waters. This preference seems to increase with age. Young shad may swim in shallow water, but older shad are rarely found there (Hassan-Williams & Bonner 2007).

Gizzard shad spawning has most likely been impacted by the straightening and industrial restructuring of the river, particularly in parts with built up banks, as it depends on near-shore vegetation for laying its eggs. However vegetation is also starting to make a resurgence, and the fish habitually migrate from deeper waters to shallow waters to spawn, so I imagine that they don't mind swimming north to where the river follows a more meandering path and offers natural banks.

Studies by the U.S. Fish and Wildlife Service in Western Lake Erie inferred that the gizzard shad, although highly fecund, experiences high larval mortality. The survival rate of one year's spawn (aprox. 100,000 individuals) was determined to be at most 0.011%. This group experiences heavy egg and larval mortality, predation and is exposed to variations in temperature due to fall and winter storms. The survivors of this group quickly grow too large to be considered prey by most predatory fish, but because they have yet to venture into deeper waters, they are still susceptible to temperature changes (Bodola 1996).

Trophic Levels of the North Branch Ecosystem

(See Appendix A)

The North Branch of the Chicago River is rich in phosphorous and nitrogen due the effects of urbanization on the landscape. A reduction in evapotranspiration due to less vegetation and an increase in impervious surfaces (i.e. pavement) cause runoff from point and non-point source pollution (e.g. agriculture, lawns and golf courses) to be rapidly funneled into the river (Gaulke 2012). As these nutrients are used by autotrophs such as algae—a principle food source for many organisms—during the process of respiration, this could be seen as a benefit. Also to the benefit of the plants are detritivorous organisms. Several species of mollusks and other invertebrates such as the sow bug, midge larvae and pimpleback mussel specialize in filtration (Klocek & Krueger 2004). The gizzard shad and its intrepid potential competitor, the Asian carp can also feed at this trophic level, although they prefer the higher energy content of phytoplankton and zooplankton.

The next trophic level is the primary producers. For this ecosystem, these include phytoplankton or diatoms and aquatic plants such as the aforementioned lizards tail, and milfoil, coontail, flat sedge, arrowleaf and white water lily. These are consumed by heterotrophic macro-invertebrates such as the riffle beetle, zooplankton and blackfly larvae along with the other primary consumers such as heterotrophic invertebrates including fingernail clams, threehorn wartyback mussels, and the creeping ancylid snail (Friends of the Chicago River 2011)

Omnivorous vertebrates and invertebrates feed on the primary producers as well as the primary consumers listed above. This group includes virile crayfish and aquatic worms (invertebrates) and vertebrates such as the golden shiner, green frog and the brook stickleback. This trophic level, secondary consumers, also includes carnivorous invertebrates such as the dobsonfly larvae, dragonfly larvae and leeches. Omnivorous bottom-feeder fish could possibly be included at this trophic level as well such as the gizzard shad.

The final trophic level in the North Branch ecosystem is the tertiary consumers starting with the carnivorous fish such as the yellow perch, the black crappie and the largemouth bass. I would also include the black bullhead catfish at this level because despite the fact that it occasional feeds on plants and scavenges dead animal matter, its primary diet consist of worms, insects, fish, and frogs. All four of these fish species along with other similar fish are consumed by humans—and prized by anglers. Other predators to these fish are the carnivorous tetrapod vertebrates such as the blue heron and the belted kingfisher (Sullivan 2003).

Energy Flow and Ecological Efficiency in the North Branch

An ecosystem, as defined by Arthur Tansley, is a collection of living and nonliving elements organized in a determinate way. It is dynamic system of interconnections that is not random but works to maintain the balance within the system (Miller & Ricklefs 2000). This balance is achieved through the flow of energy. In the North Branch ecosystem, energy starts with primary producers such as a phytoplankton. The phytoplankton captures solar energy and transforms it into energy it can use to build biomass. The total energy assimilated during photosynthesis is called gross production. As a result of this process, the phytoplankton releases oxygen which is used by the animals in the North Branch ecosystem. Photosynthesis combines inorganic compounds: carbon dioxide with water to form glucose. The phytoplankton absorbs nitrogen and phosphorous from the Chicago River and combine those with the glucose to create proteins and acids that allow it to build fats, oils and cellulose. The energy used during this process is called net production.

The leftover energy is available to the primary consumer, a blackfly larva for example, when it eats the phytoplankton. Energy is dissipated as it moves up through the trophic levels so the blackfly larva receives more energy from feeding on the phytoplankton, than a secondary consumer—such as the virile crayfish—will receive from eating it. The blackfly larva uses a percentage of the energy to build biomass and to graze on phytoplankton. The leftover energy is available to the crayfish. This process continues on to tertiary consumers such as a yellow perch.

All animals including the crayfish, the blackfly larva and the yellow perch lose some energy in three ways. The first is as a part of the metabolic process digesting their food. This energy is excreted in the form of nitrogen-containing organic wastes primarily ammonia urea.

The organisms also lose energy in the form of heat, and as excrement which mixes with the dead bodies of plants and animals, collectively known as detritus. Detritivorous organisms such as the pimpleback mussel consume this material and are able to assimilate the lost energy. Detritus also provides phosphorous and other nutrients to the aquatic plants (Miller & Ricklefs 2000).

The multiple trophic roles of the gizzard shad

During larval stages, shad use teeth to catch zooplankton, but when they reach one inch in length, they lose their teeth and develop the muscular gizzard which make them filter feeders. The gizzard is made up of hundreds of long, thin gill rakers. The shads use this suck up particulate matter from the water consuming both small invertebrates and phytoplankton and to graze on detritus, sand and other sediments found at the bottom of the river (Hassan-Williams & Bonner 2007). The preferred forage of the gizzard shad is zooplankton such as Daphina, a small planktonic crustacean (Vanni & Headworth 2004). However when zooplankton is in short supply, the gizzard shad will feed on detritus. Detritus is an abundant source but poor in nutrition (Fontenot 2006). The shad’s contribution to the food web shifts depending which of the two food sources it is relying on. When detritus is its main source of food, the shad acts a nutrient recycler; regulating the flux of nutrients from the benthic and pelagic zones. However when zooplankton is its primary fare, the shad acts as nutrient transporter, incorporating allochthonous nutrients (terrestrially derived) into the food web [figures 4 & 5] (Vanni & Headworth 2004).

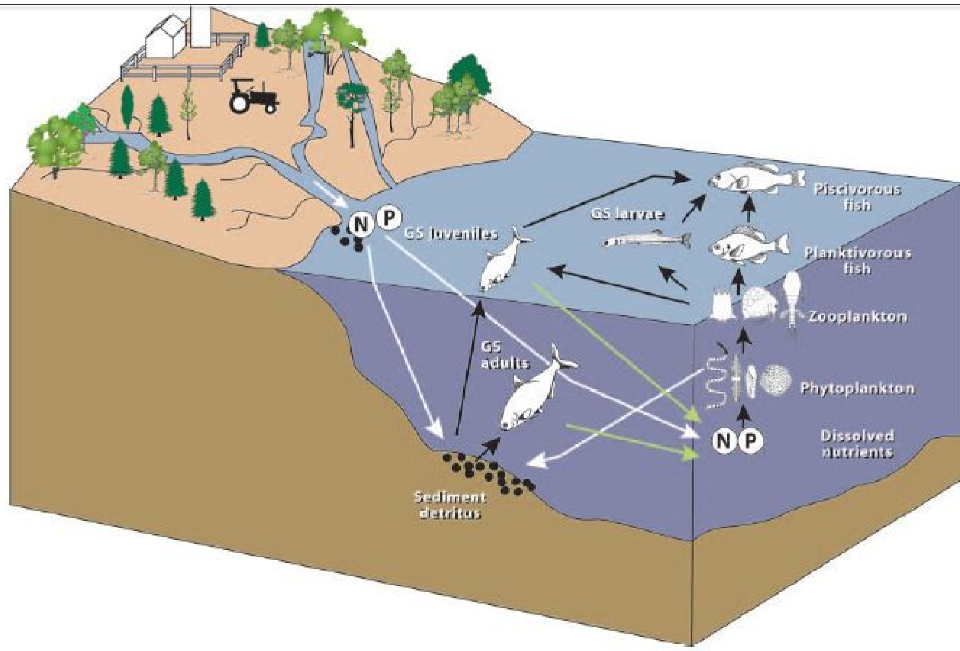


Figure 3. Gizzard shad link watersheds and the pelagic grazing food chain in reservoirs. The watershed is the ultimate regulator of reservoir food webs by providing nutrients directly to phytoplankton and detritus that subsidizes gizzard shad populations; sedimentation of phytoplankton also provides a detrital resource for gizzard shad. These fluxes of materials across ecosystem or habitat boundaries are indicated by white arrows. Gizzard shad juveniles and adults provide nutrients to phytoplankton through nutrient translocation (green arrows), thereby further stimulating primary production. Gizzard shad larvae and juveniles function as zooplanktivores, thereby reducing resources for other zooplanktivorous fish, and serve as prey for piscivorous fish. These and other feeding relationships are represented by black arrows. Organisms and ecosystems are not drawn to scale. Abbreviations: GS, gizzard shad; N, nitrogen; P, phosphorus.

Figure (Vanni & Headworth 2004)

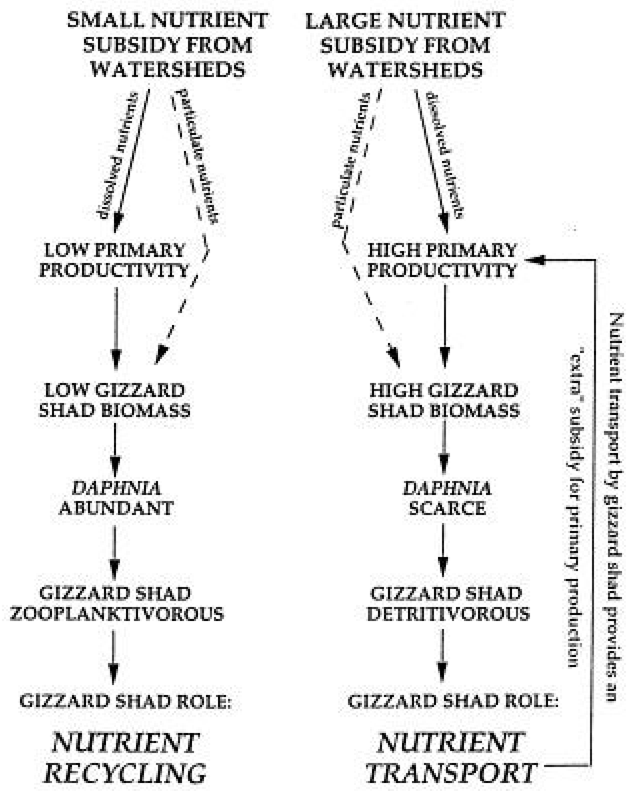


Figure (Vanni & Headworth 2004)

Brief History of the Asian carp Invasion

Ironically the fish were originally imported in response to concerns raised by the mother of the modern environmental movement, Rachel Carson. The publication of her book *Silent Spring* encouraged less toxic ways to control the algae that developed as a part of aquaculture. (Egan 2006) Government agencies such as the Arkansas Game and Fish Commission and the National Environmental Protection Agency began experiments using the fish as weed controls, to clean up sewage and as a possible domesticated food source for a growing planetary population. As security wasn't a priority at the time, escapes into the wild happened on occasion. By 1981 silver and bighead carp were being spotted in the Mississippi River. Flooding in the 1990s exacerbated the problem allowing even more carp to spread north (Alexander 2011). Now they have traveled over 1000 miles and are regularly caught in large quantities—25,000 pounds per day—in the Illinois and Ohio rivers (Egan 2006).

Potential results of silver and bighead carp recruitment in the North Branch

The shad's high fecundity and rapid growth has allowed it to thrive in the Chicago River despite a nearly equal population of largemouth bass and black bullhead catfish. However a new, more prodigious competitor may soon arrive on the scene and if the Illinois River is any indication, the shad might have reason to worry. The shad and Asian carp share similar dietary needs and inclinations. However, the appetite and size of both species of carp far surpass that of the gizzard shad.

The bighead and silver carp can grow to up to 110 pounds and eat between 20-40% of their body weight each day. (Alexander 2011). At a maximum of 18 inches and 3.5 pounds (ODNR 2012), on an individual to individual basis, the gizzard shad can't hope to compete. Although DNA evidence of both silver and big head carp has been found in the North Branch of the Chicago River, the invasive species has yet to establish itself in the CAWS (Egan 2012). It may thereby be helpful to compare the Chicago River to the Illinois River, where the carp have been well established since the late 1990s. These two ecosystems share nearly identical food webs, habitats and pre-carp native species representations. However the densities are slightly lower in the CAWS due to the aforementioned years of pollution.

Both scientists and bait shop owners noticed a marked reduction in the shad population in the Illinois River in a 2009 after the silver carp had been fully established. Biologists Wayne Herndon and Ken Russell encountered a fraction of the shad they are accustomed to observing during an Illinois Natural History Survey in August of 2009. Tom Alcorn of Tom's Bait Shop noted at the time that anglers used to be able to make a seine haul in the marina and catch 150 or 200 pounds of shad in one haul, but they haven't been able to do that in over a year (Lampe 2009).

At first glance the data does not seem to support a continuance of this trend. Since the 1990s the Illinois Natural History Survey's Long-Term Monitoring Program has documented the expansion of the silver and big head carp in Illinois River. In a 1997 survey gizzard shad represented 48.4% of the total catch in numbers and was present at all 27 test sites (Koel , Sparks, Blodgett & Whitney 1997) In 2008, the annual survey reported gizzard shad made up 8% of the total catch, compared to silver carp which represented 33.3% (McClelland & Sass 2008). A 2012 survey reported that gizzard shad represented 31.74% of the total catch (Tyszko 2012) [Chart 2]. Perhaps when the Asian carp were first introduced to the Illinois River ecosystem, they proved to be density limiting factor and reduced the shad population significantly. But the data seems to suggest that the shad are resurging.

This is consistent with the general trend of invasive species which tend to peak in abundances and biomass and later cycle down to a level commensurate with the carrying capacity of the ecosystem (Roughgarden, 1998) However, according to a study on the effect of the Asian carp invasion on gizzard shad and bigmouth buffalo in the Illinois River by Irons and colleagues, the Asian carp's effects are subtle and over the long-term detrimental. Irons observed a marked reduction (7%) of the body condition of gizzard shad after the Asian carp were established in the river. Irons noted that density dependent factors such as water quality (e.g. turbidity and conductivity), annual river conditions (e.g. temperature and discharge), predation, primary productivity (e.g. chlorophylla and total phosphorus) were not responsible for the decline in the gizzard shad's (or the bigmouth buffalo's) condition.

Long-term this could affect not only trophic relationships but the fecundity of the shad, which as mentioned above already is depleted by high larval mortality. A 5% decline in body condition has been shown to reduce fecundity by 1-5%. Furthermore a depleted condition leaves the shard more vulnerable to poor health and diseases (Irons, Sass, McClelland & Stafford 2007)

Another study by the Illinois-Indiana Sea Grant supported Iron's findings. Freedman compared the food webs in high- and low-density Asian carp sections of the Illinois River with historical data in order to determine whether the carp were having an impact. The results of this study show that in high-density sections, planktivorous fish tend to feed at lower trophic levels. According to Freedman this suggests that Asian carp are monopolizing the zooplankton supply. The study went on to say that there is marked competition between the carps and facultative planktivores such as bluegill sunfish, emerald shiner and gizzard shad.

This study did not limit its research to adult planktivores but also examined the potential cascading trophic effects on smaller minnows and juveniles of other species that also rely on plankton. It also posited a subsequent decline in benthic productivity due to nutrients being limited by phytoplankton consumption. The method used was a stable isotope analysis of carbon and nitrogen in historic food webs, compared with contemporary "invaded" food webs.

It found that gizzard shad are indeed impacted by the carps. The study noted that the carbon levels in both large and small shad were depleted. Relative to historic samples, nitrogen levels were also depleted. The study concluded that the Asian carps alter where and on what competing species feed, thereby reducing the overall food base and possibly out-competing native species (Freedman, Butler & Wahl 2012).

As suggested by Vanni & Headworth, if the gizzard shad must resort to feeding on a lower trophic level, it stands to reason that the nutrient transport role it currently plays would be interrupted perhaps depleting the benefits currently gained from allochthonous energy sources (2004).

Conclusion

The Great Lake Commission's plans to construct a permanent barrier to separate the two watersheds have yet to come into fruition (GLC 2012). In the meantime the electric dispersal barrier installed in the CAWS prevents the migration of some of the Asian carp between the watersheds. The U.S. Army Corps of Engineers (USACE) reports that by using methods including ultrasonic telemetry, netting and electrofishing techniques they can determine the efficacy of the barriers. They claim no Asian carp have been detected beyond the barriers (USACE 2012).

However many have expressed doubts as to whether the barriers are effective against smaller fish (Skiba, 2011). Also according the investigations of the Detroit Free Press, there are at least 13 other lesser-known pathways. Lam reports "Carp breach wetlands during floods, dumping them into rivers leading to the lakes. In Indiana's Wabash River, spawning carp actually are closer to Lake Erie than spawning populations near Chicago are to Lake Michigan" (Lam 2006, 6). In addition, young Asian carp are sometimes used by fishers as bait who confuse the fish with more common forms of live bait such as young gizzard shad. There is also an active trade in live fish for culinary uses mainly by urban Asian populations. It has been posited that this trade may lead to accidental deposits of carp (Egan 2006). Only time will tell when, and if, the gizzard shad will need to test its Darwinian aptitude against the Asian carp in the North Branch.

Irons and colleagues recommended that the current aquatic management plans including electric and permanent barriers coupled with further research will go a long way in ensuring the protection of the CAWS ecosystem, and mitigating the possible invasion into Lake Michigan. They argued the density of Asian carp may be reduced overtime as it reaches the carrying capacity, however proactive management through a better understanding of the Asian carp biology is to be encouraged. Close examination of competitive interactions of the planktivorous community (including organisms at different life stages) should be given special consideration. Biologists should monitor Asian carp density and test for plankton limitation in already invaded systems. They also recommended the development of commercial and sport fishing opportunities for Asian carp (Irons et al. 2007).

I second their recommendations. After closely examining the situation through research, I think caution is in order. Although the gizzard shad is a resilient and resourceful organism, the long-term effects of competition with the Asian carp could have negative consequences on its ability to thrive. I did not discuss other limiting factors facing the shad such as hypoxia due to the surplus nitrogen and phosphorus from runoff in the CAWS, or the yearly Dead Zone in the Gulf of Mexico that is largely the fault of pollution flowing south along the Mississippi River from the Chicago area. Although I did extensive research on the topic, I choose to focus on Asian carp for the purposes of this paper. It seems invasive species are only part of the problem. If we hope to protect not only the fragile North Branch of the Chicago River and local ecosystems, but also those of our precious fisheries in the Great Lakes and the Atlantic Ocean, my research indicates that separating the two watersheds with permanent barriers thereby restoring the natural divide is the wisest possible course of action.

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