A Review of the Impacts, Effects of Common Carp on Freshwater Lake Systems through Nutrient Contributions and Ecological Thresholds

Executive Summary:

When evaluating nutrient pollution and eutrophication issues comprehensively within a lake system we must evaluate the lake basin as a literal "container" for the watershed system which encapsulates its own ecosystem (Shapiro et al., p. 85). The watersheds feeding lake systems often become eutrophic due to large inductions of diffuse man made / generated nutrients (via fertilizers, development, livestock feed and waste disposal, etc.). These contributions can be exasperated by catalyzing self-propagating biological responses within the ecosystem. Specifically, this paper evaluates the effect of the benthivorous common carp (*Cyprinus carpio*) on lake basin ecosystem characteristics and functions

Common carp are nonnative fish with European and Asian origins introduced in the Midwest as game fish in the 1880s. These fish are a resilient and prolific species that can thrive and breed in the worst water quality conditions, which they help create as their populations increase to dramatic proportions within a system. Large females (average 5-10 lbs) and can lay 100,000-500,000 eggs in a single spawn. Adult carp have large life spans, mature quickly, have no natural predators and are not generally sought by anglers and thus have a low mortality rate (USGS).

Large populations of common carp can both directly and indirectly affect water quality, water clarity, aquatic habitat, and species richness (i.e. sport fish populations) within the lake system. Documented impacts to ecosystem processes fall into three categories;

- **Nutrient Inputs** – direct input and conversion of nutrients in the system through metabolic processes
- **Foraging Behavior and Bioturbation** – alteration of habitat and ecosystem processes
- **Fish Assemblage and Diversity** – domination of modified habitat and reduction of predation

Several scientific studies have "found a significant positive relationship between the biomass of common carp and chlorophyll, TP, and turbidity" and deficiencies in sport fish species richness (Chumchal, Michael, et al 2005, p.274). These dominant species create a catalytic effect within the aquatic ecosystem contributing to serious eutrophication implications and can even compromise the effects of restoration and water quality improvement efforts.

The effects these fish have within lake and various freshwater systems has been well documented for several years and the management / treatment of these species is common within several state and federal refuge management plans, US Fish and Wildlife Service planning and research documents, municipal watershed plan documents, etc. Research shows that within "Shallow, productive ecosystems with fine, loose sediment, and low abundance and diversity of aquatic macrophytes are most vulnerable to common carp perturbation and would experience the greatest improvements in water quality following carp removal (Weber and Brown, 2009, p. 531).

Grand Lake St. Marys has a population of carp estimated between 250 and 500 lbs/acre which contributes 1,000 to 2,000 lbs of phosphorus to the lakes internal loading annually. This population creates other ecosystem process impacts and creates self-perpetuating and expanding issues with eutrophication.

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Supporting Documentation of Direct and Indirect Consequences on Ecosystem Processes

Nutrient Inputs:

Common carp are known to be an omnivorous species and their diet is diverse and flexible given available resources. They can consume zooplankton, worms, insect larvae as well as other organic plant material particularly when other food sources are not readily available. They may also feed on fish eggs and larvae of other fishes. "The fish digest organic matter, and excrete soluble nutrients, thereby transforming sediment phosphorus into soluble phosphorus available for uptake by algae at the lake surface" (RWMWD, 2006, p.4).

As common carp species grow in size and populations increase, nutrients, including phosphorus, nitrogen and ammonia are directly affected within the water column which may fuel eutrophication. This growth may also be stimulated by increased nutrient loads contributed by watershed inputs. In a controlled study completed by Matthew M. Chumchal and Ray A. Drenner, scientists theorize that phosphorus loads in carp excretion and defecation rates may also increase with watershed loads, especially with regard to TP (Chumchal and Drenner, 2004, p. 151). The TP contributed directly by common carp can reach levels equal or greater than watershed loads if populations are abundant.

The impact of these direct nutrient rich inputs "may stimulate phytoplankton growth under nitrogen or phosphorus limiting conditions" (Chumchal and Drenner, 2004 p. 155). Data suggests that "at least 50% of the phosphorus excreted by common carp may be readily available for phytoplankton production" (Weber and Brown, Vol. 17 2009, p. 526). Phytoplankton drive many of the food webs within aquatic ecosystems however as their production increases with increased nutrient loading, turbidity and common carp biomass, the threat of promoting algae and blue green algae also increases (Weber and Brown, Vol. 17 2009, p.529.

These direct contributions common carp create are not well documented as the indirect ecosystem impacts are, however an extensive literature review conducted as part of this study found one pertinent paper regarding the digestive activities of carp and their specific nutrient contribution within freshwater systems. The paper written by Vincent A. LaMarra, Jr., *Digestive activities of carp as a major contributor to the nutrient loading of lakes*, in 1975 has been referenced and cited worldwide throughout limnological journals, textbooks and scientific research papers by numerous experts, institutions and scientists in the field.

In LaMarra's experiments, he was able to demonstrate "the effects of various carp densities on the Total Phosphorus (TP) and chlorophyll concentrations of the overlying water" (RWMWD, 2006 p.7). His research demonstrates "**that carp populations of 200 kg/ha can internally load a lake with Total Phosphorus at 1.07 mg P/m^2 /day to 2.18 mg P/m^2 /day**" (RWMWD, 2006, p.7). In an example developed for the Ramsey-Washington Metro Watershed District for Lake Phalen in St. Paul, Minnesota, which is 198 acres in size, "an estimate of 1,000 carp.. assuming they are an average weight of 7 pounds would result in a fish density of about 40 kg/ha (or 5 seven-pound fish per acre). With a directly proportional relationship of Mr. LaMarra's findings, the internal loading at Lake Phalen with 1,000 carp could range from about 131 to 266 pounds of TP per year" (RWMWD, 2006 p. 7). In an extremely degraded water body, where carp populations are more established, the direct TP contributions could be sizably larger. These results alone indicate that removing benthivorous rough fish from lake systems could have a dramatic impact on water quality from a TP reduction standpoint alone.

Foraging Behavior and Bioturbation:

Carp are known to vigorously roil the water and bottom substrate in search of food and during spawning seasons. In a comprehensive study completed by Weber and Brown in 2009, "Common carp increased water column nutrients in 75% of the surveyed literature.." (Weber and Brown, Vol. 17 2009, p.526). The research completed in this analysis determined that "Common carp may directly and indirectly increase water column phosphorus, nitrogen, and ammonia as a result of benthic foraging activities, excretion, or destruction and subsequent decomposition of aquatic macrophytes" (Weber and Brown, Vol. 17 2009, p.526).

With large numbers of carp spawning and swimming, the effects of large populations can literally alter the physical bottom stratus and water column within a lake, making it difficult for any native fish or vegetative species to thrive over time. Carp activities suspend the sediment and organic material on the bottom of the lake into the water column and cause turbidity or bioturbation resulting in the increased release of nutrients. This bioturbation directly "inhibits [zooplankton] … ingestion of phytoplankton (e.g. Kirk and Gilbert 1990; Kirk 1991), and loss of plant refugia permits them to be readily consumed by planktivores (e.g. Schriver et al. 1995)" (Lougheed, Vanessa, et.al. 1998, p.1190).

Bioturbation reduces or eliminates subsurface light needed for plant growth and consequently photosynthetic plant production and oxygen levels dramatically decrease which eliminate macrophytes that provide cover. "Carp also reduce zooplankton and macroinvertebrate populations by predation" (Baldry, 2000 p. 2). Ultimately, 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)" (Baldry, 2000 p. 2).

Carp "Thresholds" & Effects on Fish Assemblage and Diversity:

Not only do carp literally muddle the water they live in, they can have significant impacts on fish assemblages within lake systems. In turbid freshwater ecosystems, lakes can be "dominated by benthivores and contain few sight-feeding predators [i.e. walleye, bluegill and black bass], whereas lakes in a clear state often contain a diversity and abundance of sight-feeding predators" (Jackson, Zachary, et. al. 2010, p.14). "If a lake switches from a clear to a turbid state, consequent changes in the abundance and population structure of these fishes may greatly alter food web ecology as well as local economies that rely on income from recreational angling" (Jackson, Zachary, et. al. 2010, p.14).

In a study conducted by Zachary J. Jackson, Michael C. Quist, John A. Downing, and Joseph G. Larschied, for recreational lakes in Iowa, "High densities of common carp were related to undesirable water quality conditions and low abundance of important sport fishes" and also cause incisive disruptions and changes in lake functions (Jackson, Z., et. al. 2010, p.19). The study correlated "water quality, lake basin morphology, watershed land use and fish population variables" (Jackson, Z., et. al. 2010, p.16) The specific variables evaluated in this study included: "watershed to lake area ratio; percentage of row-crop agriculture in the watershed; mean depth; concentrations of total suspended solids, chlorophyll *a*, cyanobacteria, total phosphorus and total nitrogen; Secchi disk transparency; and RGI [Relative Growth Index] values" (Jackson, Z., et. al. 2010, p.16). The results of this study suggest "that when common carp catch rates exceed 2 kg/NN" (net night, i.e. for fyke nets fished overnight), recreational lakes in Iowa "…are likely to have high nutrients, poor water clarity and poor sport fish populations" (Jackson, Z., et. al. 2010, p.21). The Jackson, et al. study also found that within all the recreational lakes in Iowa evaluated, that "Shallow systems (natural lakes, oxbows) had higher densities of common carp compared to deeper systems (impoundments, surface mines), thereby suggesting that shallow lakes are more sensitive to the effects of common carp and that restoration efforts incorporating biomanipulation of common carp will likely be most successful in shallow systems" (Jackson, Z., et. al. 2010, p.14).

Another study completed by Vanessa L. Lougheed, Barb Crosbie, and Patricia Chow-Fraser "developed a relationship between [common carp] species richness and water turbidity for 19 wetlands in the Great Lakes basin which indicated that above an apparent threshold of 20 NTU [(Nephelometric Turbidity Unit)] there were less than five species of submergent plants, while a more diverse community existed in less turbid systems" (Lougheed, V., et.al. 1998, p.1189).

Beyond their sheer presence and population numbers in the water, carp instinctively uproot submerged aquatic plants needed for other native fish and waterfowl species as subsurface habitat for reproduction and feeding. Fish species such as black crappie, bluegill, pumpkinseed and yellow perch need macrophytic vegetation to spawn. "Fishes growth rates are sometimes reduced in the presence of common carp"(Weber and Brown, 2009, p.530). Specifically "bluegill and black crappie *Pomoxis nigromaculaatus* populations have declined with an increase in common carp population size" (Weber and Brown, 2009, p.530). Largemouth and smallmouth bass populations may also decrease when common carp are present. In another paper written by Weber and Brown, "Relationships among invasive common carp, native fishes and physiochemical characteristics in upper Midwest (USA) lakes", the scientists evaluated 81 lakes in eastern South Dakota to find that "Lakes where common carp relative abundance exceeded 0.6 fish per night had low abundance of native fishes, whereas lower abundance of common carp resulted in variable abundance of native fishes" (Weber and Brown, 2011, p. 1). This study also correlated lakes with the minimum "0.6 fish per night were also characterized by larger surface areas and watersheds and impaired water quality (higher dissolved solids and chlorophyll *a* concentrations and lower secchi depth)." (Weber and Brown, 2011, p. 1)

Above the water surface, waterfowl need macrophytic vegetation during migration for food and habitat. Duck populations have decreased in wetland and lake systems where the water is found to be turbid and carp are present (Baldry, 2000, p. 3).

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