Guilty by Association: Are All Benthivorous Fish Created Equal?

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Introduction

Invasive species threaten biodiversity and the ecological integrity of ecosystems worldwide, often causing irreversible changes in social, economic, and ecological processes at accelerating rates and extents (Vitousek et al. 1997; Mack et al. 2000; Pimentel et al. 2000; Lodge et al. 2006). Among invasive species, ecosystem engineers can have some of the most substantial impacts on other biota because of dramatic direct and indirect effects on the environment that generally outlast the life of the organism (Crooks 2002; Hastings et al. 2007). Common carp *Cyprinus carpio* is one of most widespread aquatic invasive species in the United States and has long been identified as a contributor of water quality deterioration, disrupted ecosystem processes, and shifts in biological assemblages. However, there is a paucity of information regarding the effects of native benthivorous species on aquatic systems despite sympatry with common carp and the potential to benefit from degraded habitat conditions. Therefore, understanding the interaction and interrelationships between native and non-native benthivorous fish species and water quality is critical for the management and restoration of aquatic systems. The objective of this study was to evaluate the effects of non-native common carp and native black bullhead *Ameiurus melas* on aquatic ecosystems. Specifically, we evaluated the response of water clarity, nutrient resuspension, macrophytes biomass, and abundance of zooplankton and benthic macroinvertebrates to each species. We hypothesized the direct and indirect effects of the non-native common carp on aquatic ecosystems would exceed the impacts of the native black bullhead.

Methods

We performed a mesocosm experiment with four treatments replicated four times. The treatments were: no fish (i.e., control) and additions of equal biomass (i.e., approximately 1000 g) of black bullhead, common carp, and the combination of both species (i.e., 500 g of each species). Treatments were randomly assigned to 16 mesocosms (1.2 m tall x 1.8 m diameter). Mesocosms we filled with approximately 20 cm of littoral sediment from a nearby pond and planted with 20 stems of floating leaf pondweed *Potamogeton natans* and 0.5 m^2 of coontail *Ceratophyllum demersum*. Mesocosms were immediately filled with water from a nearby pond after planting of macrophytes and allowed to establish for 28 days. The experiment began on July 16^{th} 2009 and concluded on August 20^{th} 2009 (i.e. duration of 35 days). Water clarity (i.e., turbidity) and nutrient concentrations (i.e., ionized ammonia, nitrite, nitrate, total reactive phosphorus) were measured two to three times weekly and processed in laboratory. Total macrophyte biomass was estimated at the end of the experiment by removing all macrophytes from each mesocosm and weighing. Zooplankton was sampled weekly using a tube sampler (75 cm tall x 2.5 cm diameter) with a volume of 1.4 L. Zooplankton samples were filtered through an 80 μm mesh net, preserved in 95% ethanol, and identified in the laboratory. Benthic macroinvertebrates were sampled prior to the beginning and at the end of the experiment with an Ekman dredge. Benthic invertebrates were preserved in 95% ethanol and indentified in the laboratory. A repeated measures analysis of variance (ANOVA) was used to test the treatment effects on water clarity, nutrient concentrations, and zooplankton. An ANOVA was used to test treatment effects on macrophyte biomass and total abundance of benthic macroinvertebrates.

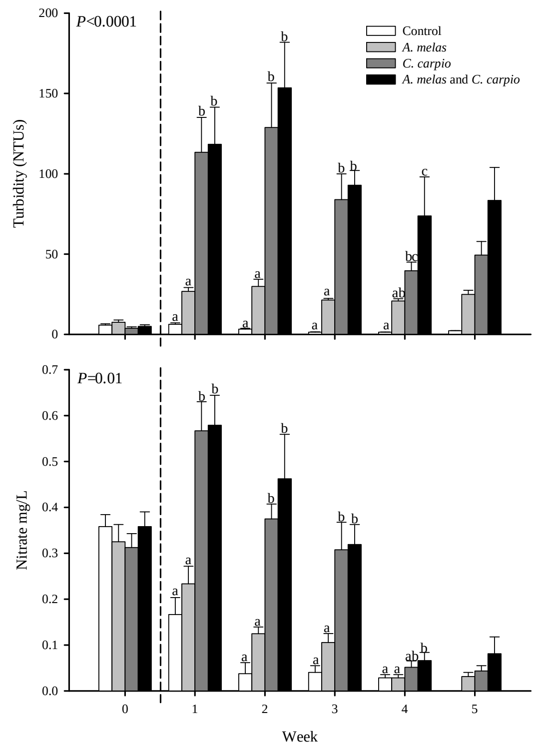

Figure 1. Turbidity (upper panel) and total phosphorus concentrations (lower panel) through time in experimental mesocosms. Dissimilar letters indicate treatments that were significantly different (P<0.05) by week. Overall, repeated measures analysis of variance P-value reported. Bars represent one standard error.

Results

Water clarity differed among treatments ($F_{3,48}$ = 11.80; P < 0.0001; Figure 1). Turbidity was elevated in the presence of common carp (i.e., carp and both species treatments) compared to control and black bullhead treatments. Over the course of the experiment mean turbidity of the control treatment was similar to black bullhead ($F_{1,48}$ = 1.13; P = 0.26), and lower than common carp ($F_{1,48}$= 16.09; P = 0.0002) and both species ($F_{1,48}$ = 27.01; P < 0.0001) treatments. Similar to water clarity, ammonium and nitrate concentrations were increased by the presence of common carp ($F_{3,40}$ = 20.81; P < 0.0001; $F_{3,40}$ = 4.22; P = 0.01, respectively; Figure 1). Mean concentrations of ammonium and nitrate were similar between control and black bullhead ($F_{1,40}$ = 1.64; P = 0.11; $F_{1,40}$ = 0.31; P = 0.58, respectively) and lower than common carp and both species treatments, which were similar ($F_{1,40}$ = 0.15; P = 0.70; $F_{1,40}$ = 0.10; P = 0.76, respectively). Phosphorus concentrations differed among treatments ($F_{3,28}$ = 4.21; P = 0.01) and were similar between control and black bullhead ($F_{1,28}$ = 3.90; P = 0.06). Phosphorus concentrations were also similar between common carp and both species ($F_{1,28}$ = 0.19; P = 0.66) treatments. Total macrophyte biomass (i.e., roots, stems, leaves) differed among treatments ($F_{3,12}$ = 3.63; P = 0.045; Figure 2). Control macrophyte biomass differed from common carp ($F_{1,3}$ = 7.52; P = 0.02) and both species ($F_{1,3}$ = 5.68; P = 0.04) treatments, but was similar to black bullhead ($F_{1,3}$ = 0.31; P = 0.59). Benthic macroinvertebrate abundance was similar among treatments ($F_{3,12}$ = 0.56; P = 0.65) prior to the beginning of the experiment and differed ($F_{3,12}$ = 13.05; P = 0.0004) after the completion of the experiment (Figure 2). Macroinvertebrate abundance was similar between control and black bullhead ($F_{1,3}$ = 1.24; P = 0.29) treatments and higher than common carp and both species treatments, which did not differ ($F_{1,3}$ = 0.20; P = 0.66). Effects of treatments on zooplankton were evaluated by taxonomic group. Copepod abundance differed among treatments ($F_{3,16}$ = 7.80; P = 0.002), but indicated a fish effect as the control treatment differed from all other treatments (*P*s<0.05). All other zooplankton taxonomic groups (i.e., cladocera, diptera, rotifer, sididae) were similar among treatments (*P*s>0.05).

Discussion

In our current study, common carp had deleterious effects on abiotic and biotic conditions regardless of black bullhead presence. We found that common carp had negative impacts on water clarity (i.e, increased turbidity), nutrient resuspension (i.e., increased ammonium, nitrate, and phosphorus concentrations), macrophytes (i.e., decreased biomass), and benthic macroinvertebrates (i.e., decreased total abundance and biomass). In contrast, black bullhead had little or no effect on measured water quality and biological variables when compared to control conditions. Overall, results from this experiment suggest that although black bullhead tend be tolerant of degraded ecosystems, they are not causing physical changes to the environment known to be responsible for perpetuating degraded water quality conditions. Therefore, increases in the abundance of native benthivorous species such as black bullhead following the invasion of common carp in aquatic systems should serve as an indicator of ecological conditions and not be causative in nature.

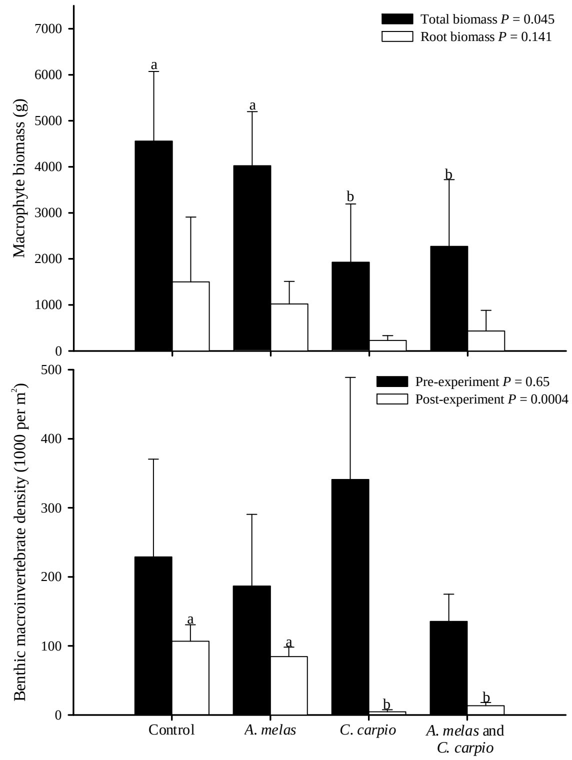

Figure 2. Macrophyte biomass (upper panel) and benthic macroinvertebrate abundance (lower panel) at the beginning and ending of an experimental mesocosm study (35 day duration). Dissimilar letters indicate significantly different (*P*<0.05) means between treatments. Overall, analysis of variance *P*-value reported. Bars represent one standard error.

References

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Key words: ecosystem, eutrophication, invasive species, native fishes and water quality

Preference: Oral presentation (PowerPoint and projector required)