

## Game Fish Response in Wetlands with Varied Common Carp Abundance

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**Abstract** – Common Carp (*Cyprinus carpio*) is identified as one of the most damaging invasive species in North America. We investigated the influence of Common Carp abundance on game fish populations in relatively pristine wetland lake complexes in the Nebraska Sandhills. We monitored wetland lakes with varying Common Carp abundance over a 4-year period. Overall, game fish abundance decreased with increasing Common Carp abundance. Bluegill (*Lepomis macrochirus*), Largemouth Bass (*Micropterus salmoides*), Yellow Perch (*Perca flavescens*), and total game fish abundance were all negatively related with Common Carp abundance. Yellow Perch condition was negatively related with Common Carp abundance while Northern Pike condition was positively related with Common Carp abundance. Results of this study provide insight into the negative impacts of Common Carp on wetland ecosystems and suggest Common Carp removal may benefit game fish in Sandhills lakes.

### Introduction

*Cyprinus carpio* L. (Common Carp) is a destructive invasive species, listed as one of the International Union for Conservation of Nature's 100 worst invasive species in the world (Boudjelas et al. 2000). Through their feeding behavior, Common Carp physically disturb the benthic zone, increasing turbidity through resuspension of sediments and nutrients (Bajer et al. 2009, Breukelaar et al. 1994, Zambrano et al. 2001). Common Carp feeding behavior has been associated with a loss of wetland plants through uprooting, decreased primary productivity, and a decline in macroinvertebrate abundance, consequently reducing ecological function (Glover 2020, Miller and Crowl 2006).

The negative impact of Common Carp on water quality is well established (Bajer and Sorensen 2015, Loughheed et al. 1998, Zambrano et al. 2001). However, most studies addressing these concerns are conducted within waterbodies that are heavily impacted by anthropogenic change (e.g., agricultural wetlands or constructed reservoirs) which may mask potential interactions among ecosystem processes. Nevertheless, these wetlands may have varied species composition and nutrient cycling rates compared to sympatric non-agricultural wetlands (Verhoeven et al. 2006). Thus, investigations are needed regarding the effects of Common Carp in unaltered wetlands within undeveloped landscapes.

Previous studies have suggested the negative effects of Common Carp on vegetation and macroinvertebrate communities may have a bottom-up effect on other fish species (Lamarra 1975, Loughheed et al. 1998, Wahl et al. 2011), thereby negatively impacting angling opportunities. Angling is an important source of outdoor recreation in the USA. In 2016, an estimated 35.8 million anglers nationwide invested US\$46.1 billion annually in sport fishing (U.S. Department of the Interior et al. 2016). Locally, providing and managing outdoor

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recreation opportunities is one of the primary goals outlined in the Nebraska Game and Parks Commission's strategic plan (Nebraska Game and Parks Commission 2018). Understanding the influence of Common Carp on game fish is critical to informing management goals including Common Carp removal.

Natural resource agencies invest substantial financial and personnel resources to remove Common Carp with the objective of restoring the ecosystem function of lakes and wetlands. Standard methods involve the application of rotenone to eradicate the extant Common Carp population and installation of barriers to prevent recolonization (Koupal et al. 2013, Schrage and Downing 2004). However, eradication measures can be costly. For example, eradication efforts in 2021 on Hackberry Lake, a 275 ha wetland on the Valentine National Wildlife Refuge in northwestern Nebraska, had an estimated cost of approximately \$600/ha. A better understanding of the influence of Common Carp is critical in evaluating whether Common Carp removal and exclusion efforts should be a priority and provide tangible return on investment.

Common Carp density may exert a threshold effect on wetland health, with levels above 100–200 kg/ha exerting a greater effect (Haas et al. 2007, Bajer et al. 2009, Vilizzi et al. 2015). Bajer et al. (2009) suggested a threshold of ~ 100 kg/ha in shallow lakes. Similarly, Hass et al. (2007) observed negative impacts of Common Carp at densities of ~ 120 kg/ha. A meta-analysis of published studies on the impact of Common Carp estimated threshold values of ~ 200 kg/ha (Vilizzi et al. 2015). However, many management agencies monitor Common Carp using the metric catch per unit effort (CPUE), not biomass, making it difficult to convert these research findings into management actions. As such, studies assessing the influence of Common Carp relative abundance on game fish species may better complement common agency data collection efforts compared to estimates of density alone. For instance, in the Nebraska Sandhills, it is speculated by local biologists that changes in the game fish assemblage occur once Common Carp relative abundance reaches a CPUE of 100 carp per hour.

Aquatic resource managers can best meet their management goals, particularly when prioritizing Common Carp removal efforts, by better understanding how Common Carp presence and abundance affect game fish populations. In this study, we evaluated the effects of Common Carp on lakes and associated emergent wetlands (hereafter, collectively referred to as 'wetlands') in the relatively pristine wetland systems of the Nebraska Sandhills. Specifically, we quantified the effects of Common Carp abundance on game fish population abundance and relative weight. Additionally, we tested the hypothesis of 3 thresholds of Common Carp abundance (i.e., no Common Carp detected, relatively low Common Carp abundance [ $< 100$  CPUE], and relatively high Common Carp abundance [ $\geq 100$  CPUE]). Measurements such as CPUE may serve as indicators for the influence of Common Carp on game fish abundance.

## Materials and Methods

### Study area

The study area for this work was located in the Sandhills ecoregion of Nebraska (Figure 1). The Sandhills ecoregion is defined by its characteristic sand dunes and is the largest stabilized sand dune system in North America (Novacek 1989). Additionally, the Sandhills is one of the largest remaining contiguous grasslands in the world (LaGrange 2023, Scholtz and Twidwell 2022). The vegetation is predominantly mixed-grass prairie interspersed with wet meadows and emergent herbaceous wetlands (LaGrange 2023). An

estimated 369,606 ha of wetland span the region, providing more wetland habitat than any other region in Nebraska (LaGrange et al. 2005). The predominant land use in the region is cattle grazing, and the area is sparsely populated, with an estimated population density of < 2 people/km<sup>2</sup> (U.S. Census Bureau 2020). Lakes in the Sandhills support healthy populations of game fish including *Perca flavescens* Mitchell (Yellow Perch), *Micropterus salmoides* Lacepede (Largemouth Bass), *Esox lucius* L. (Northern Pike), *Pomoxis nigromaculatus* Lesueur (Black Crappie), and *Lepomis macrochirus* Rafinesque (Bluegill).

**Survey methods**

We estimated Common Carp abundance using standard electrofishing methods as described in Bajer and Sorensen (2012) during 2018–2022. We used an ETS MBS generator operated electrofishing system mounted on 5.5 m long boats. We used 60 Hz DC and 25% duty cycle for electrofishing settings. At each of 16 wetlands, we selected 3–6 sampling points based on the size of the wetland. We performed ten-minute samples at each of these points between May and June. We standardized our Common Carp samples as CPUE, or the number of Common Carp caught by the amount of time spent collecting samples (10 minutes). For the years we were unable to sample wetlands due to flooding, we used electrofishing data from the previous year. We assumed the relative abundance of Common Carp among years did not change substantially and lakes with high relative abundance in a given year were assumed to have high relative abundance in the following year.

We surveyed the same 16 wetlands for 5 game fish species between March and early May each year, to compare against Common Carp abundances and condition. Methods designed to standardize catch of each species were used and followed Nebraska Game and Parks sampling protocols for assessing population status of each species. We placed modified fyke nets to collect Black Crappie, Bluegill, Northern Pike, and Yellow Perch. Sampling methods were consistent with those described in Merna et al. (1981). We calculated CPUE for

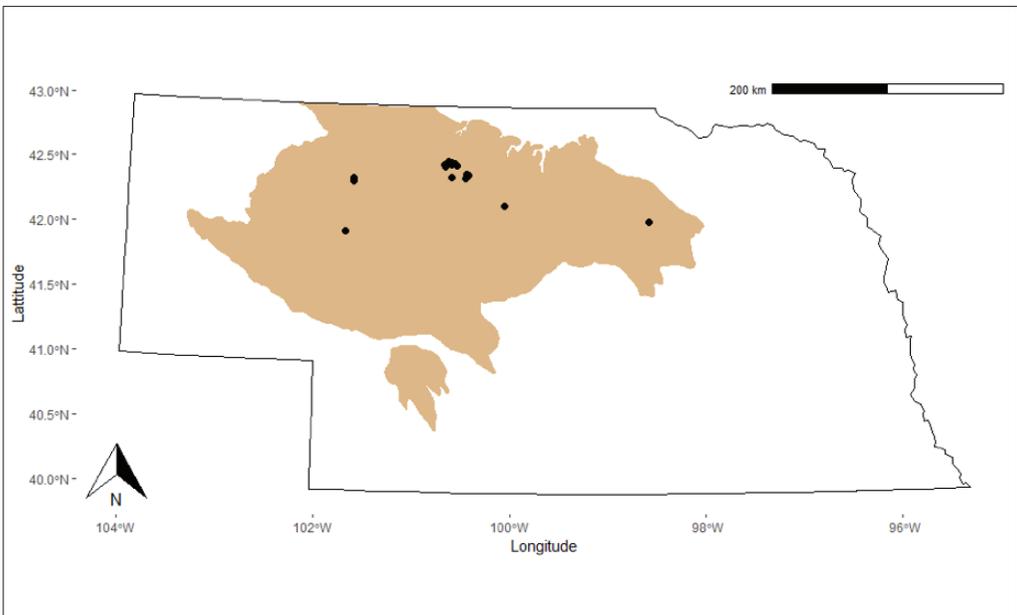


Figure 1. A map of Nebraska depicting the location of wetlands surveyed to assess the impact of Common Carp abundance on gamefish, 2018–2021. Shaded area depicts the Sandhills Ecoregion.

those species as number of fish captured per net lift. We sampled Largemouth Bass in May using nocturnal electrofishing. We measured CPUE for Largemouth Bass as the number of fish captured per hour. This study was performed under the auspices of the University of Nebraska IACUC protocol #2070.

### **Data Analysis**

We performed all analyses in Program R (R Core Team, 2024). We used linear mixed effect models to evaluate the influence of Common Carp abundance on game fish abundance. We used a Tweedie distribution given our data contained 0s but was otherwise positive and continuous. Game fish abundance (CPUE) was the dependent variable and Common Carp abundance (CPUE) was the independent variable for the 5 game fish species and overall game fish abundance. We included individual wetlands as a random effect and year as a fixed effect to account for repeated measures. We used linear mixed effect models to assess the relation between Common Carp abundance and the relative weight, a measure of fish condition, for the 5 game fish species using the standard weight parameters and equations defined in Neumann et al. (2012). We used a normal distribution and included individual wetlands as a random effect and year as a fixed effect to account for repeated measures. Additionally, we categorized Common Carp abundance of wetlands into 3 commonly encountered management groupings: wetlands in which Common Carp were undetected, those with relatively low Common Carp abundance ( $< 100$  CPUE), and those with relatively high Common Carp abundance ( $\geq 100$  CPUE). These categories portrayed different densities which were used to perform an Analysis of Variance (ANOVA) whereby total game fish abundance was the dependent variable and the categorical factor for Common Carp abundance was the explanatory variable to test thresholds which were hypothesized as meaningful regarding the impacts of Common Carp in this region. An alpha level of 0.05 was used for all analyses.

### **Results**

We performed 55 trap net surveys for Black Crappie, Bluegill, Northern Pike, and Yellow Perch, as well as 43 electrofishing surveys for Largemouth Bass. The relation between relative abundance of Common Carp and game fish varied among species but generally was negative (Figure 2). We observed a negative relation between Common Carp and Bluegill ( $P = 0.021$ ), Largemouth Bass ( $P < 0.010$ ), and Yellow Perch ( $P = 0.048$ ; Figure 2) abundance. We observed no relation between Common Carp abundance and Northern Pike ( $P = 0.368$ ) or Black Crappie ( $P = 0.485$ ). Overall, game fish abundance was negatively related with Common Carp abundance ( $P < 0.001$ ).

No linear relation existed between relative weight and Common Carp abundance for Black Crappie ( $P = 0.078$ ), Bluegill ( $P = 0.365$ ), or Largemouth Bass ( $P = 0.547$ ). A positive linear relation existed between Northern Pike relative weight and Common Carp abundance ( $P < 0.001$ ). A negative linear relation existed between Yellow Perch relative weight and Common Carp abundance ( $P = 0.020$ ; Figure 3).

There was a difference in game fish abundance between wetlands where no Common Carp were detected, wetlands with low Common Carp abundance ( $< 100$  CPUE), and wetlands with high Common Carp abundance ( $\geq 100$  CPUE; ANOVA,  $F_{2, 57} = 30.48$ ,  $P < 0.001$ ). Mean CPUE of game fish was 55.3% lower on wetlands with low Common Carp abundance than on wetlands where no Common Carp were detected. Mean CPUE of game fish on wetlands with  $\geq 100$  CPUE for Common Carp was 80.4% lower than wetlands with no Common Carp, and 58.3% lower than wetlands with 0–100 CPUE for Common Carp.

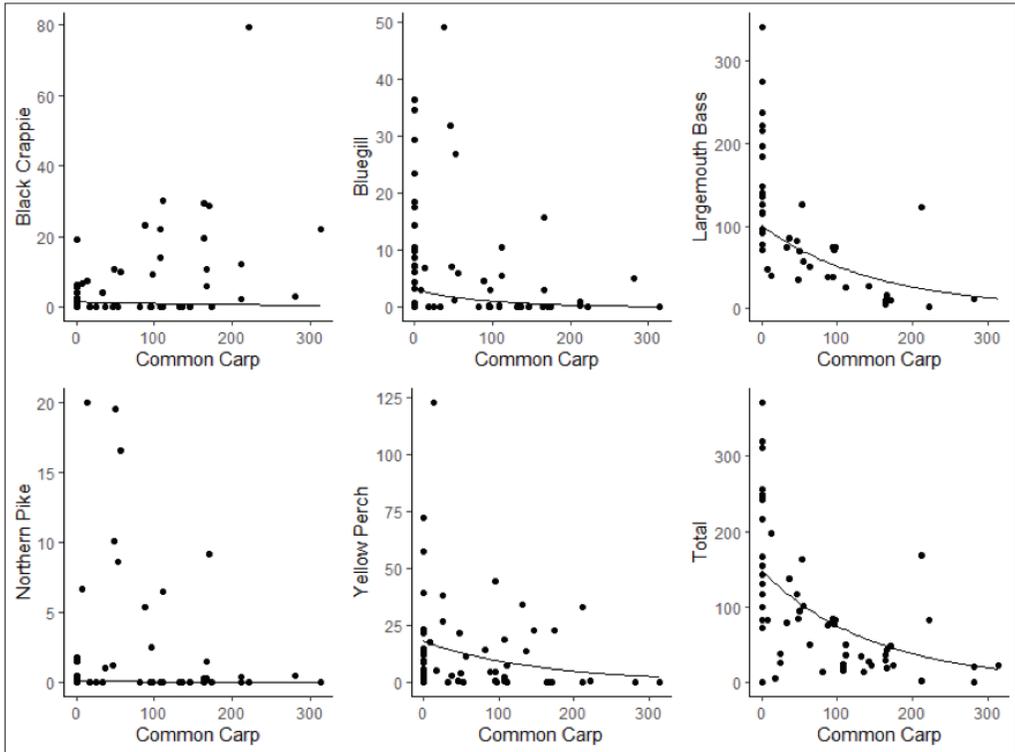


Figure 2. Catch per unit effort (CPUE) for 5 game fish species and all game fish as a function of Common Carp abundance for surveyed wetlands in the Nebraska Sandhills, 2018–2021. Dashed lines depict the estimated relationship based on linear regression.

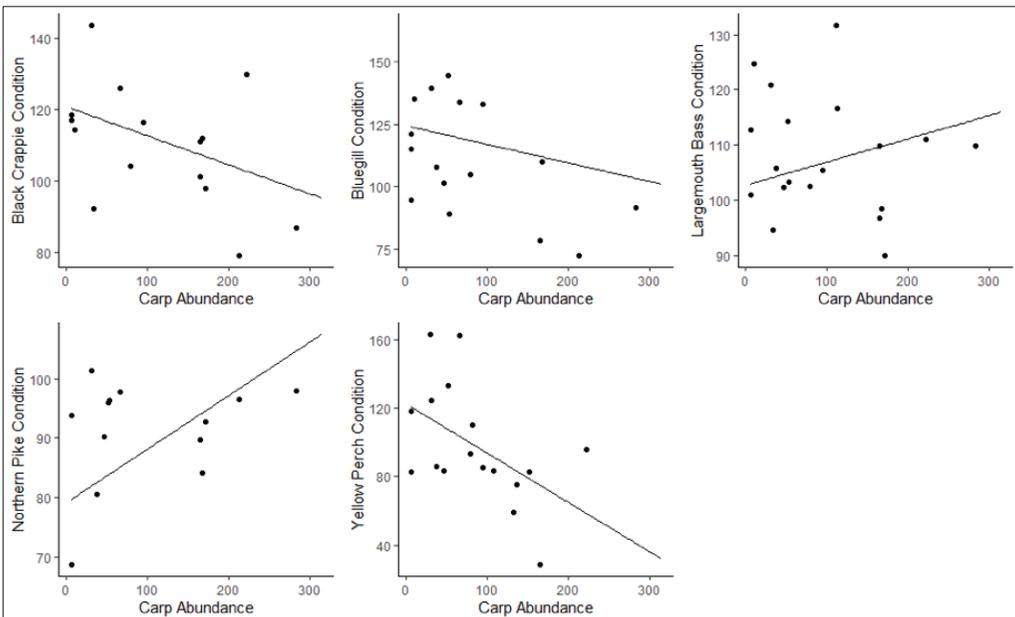


Figure 3. Condition, measured using relative weight, for 5 game fish species and all game fish as a function of Common Carp abundance for surveyed wetlands in Nebraska Sandhills, 2018–2021.

## Discussion

Common Carp appear to influence community structure and population characteristics of game fish within the wetlands of the Nebraska Sandhills. Increased Common Carp abundance was associated with a decrease in overall game fish abundance, consistent with findings from previous studies in more disturbed systems (Jackson et al. 2010, Weber and Brown 2011, Weber and Brown 2018). As such, the relatively pristine nature of Sandhills wetlands may not offer protection from the deleterious influences of Common Carp. Further, increased Common Carp abundance was associated with decreased condition of Yellow Perch and an increased condition of Northern Pike. Weber and Brown (2018) suggested competition by adult Common Carp may negatively influence Yellow Perch abundances. Weber and Brown (2011) suggested predation by native fishes on Common Carp may benefit some native predators such as Northern Pike. As such, the presence of Common Carp may influence community structure and population characteristics in contrasting and complex ways. Previous studies in the region have suggested that the success of game fish may be tied to emergent vegetation, either as foraging habitat or visual obstruction from predators (Paukert et al. 2002). Other studies have suggested that Common Carp exert bottom-up pressure on fish species through removal of aquatic vegetation and predation on macroinvertebrates (Wahl et al. 2011, Weber and Brown 2011). The biological influence of Common Carp on wetlands may be a source of the observed variation in game fish abundance and condition aligning with the abiotic-biotic constraining hypothesis (Quist et al. 2003, Weber and Brown 2011).

Common Carp are expected to impart bottom-up influences on fish assemblages (Wahl et al. 2011). Nevertheless, we observed no relation with Black Crappie or Northern Pike abundance associated with increased Common Carp abundance. Our results are contrary to previous studies which suggest that Common Carp and the associated increased turbidity of a system have negative influences on Black Crappie survival and abundance (Ellison 1984, Pope 1996, Weber and Brown 2011). Similarly, Northern Pike abundance has been negatively related to increased Common Carp abundance (Weber and Brown 2011). Common Carp across study wetlands may not have reached the densities needed to negatively influence Black Crappie or Northern Pike. Alternatively, linear relations as sought in the current study may not exist and more abrupt changes (i.e., thresholds) may occur as Common Carp densities increase. No matter the mechanism, the negative bottom-up effects of Common Carp may not always appear as reduced abundances of some sport fish.

Our results support previous findings that thresholds exist related to the influence of Common Carp abundance on native fish population characteristics (Jackson et al. 2010, Weber and Brown 2011, Bouska 2020). Fisheries biologists in the Sandhills have speculated that there is a threshold around 100 CPUE for Common Carp which substantially impacts game fish populations, and that a second threshold at 200 CPUE for Common Carp devastates game fish populations. During this study, we only had 6 observations above 200 CPUE for Common Carp so we were unable to adequately test that threshold. This study does provide support for the existence of a biological threshold around 100 CPUE for Common Carp given a reduced abundance of game fish above this level. Further, we observed a decline in game fish populations between Common Carp free wetlands and wetlands that contain any detectable Common Carp populations. Therefore, while support exists to prioritize restoration on waterbodies with > 100 CPUE for Common Carp due to logistical and monetary restraints, complete removal and exclusion of Common Carp may be desirable for game fisheries management. Our study provides support for the hypothesis that the negative

impacts of Common Carp on wetland function may produce a trophic response, in this case altering the fish community (Bouska 2020). Thus, Common Carp eradication and exclusion may be considered a critical tool for restoring and maintaining wetland function.

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