

SILVER CARP (*Hypophthalmichthys molitrix*) AND BIGHEAD CARP (*H. nobilis*) IN THE MISSISSIPPI RIVER BASIN: OCCURRENCE DATA AND DISPERSAL PATTERNS

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Abstract

Silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*) are Asian fishes that have become established in the Mississippi River Basin of North America. Because of the potential threat these invaders pose to native aquatic ecosystems, there is interest in determining their dispersal dynamics. We recently used a simple diffusion model as a heuristic tool to gain insight into the dispersion of another aquatic invader, the Rio Grande cichlid (*Herichthys cyanoguttatus*), in southeastern Louisiana. This approach correctly predicted the unexpected occurrence of this freshwater species in estuarine habitats. We attempted to use this approach to better understand the expansion of Asian carp. Occurrence data from fish museums and natural resource managers covering over thirty years of sampling in the Mississippi River Basin and nearby river systems were combined into a geographic information system (GIS) database and used to create yearly distribution maps for each species. Preliminary results suggest that the known occurrence patterns for both species are the result of multiple introductions from different points. It is unlikely that expanding carp populations in the Mississippi River Basin began from a single origin. Also, as we saw with *H. cyanoguttatus* dispersion, Asian carp expansion exhibits periods of apparent stasis during which significant range extensions do not occur. Data suggest that these periods do not reflect an actual slowing of expansion but are artifacts of the limited scope of sampling efforts. While it may be incorrectly assumed that during these periods expansion is limited or has been curtailed, the invaders are likely extending their range "under the radar" of standardized sampling.

Introduction

- Bighead Carp (*Hypophthalmichthys nobilis*) were imported into the United States in 1973 to improve water quality in catfish ponds in Arkansas (Henderson 1976) and were first documented in the Mississippi River Basin (MRB) in 1981 in the lower Ohio River (Freeze and Henderson 1982).
- Silver Carp (*H. molitrix*) were imported into the United States in 1973 by a private fish farmer and this species was documented in the Arkansas River drainage in 1975 (Ramsey unpubl. report 1975).
- Chick and Pegg (2001) reported exponential growth of the Bighead Carp in navigation pool 26 and increased harvest by commercial fishers in the Mississippi River (5000+ kg in 1994 to 50,000+ kg since 1997).
- The potential magnitude of dispersion of these species in the MRB is largely unknown. Past introductions suggest that degraded systems, such as the Illinois River, are often more susceptible to exotic species invasion and successful establishment (Taylor et al. 1984; Gido and Brown 1999).
- Because of these uncertainties, the U.S. Fish and Wildlife Service (USFWS) identified several specific areas of research that need to be addressed for successful control and management of Asian Carp (Greg Conover, pers. comm.) including: 1) creating a Geographic Information System (GIS) database to document the current distribution of Asian Carp and 2) predicting the potential expansion of Asian Carp if no actions are taken to limit dispersal.
- Hence, the objectives of our study were to provide analyses to fill two information gaps identified by the USFWS.

Materials and Methods

We developed a simple dispersal model of Asian Carp movement based on geo-referenced occurrence data compiled from states, universities, and museums and telemetry data (e.g., maximum annual movement, proportion of population that will move upstream, downstream, or remain) and population growth data from previous research (provided by Mark Pegg, INHS). Maximum annual movement was calculated as the average daily movement of the 42 radio-tagged fishes (0.74 km) multiplied by 365 days: ca. 270 km/year. We interpreted this as the distance an Asian Carp could travel if it moved the average daily distance in one direction every day of the year. Based on this, we divided the entire Mississippi River Basin into 270 km segments (n = 213 segments) to model Asian Carp movement on a yearly basis (Fig. 1). Finally, for Asian Carp populations in each segment of the model we used a $\lambda = 1.1$ to represent the rate of change relative to population size in the previous year. Basically, for every 100 Asian Carp remaining within a segment, 110 Asian Carp will be present in the following year and, the number of Asian Carp in any given segment (i.e., density) was calculated as follows:

$$\text{density}(t) = \lambda [\text{density}(t-1)] - 0.24 [\text{density}(t-1)] - 0.28 [\text{density}(t-1)] + 0.24 [\text{density us}(t-1)] + 0.28 [\text{density ds}(t-1)], \text{ where}$$

density(t) = number of Asian Carp in a given segment at time t
 λ = rate of annual population growth
 density(t-1) = number of Asian Carp in previous year
 density us(t-1) = number of Asian Carp in segment(s) immediately upstream of segment at time t-1
 density ds(t-1) = number of Asian Carp in segment(s) immediately downstream of segment at time t-1
 0.28 = the proportion of Asian Carp emigrating upstream from the segment in a year
 0.24 = the proportion of Asian Carp emigrating downstream from the segment in a year.

To calculate changes in Asian Carp numbers for all 213 river segments over thirty years (or more for calculations of future densities), a matrix for each scenario was created whereby the above equation was calculated for each segment over time. Lambda can be modified as new information becomes available.



Figure 1. The Mississippi River Basin divided in 213 segments of 270 km each representing the maximum annual movement of an Asian Carp as calculated from average daily movements. These segments (delineated by black arrows) were used by the dispersal model to show changes in Carp density as simulated populations expand.

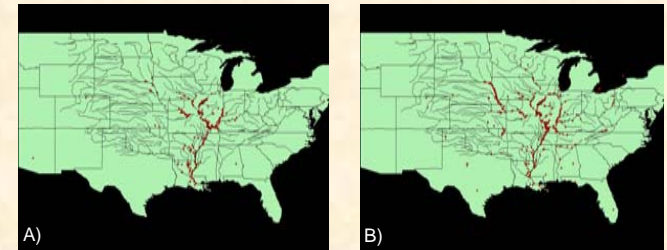


Figure 2. Occurrence data for Silver Carp (A) and Bighead Carp (B) in the Mississippi River Basin and other parts of the United States.

Results and Conclusions

Based on our year-to-year occurrence maps, there appears to be little evidence that there are existing barriers and their continuing seems unimpeded throughout the entire Basin (Fig. 2).

Regardless of the locality of introduction, numbers of introductions, etc., most of the model scenarios suggest that river reaches that have Asian Carp densities of "zero" are rare. Although Asian Carp may have yet to be collected from some of these reaches, in all likelihood they are present in low densities and have just not been detected yet.

When we run scenarios out to 50 years, we can roughly predict where Asian Carp "hot spots" of relatively high densities will occur. This information can be used to identify areas for barrier dispersal to prevent or limit migration into tributaries and other water-bodies used for spawning.

In summary, our occurrence data and the preliminary results from our model suggest that, it is very likely that Asian Carp are already throughout the entire Mississippi River Basin and other connected systems, which underscores the importance of preventing the distribution of live fish through additional basins where intentional or unintentional introductions could have devastating effects.

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