Silver Carp (*Hypophthalmichthys molitrix*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, February 2019
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1 Native Range and Status in the United States

Native Range

From Nico et al. (2019):

"Several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia south through much of eastern half of China to Pearl River, possibly including northern Vietnam (Berg 1949; Li and Fang 1990)."

Status in the United States

According to Nico et al. (2019), *Hypopthalmichthys molitrix* has been reported from the following states (year of last reported observation is indicated in parentheses): Alabama (2017), Arizona (1972), Arkansas (2016), Colorado (1996), Hawaii (1992), Illinois (2018), Indiana (2017), Iowa (2018), Kansas (2015), Kentucky (2017), Louisiana (2017), Minnesota (2017), Mississippi (2018), Missouri (2018), Nebraska (2014), Nevada (2006), North Dakota (2018), Ohio (2016), Puerto Rico (1972), South Dakota (2015), Tennessee (2017), and Wisconsin (2017). Detailed nonindigenous occurrence information is available in the USGS Nonindigenous Aquatic Species database (https://nas.er.usgs.gov).

From Nico et al. (2019):

"It is apparently established in Louisiana (Douglas et al. 1996) and is possibly established in Illinois […] Douglas et al. (1996) collected more than 1600 larvae of this genus from a backwater outlet of the Black River in Louisiana in 1994. Burr et al. (1996) found young-of-the-year in a ditch near Horseshoe Lake and reported this as the first evidence of successful spawning of silver carp in Illinois waters and the United States. They felt that the species would be 'established' in the state within the next ten years. Based on the occurrence of juvenile fish in Illinois waters, Pflieger (1997) felt that successful spawning of silver carp in Missouri seems inevitable. In the early 1980s commercial fishermen in Arkansas had caught 166 silver carp from seven different sites; however, during an intensive 1980-1981 survey to determine the distribution and status of bighead and silver carp in state open waters, Arkansas Game and Fish Commission personnel were unsuccessful in procuring any additional specimens (Freeze and Henderson 1982). Although Arkansas state personnel did not find young-of-the-year fish, several specimens taken by the commercial fishermen were sexually mature and exhibited secondary sexual characteristics (Freeze and Henderson 1982). Nevertheless, Robison and Buchanan (1988) reported that there was still no evidence of natural reproduction in Arkansas waters. Rinne (1995) listed silver carp as introduced to Arizona in 1972 and denoted it as established. Apparently in reference to the same record, William Silvey of the Arizona Game and Fish Department recently informed us that the only silver carp documented in Arizona open waters was a population inhabiting an urban lake in Chandler during the early 1970s. However, further investigation has shown that it was most likely a bighead x grass carp hybrid population (P. Marsh, pers. comm.). That population, along with a large population of diploid grass carp, was exterminated in 1975 or 1976 by personnel from the Arizona Game and Fish Department and Arizona State University (W. Silvey, personal communication). Pearson and Krumholz (1984) documented records from the Ohio River, but they did not include it as one of the species that exist in well-established, reproducing populations. Etnier and Starnes (1993) provided information on silver carp, but by publication they were unaware of any records of the species in the state of Tennessee."

"Although silver carp has not been physically detected in the Great Lakes, environmental DNA (eDNA) has been found in water samples collected in several areas in 2012: above electric barriers from Lake Calumet, the Little Calumet River, the North Shore Channel, and the Chicago River (USACE 2012), as well as Maumee Bay, Lake Erie (Jerde et al. 2013)."

Nico et al. (2019) also report an occurrence in "Calumet Sag Channel of the Chicago Area Waterway, near Dolton, above the electric barrier" in 2017, reporting "Two weeks of intense sampling immediately following found no more specimens."

From USFWS (2007):

"The U.S. Fish and Wildlife Service (Service or we) adds all forms of live silver carp (*Hypophthalmichthys molitrix*), gametes, viable eggs, and hybrids; and all forms of live largescale silver carp (*Hypophthalmichthys harmandi*), gametes, viable eggs, and hybrids to the list of injurious fish, mollusks, and crustaceans under the Lacey Act. The best available information indicates that this action is necessary to protect the interests of human beings, and wildlife and wildlife resources, from the purposeful or accidental introduction, and subsequent establishment, of silver carp and largescale silver carp populations in ecosystems of the United States. Live silver carp and largescale silver carp, gametes, viable eggs, and hybrids can be imported only by permit for scientific, medical, educational, or zoological purposes, or without a permit by Federal agencies solely for their own use; permits will also be required for the interstate transportation of live silver or largescale silver carp, gametes, viable eggs, or hybrids currently within the United States. Interstate transportation permits may be issued for scientific, medical, educational, or zoological purposes. […] This rule is effective August 9, 2007."

Means of Introductions in the United States

From Nico et al. (2019):

"This species was imported and stocked for phytoplankton control in eutrophic water bodies and also apparently as a food fish. It was first brought into the United States in 1973 when a private fish farmer imported silver carp into Arkansas (Freeze and Henderson 1982). By the mid 1970s the silver carp was being raised at six state, federal, and private facilities, and by the late 1970s it had been stocked in several municipal sewage lagoons (Robison and Buchanan 1988). By 1980 the species was discovered in natural waters, probably a result of escapes from fish hatcheries and other types of aquaculture facilities (Freeze and Henderson 1982). The occurrence of silver carp in the Ouachita River of the Red River system in Louisiana was likely the result of an escape from an aquaculture facility upstream in Arkansas (Freeze and Henderson 1982). The Florida introduction was probably a result of stock contamination, a silver carp having been inadvertently released with a stock of grass carp being used for aquatic plant control (Middlemas 1994). In a similar case, the species was apparently introduced accidentally to an Arizona lake as part of an intentional, albeit illegal, stock of diploid grass carp (W. Silvey, personal communication). Pearson and Krumholz (1984) suggested that individuals taken from the Ohio River may have come from plantings in local ponds or entered the Ohio River from populations originally introduced in Arkansas."

Remarks

From Lamer et al. (2010):

"Hybridization between bighead carp and silver carp appears to be a relatively uncommon phenomenon within their native ranges, even where the species' ranges overlap (Kolar et al. 2007). Yet, the capacity for interbreeding between these species is well established in aquaculture and experimental settings with prevailing fertility and the absence of well-reinforced reproductive barriers (Green and Smitherman 1984; Marian et al. 1986; Slechtova et al. 1991; Almeida-Toledo et al. 1995). For example, Voropaev (1978) and Green and Smitherman (1984) reported that first generation (F_1) reciprocal hybrids between these two species could be cultured as a high-quality food fish and for water quality improvement in aquaculture production ponds. Moreover, these artificial and captive F_1 hybrids displayed improved performance in terms of growth rate, disease resistance, and survival rate over that of intercrossing parental species (Voropaev 1978; Green and Smitherman 1984). Importantly, any observed hybrid superiority in terms of growth and fitness in the F_1 generation disappeared in later generations and, in fact, the performance of hybrids fell below that observed for either parental species (Voropaev 1978)."

"Where bighead carp and silver carp have been introduced or escaped from captivity, interspecific hybrids have been suspected and putatively identified based on a suite of morphological traits, the identifications later being confirmed with diagnostic molecular probes (Marian et al. 1986; Slechtova et al. 1991; Almeida-Toledo et al. 1995; Mia et al. 2005). Although interspecific hybrids are routinely, albeit incorrectly, presumed to be sterile, Asian carp hybrids are fertile and capable of second- or later-generation hybridization and backcrossing, which has led to extensive interbreeding and introgression (Brummett et al. 1988; Slechtova et al. 1991; Mia et al. 2005) and the potential formation of a hybrid swarm. In North American waters, the rapid expansion of bighead carp and silver carp may cause or accelerate introgression as densities continue to increase."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2018):

"Kingdom Animalia
 Subkingdom Bilateria
  Infrakingdom Deuterostomia
   Phylum Chordata
    Subphylum Vertebrata
     Infraphylum Gnathostomata
      Superclass Actinopterygii
       Class Teleostei
        Superorder Ostariophysi
         Order Cypriniformes
          Superfamily Cyprinoidea
           Family Cyprinidae
            Genus *Hypophthalmichthys*
             Species *Hypophthalmichthys molitrix* (Valenciennes in Cuvier and Valenciennes, 1844)"

From Fricke et al. (2018):

"Current status: Valid as *Hypophthalmichthys molitrix* (Valenciennes 1844). Xenocyprididae."

Size, Weight, and Age Range

From Froese and Pauly (2018):

"Maturity: L_m 51.7 range ? - ? cm
Max length : 105 cm TL male/unsexed; [IGFA 2001]; common length : 18.0 cm SL male/unsexed; [Nichols 1943]; max. published weight: 50.0 kg [Billard 1997]"

From Nico et al. (2019):

"In their native range, silver carp reach maturity at between 4 and 8 years old but are noted in North America to mature as early as just 2 years old. They can live to 20 years."

From Kolar et al. (2007):

"Like Bighead Carp, Silver Carp can grow quickly. […] Silver Carp can also grow quickly in reservoirs and natural waters: 20+ kg in 5 years (Leventer 1987) in a wastewater reservoir. […] In 2003, Silver Carp from the middle Mississippi River attained mean total lengths (back calculated from fin rays) of 318 mm by the end of the first year, and 650 mm by age 3 (Williamson and Garvey [2005])."

"Longevity data for Silver Carp are scarce largely because Silver Carp are difficult to age."

Environment

From Froese and Pauly (2018):

"Freshwater; brackish; benthopelagic; potamodromous [Riede 2004]; depth range 0 - 20 m [Shao and Lim 1991]."

"In aquaculture, it can survive brackish water (up to 7 ppt) when released into estuaries and coastal lakes [Kottelat and Freyhof 2007]."

From Kolar et al. (2007):

"The ultimate upper lethal temperature of larval Silver Carp (aged 3 to 28 days) was 43.5-46.5°C (Opuszynski et al. 1989). Silver Carp are quite tolerant to low water temperatures. In Alberta, Canada, Silver Carp successfully overwinter in ponds that are near 0ºC from around the beginning of November through the end of April (B. MacKay, Alberta Department of Agriculture, Food and Rural Development, Lethbridge, Alberta, personal communication, 2004)."

Climate/Range

From Froese and Pauly (2018):

"Subtropical; […] 64°N - 43°S"

From Kolar et al. (2007):

"Kamilov and Komrakova (1999) reported the Silver Carp to be endemic to the large rivers of southern Asia, eastern China, and far eastern Russia that flow into the Pacific Ocean […]. Others stated that the Silver Carp is native to large lakes and rivers of China, northern Vietnam, and Siberia ranging from 21º N to 54º N latitude (Laird and Page 1996; Xie and Chen 2001; Froese and Pauly 2004)."

Distribution Outside the United States

Native

From Nico et al. (2019):

"Several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia south through much of eastern half of China to Pearl River, possibly including northern Vietnam (Berg 1949; Li and Fang 1990)."

Introduced

From Kolar et al. (2007):

"The Silver Carp has been widely introduced throughout the world. The species has been imported into or has spread by way of connected waterways to at least 88 countries and territories […]. Of these introductions, there are reproducing populations of Silver Carp in 24 countries (or 27% of all countries where introduced) [Afghanistan, Cyprus, Czech Republic, Hungary, India, Iraq, Israel, Italy, Japan, Kazakstan, Kyrgyzstan, Latvia, Pakistan, Poland, Romania, Russia, Slovakia, Tajikistan, Turkmenistan, Ukraine, United States, Uzbekistan, Vietnam, Yugoslavia]. The database of introductions of aquatic species maintained by the FAO (2004) lists another 23 countries not thought to have reproducing populations that stock Silver Carp annually. There are an additional 33 countries in which Silver Carp are either believed to be "probably established" (n=11 [Armenia, Cuba, Dominican Republic, France, Germany, Greece, Laos, Morocco, Puerto Rico, South Africa, Turkey]) or are "probably not" established (n=22 [21? Albania, Algeria, Bangladesh, Brazil, Costa Rica, Denmark, Ethiopia, Fiji, Honduras, Korean Republic, Lebanon, Mexico, Moldova, Netherlands, Panama, Peru, Rwanda, Saudi Arabia, Sweden, Tunisia, United Kingdom]). There are an additional 23 [24?] countries in which the Silver Carp fails to have reproducing populations [Austria, Belgium, Bhutan, Bulgaria, Egypt, Estonia, Indonesia, Iran, Lesotho, Luxembourg, Madagascar, Malawi, Malaysia, Mozambique, Nepal, New Zealand, Nigeria, Philippines, Singapore, Sri Lanka, Switzerland, Taiwan, Tanzania, Thailand]. It remains unknown whether Silver Carp have become established in eight countries in which they have been introduced [Colombia, Guam, Jamaica, Jordan, Mauritius, Papua New Guinea, Zambia, Zimbabwe]."

"Reports of this species from northern Vietnam are probably based on introduced populations."

Ellender and Weyl (2014) confirm that *H. molitrix* is established in South Africa. Froese and Pauly (2018) confirm that *H. molitrix* is established in Cambodia and not in France, Germany, or

Laos. Povž and Šumer (2005) confirm that *H. molitrix* is not established in Slovenia. Pofuk et al. (2017) confirm that *H. molitrix* is not established in Croatia.

Means of Introduction Outside the United States

From Froese and Pauly (2018):

"Introduced around the world for aquaculture and control of algal blooms."

"Escape from fish farms are widely known even as they are stocked in large rivers and almost all still water bodies like lakes and ponds."

Short Description

From Froese and Pauly (2018):

"Dorsal spines (total): 1 - 3; Dorsal soft rays (total): 6-7; Anal spines: 1-3; Anal soft rays: 10 - 14. Body olivaceous to silvery. Barbels absent. Keels extend from isthmus to anus. Edge of last simple dorsal ray not serrated. Branched anal rays 12-13.5 [Kottelat et al. 1993]. Differs from *Hypophthalmichthys nobilis* by having sharp scaleless keel from pectoral region to anal origin, 650-820 long, slender gill rakers, head length 24-29% SL [standard length], and plain pale coloration, greenish grey above, whitish below [Kottelat and Freyhof 2007]."

From Kolar et al. (2007):

"The Silver Carp is deep-bodied, spindle-shaped, laterally compressed with a well-developed keeled abdomen that extends from the throat to the vent […]. The keel is scaled anteriorly, but is scaleless posteriorly. Adult coloration is typically gray-black dorsally, upper sides olivaceous grading to silver laterally and ventrally. Lower jaw has a small tubercle, and the upper jaw is slightly notched. The scales are small, cycloid, lateral line scale counts typically range from 85 to 108, 29-30 scales above the lateral line, and scales below the lateral line 16-17. Fins are dark and without true spines; however, in larger individuals the anterior ray of the pectoral fins is thickened, stiff and is finely serrated posteriorly. The dorsal fin typically has three unbranched and seven branched rays; anal fin with two or three unbranched and 11-15 branched fin rays."

Biology

From Froese and Pauly (2018):

"Found in their natural range in rivers with marked water-level fluctuations and overwinters in middle and lower stretches, swimming just beneath the surface. They feed in shallow (0.5-1.0 m deep) and warm (over 21°C) backwaters, lakes and flooded areas with slow current on phytoplankton and zooplankton [Etnier and Starnes 1993; Billard 1997]. Bigger individuals from about 1.5 cm SL feed only on phytoplankton while larvae and small juveniles prey on zooplankton [Kottelat and Freyhof 2007]. Adults breed in rivers or tributaries over shallow rapids with gravel or sand bottom, in upper water layer or even at surface during floods when the water level increases by 50-120 cm above normal level. Conditions for spawning include high current (0.5-1.7 m/s), turbid water, temperatures above 15°C (usually 18-26°C) and high oxygen concentrations [Kottelat and Freyhof 2007]. Spawning ceases if conditions change (especially sensitive to water-level fall) and resumes again when water level increases. Juveniles and adults form large schools during spawning season. Mature individuals undertake long distance upriver migration at start of a rapid flood and water-level increase, able to leap over obstacles up to 1 m. After spawning, adults migrate to foraging habitats[.] In autumn, adults move to deeper places in main course of river where they remain without feeding. Larvae drift downstream and settle in floodplain lakes, shallow shores and backwaters with little or no current [Kottelat and Freyhof 2007]."

Human Uses

From Froese and Pauly (2018):

"Fisheries: commercial; aquaculture: commercial"

"Utilized fresh for human consumption and also introduced to many countries where its ability to clean reservoirs and other waters of clogging algae is appreciated even more than its food value [Frimodt 1995]. One of among 3 or 4 species of cyprinids whose world production in aquaculture exceeds 1 million tons per year [Billard 1997]."

From Kolar et al. (2007):

"Li and Xu (1995) described capture fisheries for Bighead and Silver carps in Chinese reservoirs."

"Commercial fisheries for Bighead and Silver carps exist on the Mississippi, Missouri, and Illinois rivers, and probably in other locations where *Hypophthalmichthys* occur in large numbers and commercial fishing is legal. Fishes are sold live or dead. Live fish have a higher value but have more difficult handling requirements."

"More Silver Carp are produced than any other species of freshwater fish in the world […]. Worldwide production of Silver Carp has increased substantially from 1988 to 1997 (from 1.6 to 3.1 million metric tons; FAO 1999). […] Although processed food products such as vacuum packed sliced fillets, canned fish with oil, tomato sauce, mayonnaise, cream, mustard, or other sauces, are made from Silver Carp (e.g., Trading House Supoy, Ltd. 2004), the highest market demand for Silver Carp is for live fish."

"The ability of Silver Carp to effectively filter particles as small as 7 µm and reliance on phytoplankton for much of its diet (Cremer and Smitherman 1980; Kaushal et al. 1980; Spataru et al. 1983) has lead [*sic*] to the use of Silver Carp as a biological control agent for phytoplankton (Sirenko et al. 1976; Costa-Pierce et al. 1985; Smith 1985)."

"Silver Carp have been used in Arkansas for removal of excessive algae from wastewater (Henderson 1977). Some authors (Starling and Rocha 1990) suggested that Silver Carp may be used to selectively control blue-green algae (Cyanobacteria). […] the use of Silver Carp to control blue-green algae is not fully understood and has met with varied success."

"In the 1970s, much attention was focused on Silver Carp as a potential tool for controlling eutrophication (Vörös et al. 1997). […] Experiment results, however, are contradictory."

"Silver Carp are sometimes raised in polyculture in other countries around the world with other carp species not only as a food fish but also to stimulate growth of other fishes in ponds."

"Heggelund and Pigott (1977, in Maddox et al. 1978) suggested that Silver Carp could be used as a supplemental protein source in livestock rations and as a milk replacement in the diet of weanling calves. Sumantadinata et al. (1990) found that ultraviolet-irradiated sperm of Silver Carp can be used to inseminate eggs of Common Carp to obtain gynogenesis."

Diseases

From Kolar et al. (2007):

"The only viral disease agent of Silver Carp that we found in the literature is *Rhabdovirus carpio*, the causative agent for spring viraemia of carp, a systemic, acute, and highly contagious infection commonly occurring in the spring when water temperatures are below 18ºC."

"Silver Carp are susceptible to several bacterial diseases […] He et al. (1992) reported isolating more than 10 strains of pathogenic bacteria from Silver Carp in Shashi District, China."

"Silver Carp are susceptible to many diseases caused by parasitic protozoans […]"

"Many trematodes have also been reported from Silver Carp."

"Several crustaceans also parasitize Silver Carp."

Infection with spring viremia of carp virus is an OIE-reportable disease.

From Froese and Pauly (2018):

"*Bothriocephalus* Infestation 2, Parasitic infestations (protozoa, worms, etc.)
Myxobolus Infection 4, Parasitic infestations (protozoa, worms, etc.)
Myxobolus Infection 2, Parasitic infestations (protozoa, worms, etc.)
Anchorworm Disease (*Lernaea* sp.), Parasitic infestations (protozoa, worms, etc.)
Dactylogyrus Gill Flukes Disease, Parasitic infestations (protozoa, worms, etc.)
Trichodinosis, Parasitic infestations (protozoa, worms, etc.) […]
Enteric Redmouth Disease, Bacterial diseases"

From Alam et al. (2012):

"The present study reports the intensity of parasitic infestation in 216 specimens of *H. molitrix* collected from different fish markets in Rajshahi City, Bangladesh. Nine different parasite species (*Trichodina pediculatus*, *Dactylogyrus vastator*, *Ichthyophthirius multifilis*, *Gyrodactylus elegans*, *Lernaea* sp., *Apiosoma* sp., *Myxobolus rohitae*, *Camallanus ophiocephali*, and *Pallisentis ophiocephali*) were recovered from the gill, skin, stomach, and intestine of host fish.

The highest level of infection was observed for host skin, while lower levels were observed for host gill, stomach, and intestine. The results also revealed that the intensity of parasite infection in different organs of H. molitrix varied with the season. In particular, the highest levels of infection were recorded during the winter period (November–February), when fish are most susceptible to parasites."

From Sarkar and Rashid (2012):

"*A*[*eromonas*] *hydrophila* is the causative agent of MAS (motile *Aeromonas* septicemia). Both farmed and wild fishes have been found to be affected by this disease. […] Sabur (2006) observed that *A. hydrophila* was found to be pathogenic for both indigenous (rui *Labeo rohita*, catla *Catla catla* and mrigal *Cirrhinus cirrhosus*) and exotic (silver carp *Hypophthalmichthys molitrix* and common carp *Cyprinus carpio*) carps."

Threat to Humans

From Froese and Pauly (2018):

"Potential pest"

From Kolar et al. (2007):

"Reports of large jumping Silver Carp seriously injuring boaters and water-skiers and severely damaging watercraft are becoming more frequent (Beattie 2002; Deardorff 2002; Kilborn 2002; Perea 2002; Lien 2003; Myhre 2003; Williams 2003). Occurrences of Silver Carp landing in boats and hitting boaters are commonplace."

"In addition to personal injury, Silver Carp also cause property damage and leave a mess for boaters to clean. One author (DCC) has observed damage to recreational boats on the Missouri River, including a broken windshield and a broken Plexiglas faring. Other reports of damage from jumping Silver Carp include a broken generator (B. Canaday, Missouri Department of Conservation, Jefferson City, Missouri, personal communication, 2003), and broken radios and depth finders (M. Pegg, Illinois Natural History Survey, Havana, Illinois, personal communication, 2003). When a Silver Carp lands in a boat, even if it does not break anything of value, it leaves slime, scales, and feces for boaters to contend with. Some fisheries professionals, including one author (DCC), who work in areas where Silver Carp are common, have added screens or netting to their vessels to deflect carp and thus reduce injuries and equipment damage."

"Some disease-causing agents harbored by Silver Carp pose health risks to humans. The psychotropic pathogen *Listeria monocytogenes* has been found in market and fish farm samples of Silver Carp (Akhondzadeh Basti and Zahrae Salehi 2003). *Clostridium botulinum* was found in 1.1% of fresh and smoked samples of Silver Carp from the Mazandaran Province (Safari and Khandagi 1999). Ebrahimzadeh Mousavi et al. (2000) found the toxigenic fungi *Aspergillus flavus*, *Alternaria*, *Penicillium*, and *Fusarium* from Silver Carp and from pond water in which they were raised at a fish farm in northern Iran. In addition, live *Salmonella* sp. can be found in

Silver Carp for at least 14 days after transfer to clean water and should, therefore be considered as a potential carrier for *Salmonella* (*S. typhimumium*; Bocek et al. 1992)."

3 Impacts of Introductions

From Nico et al. (2019):

"Pflieger (1997) considered the impact of this species difficult to predict because of its place in the food web. In numbers, the silver carp has the potential to cause enormous damage to native species because it feeds on plankton required by larval fish and native mussels (Laird and Page 1996). This species would also be a potential competitor with adults of some native fishes, for instance, gizzard shad, that also rely on plankton for food (Pflieger 1997). A study by Sampson et al. (2009) found that Asian carp (silver and bighead carps) had dietary overlap with gizzard shad and bigmouth buffalo, but not much of one with paddlefish."

"Asian carps have been shown to affect zooplankton communities (Burke et al. 1986, Lu et al. 2002, Cooke et al 2009; Calkins et al. 2012; Freedman et al. 2012; Sass et al. 2014)."

"Freedman et al. (2012) showed that resource use and trophic levels of the fish community change when Asian carps are present. They also demonstrated an impact on Bigmouth Buffalo and found isotopic values similar to Bluegill, Gizzard Shad, and Emerald Shiner."

From Irons et al. (2007):

"Despite variable recruitment, Asian carps abundance and biomass have increased since 2000, as evidenced by commercial landings, and Asian carps now dominate the fish community on La Grange Reach. Previous research suggests dietary overlap among bighead and silver carps and two native Illinois River fishes, gizzard shad *Dorosoma cepedianum* and bigmouth buffalo *Ictiobus cyprinellus*. Total length and mass data from *c.* 5000 fishes were used to test for changes in gizzard shad and bigmouth buffalo body condition after Asian carps establishment and investigate potential competitive interactions and changes in fitness. Analyses revealed significant declines in body condition of gizzard shad (-7%) and bigmouth buffalo (-5%) following the Asian carps invasion from 2000 to 2006. Segmented regression analyses showed no significant change in the rate of decline in gizzard shad condition after 2000, whereas the rate of decline in bigmouth buffalo condition increased significantly after 2000. Statistically significant differences in gizzard shad condition after Asian carps establishment (2000–2006) was observed, whereas condition of bigmouth buffalo was significantly lower in all years following Asian carps establishment as compared to 2000. Declines in gizzard shad and bigmouth buffalo condition were significantly correlated with increased commercial harvest of Asian carps and poorly correlated with other abiotic and biotic factors (*e.g.* temperature, chlorophyll *a* and discharge) that may influence fish body condition. These results may suggest that Asian carps are influencing native planktivore body condition, and future research should focus on determining whether food is limited in the Illinois River for native planktivores and other fish species."

From Sass et al. (2014):

“In lentic systems, bighead and silver carp have been observed to reduce total zooplankton abundances and particularly those of larger-bodied zooplankters, such as cladocerans and copepods (Fukushima et al., 1999; Shao et al., 2001; Stone et al., 2000; Yang et al., 1999).”

“The objective of our study was to test for bighead and silver carp effects on zooplankton community composition and biomass within the Illinois River using two complementary comparative studies. First, we tested for differences in zooplankton community samples collected and archived prior to the establishment of bighead and silver carp (1994–2000) with samples collected following the establishment of these invasive fishes (2009–2011) in the La Grange reach, Illinois River. Second, we tested for differences in zooplankton community composition and biomass among six reaches of the Illinois River that varied in bighead and silver carp relative abundances during 2009–2011.”

“Mean total zooplankton, cladoceran, and copepod abundances (55 µm filter) decreased significantly between pre- and post-bighead and silver carp establishment time periods in the La Grange reach, Illinois River […]. Mean rotifer abundance (55 µm filter) increased significantly among time periods […]. Mean total zooplankton abundance decreased from 166.1 to 121.7/L before and after bighead and silver carp establishment, respectively ($N = 257$, $T_{255} = 2.17$, $P = 0.03$). Between time periods, the mean rotifer abundance increased from 75.2 to 117.0/L ($N = 257$, $T_{255} = 2.16$, $P = 0.03$). Mean cladoceran and copepod abundances declined significantly from 19.7 to 2.0 and from 71.2 to 2.7/L, respectively prior to and after bighead and silver carp establishment in the La Grange reach, Illinois River (cladocerans, $N = 257$, $T_{255} = 13.15$, $P < 0.001$; copepods, $N = 257$, $T_{255} = 16.52$, $P < 0.001$).”

“Our results suggest that the establishment of invasive bighead and silver carp is correlated with an alteration of the zooplankton community to potentially benefit themselves. Increases in rotifer abundances directly benefit bighead and silver carp because their capacities to filter very small particles far exceed those of many native fishes and rotifers are a dominant prey item in their diets (Sampson et al., 2009; Williamson and Garvey, 2005).”

From Kolar et al. (2007):

“Excrement from Silver Carp (which can equal their body weight in 10 days; Herodek et al. 1989) has been found to organically enrich lake bottoms and alter the structure of the benthic macroinvertebrate community (Leventer and Teltsch 1990).”

“In India, the introduction of Silver Carp into several reservoirs has resulted in the decline of native planktivores. The accidental establishment of Silver Carp in the Gobindsagar Reservoir in 1971 has generated animated debate from ecologists and fishery managers because of the propensity of the species to negatively affect native planktivorous species, particularly Catla and Rohu (Shetty et al. 1989; Sugunan 1997; Esmaeili and Johal 2003). After the introduction of Silver Carp, commercial fish catches from the reservoir changed dramatically (Petr 2002). Silver and Common carps dominated catch within 10 years of establishment (Petr 2002). At first, as the catch of Silver Carp increased, catches of Catla and Rohu declined, as did total catch (Shetty et al. 1989). Dey et al. (1979) and Natarajan (1988) documented similar declines in Kulgarhi Reservoir, India. Then, from 1987 to 1993, total catch from Gobindsagar Reservoir increased each year (Petr 2002). Between 1974 and 1975 (before introduction of Silver Carp) and 1992-93 (15 years after Silver Carp were introduced), catch of the indigenous Golden Mahseer (*Tor putitora*) in Gobindsagar Reservoir declined from 16.8% to 0.5% of the catch (although total catches increased over the same period from 28.7 tons of Golden Mahseer in 1974-75 to 46 tons in 1992-93; Sugunan 1995)."

"After their introduction into the Aral Sea Basin in the 1960s, Silver Carp fry quickly became 85-90% of total larval fish present in the basin (Pavlovskaya 1995). During the same period, larvae of the Aral Barbel (*Barbus brachycephalus*) declined from 80% to 0.04% of larval fishes in the basin (Pavlovskaya 1995). Although the Amu Dar'ya and other catchment rivers of the Aral Sea Basin historically harbored 43 species of fishes in the 1960s, only 22 species were collected in the early 1980s (though some of the extirpated species required riverine habitat lost by water removal for irrigation). Pavlovskaya (1995) credited the introduction of Asian carps and water manipulation for irrigation of aquaculture as the primary causes of the loss of fish biodiversity (Pavlovskaya 1995). Silver Carp were stocked into Lake Kinneret, Israel, in 1969 to increase production of harvestable fishes (Spataru and Gophen 1985). Spataru and Gophen (1985) speculated that Silver Carp competition with tilapias led to declines of the economically more important native tilapias in the lake."

"Costa-Pierce (1992) reported that economically important planktivores such as Able de Heckel (*Leucaspius delineatus*) and Bleak (*Alburnus alburnus*), as well as piscivorous (as adult) Zander (*Sander lucioperca*) were "nearly wiped out" by dense stocking of Silver Carp into a lake in Germany in 1977. Zander populations rebounded dramatically after the removal of Silver Carp. In that study, fish species most negatively affected by the presence of Silver Carp were those that spawn in the sublittoral zone and have pelagic, plankton-eating fry."

4 Global Distribution

Figure 1. Known global distribution of *Hypophthalmichthys molitrix*, reported from the United States, Mexico, Europe, and Asia. Map from GBIF Secretariat (2017). Points in Mexico, Brazil, western Europe, Bangladesh, Taiwan, Laos, and New Zealand were excluded from the climate matching analysis because *H. molitrix* is not established in these locations. Only established occurrences in the United States were included in the climate matching analysis, following Nico et al. (2019; see Section 5).

5 Distribution Within the United States

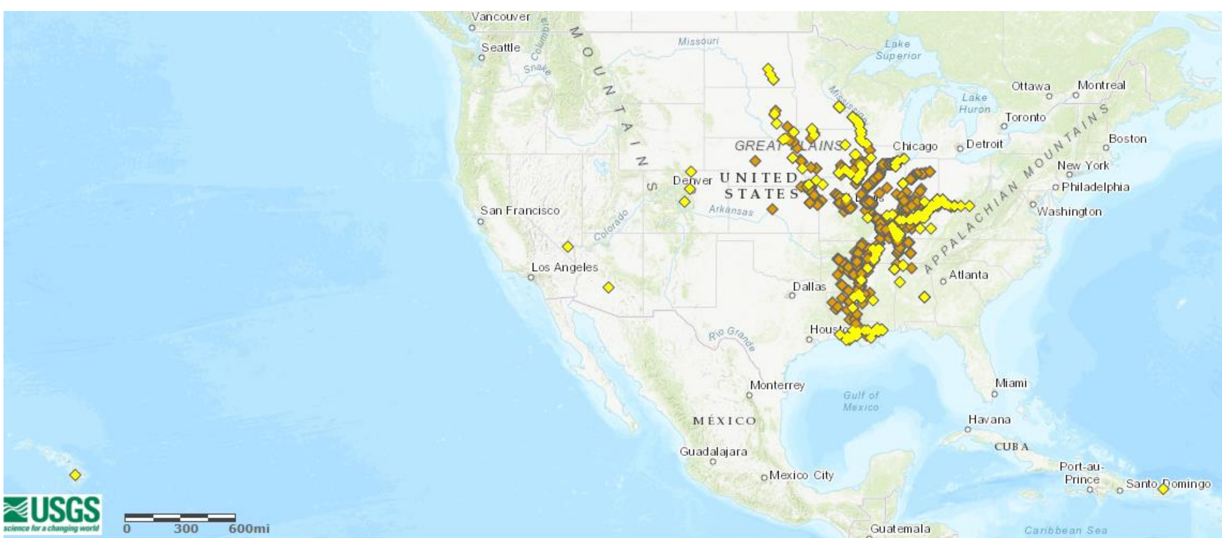

Figure 2. Known distribution of *Hypophthalmichthys molitrix* in the United States. Map from Nico et al. (2019). Orange points represent established occurrences, while yellow points (including all occurrences in Arizona, Colorado, Hawaii, North Dakota, Nevada, and Puerto Rico) represent populations that have been extirpated, failed, or have unknown status. Only established occurrences were used as source locations for the climate matching analysis.

6 Climate Matching

Summary of Climate Matching Analysis

The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for the contiguous United States was 0.717, indicating a high climate match. Scores of 0.103 and above are classified as high match. The climate score was high in every state in the contiguous United States. Climate match was particularly low in coastal areas of the Pacific Northwest. The areas of highest match were in the Mississippi River basin, which is the established range of *Hypophthalmichthys nobilis* in the United States, as well as in the Mid-Atlantic region and central California.

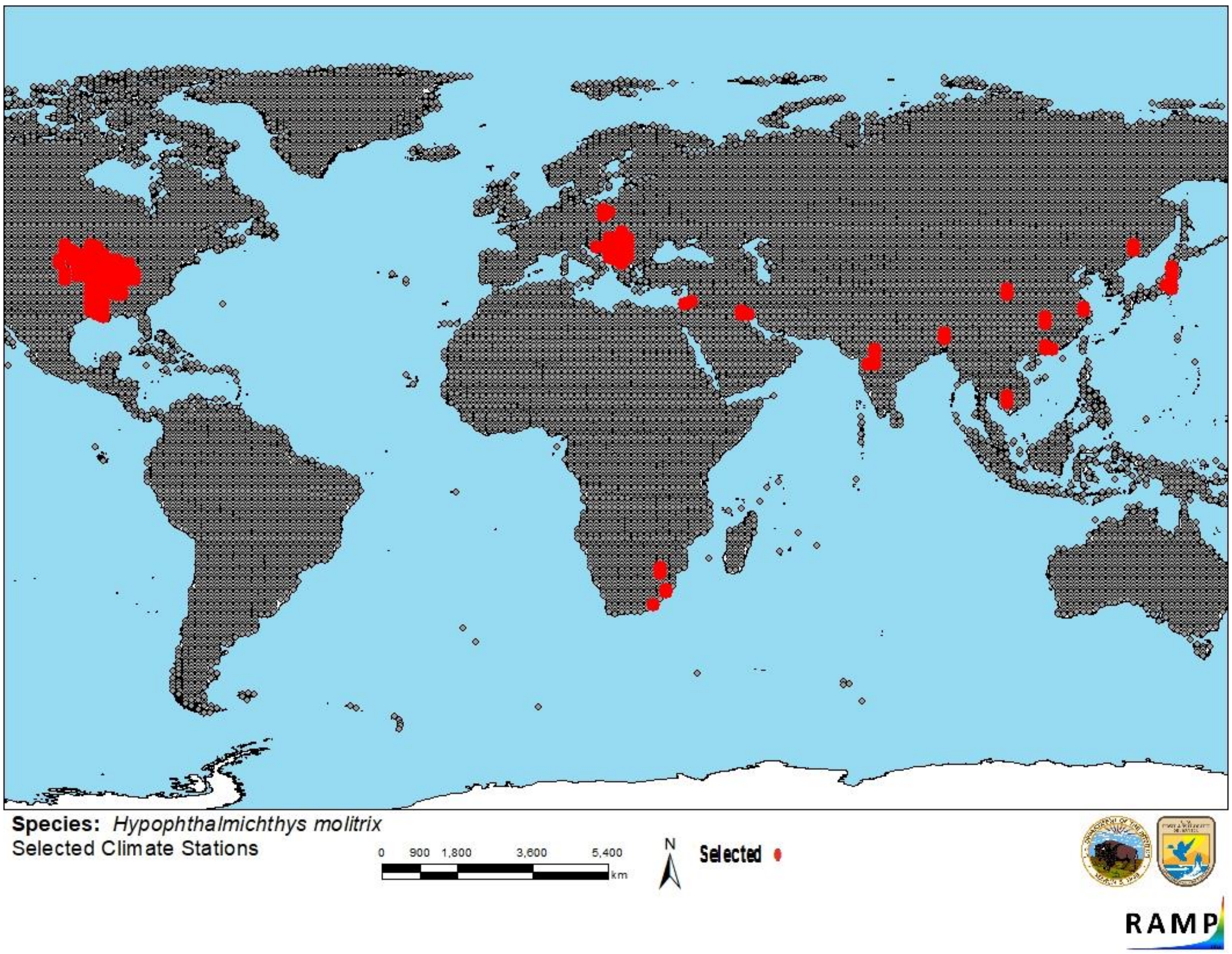

Figure 3. RAMP (Sanders et al. 2018) source map showing weather stations selected as source locations (red; United States, South Africa, Hungary, Romania, Serbia, Bosnia and Herzegovina, Montenegro, Macedonia, Albania, Bulgaria, Israel, Iraq, India, China, Russia, Japan, Cambodia) and non-source locations (gray) for *Hypophthalmichthys molitrix* climate matching. Source locations from GBIF Secretariat (2017) and Nico et al. (2019).

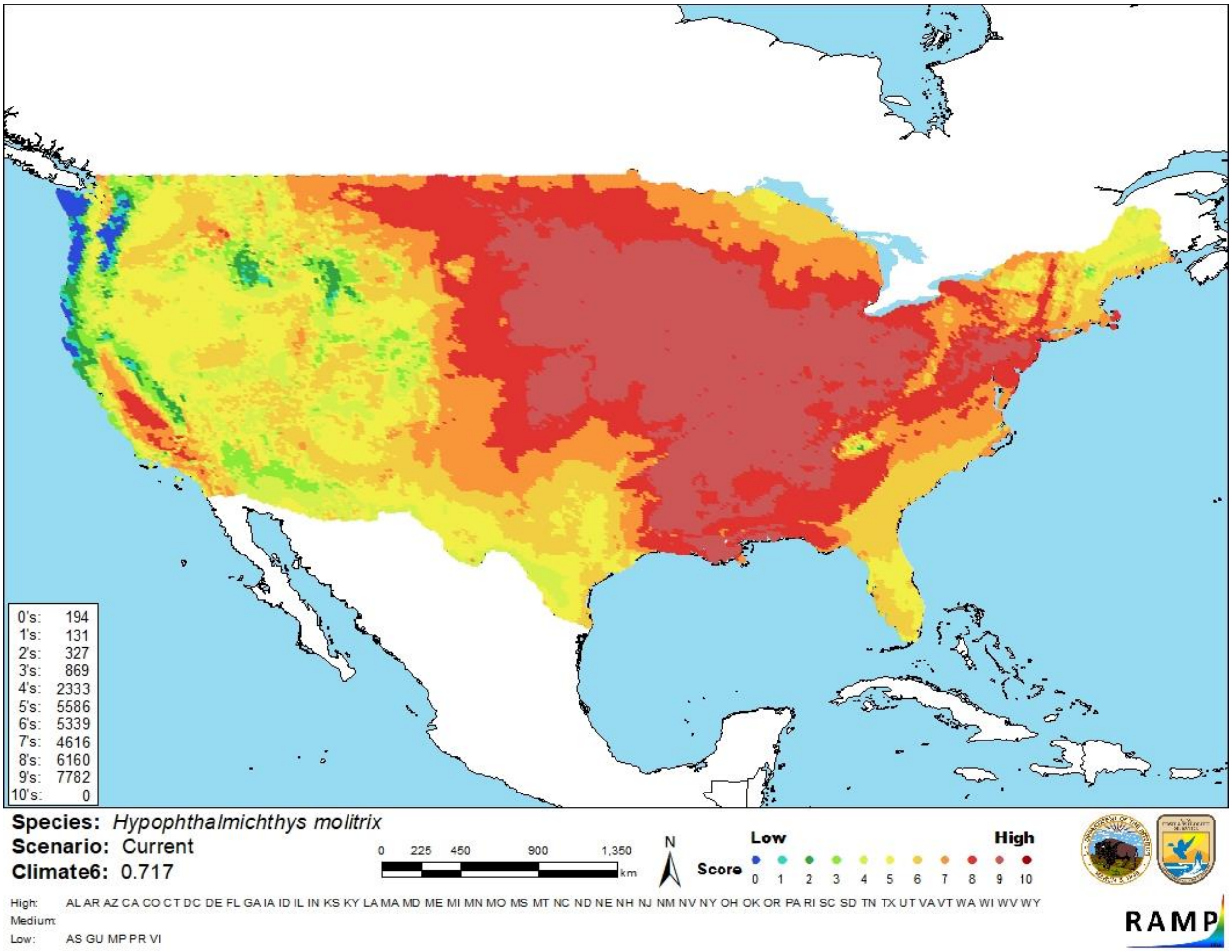

Figure 4. Map of RAMP (Sanders et al. 2018) climate matches for *Hypophthalmichthys molitrix* in the contiguous United States based on source locations reported by GBIF Secretariat (2017) and Nico et al. (2019). 0= Lowest match, 10= Highest match. Counts of climate match scores are tabulated on the left.

The "High", "Medium", and "Low" climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

7 Certainty of Assessment

There is adequate information available on the biology, ecology, and distribution of *Hypophthalmichthys molitrix.* Although the overall impact of this species on ecosystems in the contiguous United States is not fully understood, several credible scientific sources have documented negative impacts of this species in the contiguous United States. The invasive history of this species both within and outside the United States has been extensively documented, and its established distribution is well-known. It often occurs with its congener *H. nobilis,* and because of their similarity, much available research does not distinguish between impacts of these two species. Because of these factors, the certainty of this assessment is medium.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Hypophthalmichthys molitrix, the Silver Carp, is a carp species native to eastern Asia. This species has a high history of invasiveness: since being introduced to the United States via aquaculture in the 1970s, it has escaped captivity and spread rapidly in the Mississippi and Missouri River basins with documented negative impacts. Negative impacts to the United States attributed to *H. molitrix* and its congener *H. nobilis* include alterations to the zooplankton community and lowered body condition of native planktivores. Such impacts have also been documented in other locations where *H. molitrix* has been introduced and has become established. Threats to humans are significant, including transfer of zoonotic pathogens and bodily injury and property damage from jumping fish. *H. molotrix* has a high climate match with the contiguous United States, with all 48 states scoring as high match. Certainty of this assessment is medium because information available on negative impacts of this species does not often distinguish between the effects of *H. molitrix* and *H. nobilis*. Despite this, the overall risk assessment category is still High.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): Medium**
- **Important additional information: Listed as federally injurious by the U.S. Fish and Wildlife Service in 2007. Susceptible to infection by spring viremia of carp virus, an OIE-reportable disease.**
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

Alam, M. M., M. A. Khan, M. A. Hussain, D. Moumita, A. G. Mazlan, and K. D. Simon. 2012. Intensity of parasitic infestation in silver carp, *Hypophthalmichthys molitrix*. Journal of Zhejiang University-SCIENCE B 13(12):1024-1028.

Ellender, B. R., and O. L. F. Weyl. 2014. A review of current knowledge, risk and ecological impacts associated with non-native freshwater fish introductions in South Africa. Aquatic Invasions 9(2):117-132.

Fricke, R., W. N. Eschmeyer, and R. van der Laan, editors. 2018. Catalog of fishes: genera, species, references. Available: http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp. (November 2018).

Froese, R., and D. Pauly, editors. 2018. *Hypophthalmichthys molitrix* (Valenciennes, 1844). FishBase. Available: https://www.fishbase.de/Summary/SpeciesSummary.php?ID=274&AT=silver+carp (November 2018, February 2019).

GBIF Secretariat. 2017. GBIF backbone taxonomy: *Hypophthalmichthys molitrix* (Valenciennes, 1844). Global Biodiversity Information Facility, Copenhagen. Available: https://www.gbif.org/species/2413541. (October 2018, February 2019).

Irons, K. S., G. G. Sass, M. A. McClelland, and J. D. Stafford. 2007. Reduced condition factor of two native fish species coincident with invasion of non-native Asian carps in the Illinois River, U.S.A. Is this evidence for competition and reduced fitness? Journal of Fish Biology 71:258-273.

ITIS (Integrated Taxonomic Information System). 2018. *Hypophthalmichthys molitrix* (Valenciennes in Cuvier and Valenciennes, 1844). Integrated Taxonomic Information System, Reston, Virginia. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=163691#null. (November 2018).

Kolar, C. S., D. C. Chapman, W. R. Courtenay Jr., C. M. Housel, J. D. Williams, and D. P. Jennings. 2007. Bigheaded carps: a biological synopsis and environmental risk assessment. American Fisheries Society, Special Publication 33, Bethesda, Maryland.

Lamer, J. T., C. R. Dolan, J. L. Petersen, J. H. Chick, and J. M. Epifanio. 2010. Introgressive hybridization between bighead carp and silver carp in the Mississippi and Illinois Rivers. North American Journal of Fisheries Management 30(6):1452-1461.

Nico, L., P. Fuller, and J. Li. 2019. *Hypophthalmichthys molitrix* (Valenciennes in Cuvier and Valenciennes, 1844). U. S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=549. (February 2019).

Pofuk, M., D. Zanella, and M. Piria. 2017. An overview of the translocated native and non-native fish species in Croatia: pathways, impacts and management. Management of Biological Invasions 8(3):425-435.

Povž, M., and S. Šumer. A brief review of non-native freshwater fishes in Slovenia. Journal of Applied Ichthyology 21:316-318.

Sanders, S., C. Castiglione, and M. H. Hoff. 2018. Risk Assessment Mapping Program: RAMP, version 3.1. U.S. Fish and Wildlife Service.

Sarkar, M. J. A., and M. M. Rashid. 2012. Pathogenicity of the bacterial isolate *Aeromonas hydrophila* to catfishes, carps and perch. Journal of the Bangladesh Agricultural University 10(1):157-161.

Sass, G. G., C. Hinz, A. C. Erickson, N. N. McClelland, M. A. McClelland, and J. M. Epifanio. 2014. Invasive bighead and silver carp effects on zooplankton communities in the Illinois River, Illinois, USA. Journal of Great Lakes Research 40:911-921.

USFWS (U.S. Fish and Wildlife Service). 2007. Injurious wildlife species; Silver Carp (Hypophthalmichthys molitrix) and Largescale Silver Carp (Hypophthalmichthys harmandi). Federal Register 72:37459-37469. July 10. Available: https://www.fws.gov/policy/library/2007/E7-13371.pdf

10 References Quoted But Not Accessed

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

Akhondzadeh Basti, A., and T. Zahrae Salehi. 2003. Incidence of *Listeria monocytogenes* in fresh and smoked fish in Iran. Pages 163-165 *in* B. Phillips, B. A. Megrey, and Y. Zhou, editors. Proceedings of the Third World Fisheries Congress; feeding the world with fish in the next millennium—the balance between production and the environment. American Fisheries Society, Bethesda, Maryland.

Almeida-Toledo, L. F., A. P. Bigoni, G. Bernardino, and S. Filho. 1995. Chromosomal location of Nors and C bands in F_1 hybrids of bighead carp and silver carp reared in Brazil. Aquaculture 135:277-284.

Beattie, J. 2002. Alien invasion: voracious carp threatens fish supply in Great Lakes. (November 12). Available: http://www.greatlakesdirectory.org/zarticles/111602_great_lakes.htm. (March 2005).

Berg, L. S. 1948-1949. Freshwater fishes of the U.S.S.R. and adjacent countries, 4th edition. Three volumes. Translated from Russian, 1962-1965, for the Smithsonian Institution and the National Science Foundation, by Israel Program for Scientific Translations, Jerusalem, Israel.

Billard, R. 1997. Les poissons d'eau douce des rivières de France. Identification, inventaire et répartition des 83 espèces. Delachaux & Niestlé, Lausanne, Switzerland.

Bocek, A. J., Y. J. Brady, and W. A. Rogers. 1992. Exposure of silver carp, *Hypophthalmichthys molitrix*, to *Salmonelle typhimurium*. Aquaculture 103:9-16.

Brummett, R. E., R. O. Smitherman, and R. A. Dunham. 1988. Isozyme expression in bighead carp, silver carp and their reciprocal hybrids. Aquaculture 70:21-28.

Burke, J. S., D. R. Bayne, and H. Rea. 1986. Impact of silver and bighead carps on plankton communities of channel catfish ponds. Aquaculture 55:59-68.

Burr, B. M., D. J. Eisenhour, K. M. Cook, C. A. Taylor, G. L. Seegert, R. W. Sauer, and E. R. Atwood. 1996. Nonnative fishes in Illinois waters: what do the records reveal? Transactions of the Illinois State Academy of Science 89(1/2):73-91.

Calkins, H. A., S. J. Tripp, and J. E. Garvey. 2012. Linking silver carp habitat selection to flow and phytoplankton in the Mississippi River. Biological Invasions 14:949-958.

Cooke, S., W. R. Hill, K. P. Meyer. 2009. Feeding at different plankton densities alters invasive bighead carp (*Hypophthalmichthys nobilis*) growth and zooplankton species composition. Hydrobiologia 625:185-193.

Costa-Pierce, B. A. 1992. Review of the spawning requirements and feeding ecology of silver carp (*Hypophthalmichthys molitrix*) and reevaluation of its use in fisheries and aquaculture. Reviews in Aquatic Sciences 6:257-273.

Costa-Pierce, B. A., S. R. Malecha, and E. A. Laws. 1985. Effects of polyculture and manure fertilization on water quality and heterotrophic productivity in *Macrobrachium rosenbergii* ponds. Transactions of the American Fisheries Society 114:826-836.

Cremer, M. C., and R. O. Smitherman. 1980. Food habits and growth of silver and bighead carp in cages and ponds. Aquaculture 20:57-64.

Deardorff, J. 2002. Giant carp ready to eat way through Great Lakes. Chicago Tribune (July 18). Available: http://www.chicagotribune.com/news/local/chi-0207180219jul18.story.

Dey, R. K., P. V. G. K. Reddy, S. B. Singh, and D. S. Murty. 1979. Note on compatibility and competition between silver carp and rohu. Journal of the Inland Fisheries Society of India 11:125-127.

Douglas, N. H., S. G. George, J. J. Hoover, K. J. Killgore, and W. T. Slack. 1996. Records of two Asian carps in the lower Mississippi Basin. Page 127 *in* Abstracts of the 76th Annual Meeting of the American Society of Ichthyologists and Herpetologists. University of New Orleans, New Orleans, Louisiana.

Ebrahimzadeh Mousavi, A., R. Khosrari, and G. Azari Takami. 2000. A survey of fungal flora of cultivated cyprinids in Sefrid Rood Fish Farmed Center. Journal of the Faculty of Veterinary Medicine, University of Tehran 55:57-60.

Esmaeili, H. R., and M. S. Johal. 2003. Age, growth, and fisheries of silver carp *Hypophthalmichthys molitrix* (Val., 1844) in Gobindsagar Reservoir, India. Pages 127-

138 *in* B. Phillips, B. A. Megrey, and Y. Zhou, editors. Proceedings of the Third World Fisheries Congress: feeding the world with fish in the next millennium—the balance between production and environment. American Fisheries Society Symposium 38. American Fisheries Society, Bethesda, Maryland.

Etnier, D. A., and W. C. Starnes. 1993. The fishes of Tennessee. The University of Tennessee Press, Knoxville, Tennessee.

FAO. 1999. Aquaculture production statistics: 1988-1997. FAO Fisheries Circular 815, Revision 11.

FAO. 2004. Fisheries global information system. Database on introductions of aquatic species. Available: http://www.fao.org/figis/servlet/static?dom=root&xml=introsp/introsp_search.xml.

Freedman, J. A., S. E. Butler, and D. H. Wahl. 2012. Impacts of invasive Asian carps on native food webs. Final project report. Kaskaskia Biological Station, Illinois Natural History Survey, University of Illinois at Urbana-Champaign, Illinois.

Freeze, M., and S. Henderson. 1982. Distribution and status of the bighead carp and silver carp in Arkansas. North American Journal of Fisheries Management 2(2):197-200.

Frimodt, C. 1995. Multilingual illustrated guide to the world's commercial warmwater fish. Fishing News Books, Osney Mead, Oxford, U.K.

Froese, R., and D. Pauly, editors. 2004. FishBase, version 9/2004. Available: http://www.fishbase.org.

Fukushima, M., N. Takamura, L. Sun, M. Nakagawa, K. Matsushige, and P. Xie. 1999. Changes in the plankton community following introduction of filter-feeding planktivorous fish. Freshwater Biology 42:719-735.

Green, B. W., and R. O. Smitherman. 1984. Relative growth, survival and harvestability of bighead carp, silver carp, and their reciprocal hybrids. Aquaculture 37:87-95.

He, L., W. Zou, C. Cai, X. Ai, and J. He. 1992. A study on pathogen of our-breaking infectious diseases of fishes in Shashi, District. Freshwater Fisheries 3:13-16. (In Chinese).

Henderson, S. 1977. An evaluation of filter feeding fishes for water quality improvement. Arkansas Game and Fish Commission, Little Rock, Arkansas.

Herodek, S., I. Tàtrai, J. Olàh, and L. Vörös. 1989. Feeding experiments with silver carp (*Hypophthalmichthys molitrix*) fry. Aquaculture 83:331-344.

IGFA. 2001. Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, Florida.

Jerde, C. L., W. L. Chadderton, A. R. Mahon, M. A. Renshaw, J. Corush, M. L. Budny, S. Mysorekar, and D. M. Lodge. 2013. Detection of Asian carp DNA as part of a Great Lakes basin-wide surveillance program. Canadian Journal of Fisheries and Aquatic Sciences 70(4):522-526.

Kamilov, B. G., and M. Y. Komrakova. 1999. Maturation and fecundity of the silver carp, *Hypophthalmichthys molitrix*, in Uzbekistan. Israeli Journal of Aquaculture (Bamidgeh) 51:40-43.

Kaushal, D. K., M. D. Pisolkar, and Y. R. Rao. 1980. A note of the food habits of silver carp *Hypophthalmichthys molitrix* Valenciennes from the Gobindsagar reservoir, Himachal Pradesh. Journal of the Inland Fisheries Society of India (Barrackpore) 12:129-130.

Kilborn, P. T. 2002. A huge, boat-hurdling carp is no Mississippi fish story. The New York Times (August 26). Available: http://www.nytimes.com/2002/08/26/national/26CARP.html.

Kottelat, M., A. J. Whiten, S. N. Kartikasari, and S. Wirjoatmodjo. 1993. Freshwater fishes of western Indonesia and Sulawesi. Periplus Editions (HK) Ltd. Collaboration with the Environmental Management Development in Indonesia (EMDI) Project Ministry of State for Population and Environment, Republic of Indonesia.

Kottelat, M., and J. Freyhof. 2007. Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin.

Laird, C. A., and L. M. Page. 1996. Non-native fishes inhabiting the streams and lakes of Illinois. Illinois Natural History Survey Bulletin 35(1):1-51.

Leventer, H. 1987. Contribution of silver carp (*Hypophthalmichthys molitrix*) to the biological control of reservoirs. Mekoroth Water Company, Jordan District, Nazareth, Israel.

Leventer, H., and B. Teltsch. 1990. The contribution of silver carp (*Hypophthalmichthys molitrix*) to the biological control of Netofa reservoirs. Trophic relationships in inland waters. Hydrobiologia 191:47-55.

Li, S., and F. Fang. 1990. On the geographical distribution of the four kinds of pond-cultured carps in China. Acta Zoologica Sinica 36(3):244-250.

Li, S., and X. Xu. 1995. Culture and capture of fish in Chinese reservoirs. International Development Research Center, Ottawa, Canada.

Lien, D. 2003. Asian carp pose formidable threat to Midwest waters. St. Louis Post-Dispatch (November 30). Available: http://www.greatlakesdirectory.org/mn/112603_great_lakes.htm. (March 2005).

Lu, M., P. Xie, H. Tang, Z. Shao, and L. Xie. 2002. Experimental study of trophic cascade effect of silver carp (*Hypophthalmichthys molitrix*) in a subtropical lake, Lake Donghu: on plankton community and underlying mechanisms of changes of crustacean community. Hydrobiologia 487(1):19-31.

Maddox, J. J., L. L. Behrends, C. E. Madewell, and R. S. Pile. 1978. Algae-swine manure system for production of silver carp, bighead carp, and tilapia. Pages 109-115 *in* R. O. Smitherman, W. L. Shelton, and J. H Grover, editors. Symposium on culture of exotic fishes. Fish Culture Section, American Fisheries Society, Bethesda, Maryland.

Marian, T., Z. Krasznai, and J. Olah. 1986. Characteristic karyological, biochemical and morphological markers of silver carp (*Hypophthalmichthys molitrix* Val.), bighead carp (*Aristichthys nobilis* Rich.) and their hybrids. Aquacultura Hungarica 5:15-30.

Mia, M. Y., J. B. Taggart, A. E. Gilmour, A. A. Gheyas, T. K. Das, A. H. M. Kohinoor, M. A. Rahman, M. A. Sattar, M. G. Hussain, M. A. Mazid, D. J. Penman, and B. J. McAndrew. 2005. Detection of hybridization between Chinese carp species (*Hypophthalmichthys molitrix* and *Aristichthys nobilis*) in hatchery broodstock in Bangladesh, using DNA microsatellite loci. Aquaculture 247:267-273.

Middlemas, K. 1994. Local angler hooks a peculiarity. The News Herald, Panama City, Florida (September 25).

Myhre, L. 2003. Pesky silver carp spotted on Missouri. Sioux City Journal (September 3). Available: http://siouxcityjournal.townnews.com/articles/2005/03/08/sports/outdoors/f0bee9026f9fe79286256d9300709ebc.txt. (March 2005).

Natarajan, A.V. 1988. Ecological and aquacultural roles of exotic fishes in aquatic productivity in India. Paper presented at the workshop on exotic aquatic species in India, Mangalore, April 25-26, 1988.

Nichols, J. T. 1943. The freshwater fishes of China. Natural history of Central Asia, volume IX. The American Museum of Natural History, New York.

Opuszynski, K., A. Lirski, L. Myszkowski, and J. Wolnicki. 1989. Upper lethal and rearing temperatures for juvenile common carp, *Cyprinus carpio* L. and silver carp, *Hypophthalmichthys molitrix* (Valenciennes). Aquaculture and Fisheries Management 20:287-294.

Pavlovskaya, L. P. 1995. Fishery in the lower Amy-Dar'ya under the impact of irrigated agriculture. Pages 42-57 *in* T. Petr, editor. Inland fisheries under the impact of irrigated agriculture: Central Asia. FAO Fisheries Circular 894.

Pearson, W. D., and L. A. Krumholz. 1984. Distribution and status of Ohio River fishes. ORNL/sub/79-7831/1. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Perea, J. P. 2002. Asian carp invasion: fish farm escapees threaten native river fish communities and boaters as well. Outdoor Illinois 10(5):8.

Petr, T. 2002. Cold water fish and fisheries in countries of the high mountain arc of Asia (Hindu Kush-Pamir-Karakoram-Himalayas). A review. Pages 1-38 *in* T. Petr, and D. B. Swar, editors. Cold water fisheries in the Trans-Himalayan countries. FAO Fisheries Technical Paper 431.

Pflieger, W. L. 1997. Fishes of Missouri. Missouri Department of Conservation, revised edition.

Riede, K. 2004. Global register of migratory species - from global to regional scales. Final report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany.

Rinne, J. N. 1995. The effects of introduced fishes on native fishes: Arizona, southwestern United States. Pages 149-159 *in* D. P. Philipp, J. M. Epifanio, J. E. Marsden, and J. E. Claussen, editors. Protection of Aquatic Biodiversity. Proceedings of the World Fisheries Congress, Theme 3. Science Publishers Inc., Lebanon, New Hampshire.

Robison, H. W., and T. M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, Arkansas.

Sabur, M. A. 2006. Studies on the ecology of the pathogenic bacteria *Aeromonas hydrophila* in indigenous and exotic carps under polyculture condition. Doctoral thesis. Department of Aquaculture, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Safari, R., and A. Khandagi. 1999. Evaluation and isolation of *Clostridium botulinum* type E from fresh and smoked *Cyprinus carpio*, *Rutilus frisii kutum*, and *Hypophthalmichthys (sic.) molitrix*. Iranian Journal of Fisheries Sciences 7(4):19-23. (In Farsi).

Sampson, S. J., J. H. Chick, and M. A. Pegg. 2009. Diet overlap among two Asian carp and three native fishes in backwater lakes on the Illinois and Mississippi rivers. Biological Invasions 11:483-496.

Shao, K.-T., and P. L. Lim. 1991. Fishes of freshwater and estuary. *In* Encyclopedia of field guide in Taiwan. Recreation Press, Co., Ltd., Taipei, Taiwan.

Shao, Z., P. Xie, and Y. Zhuge. 2001. Long-term changes of planktonic rotifers in a subtropical Chinese lake dominated by filter-feeding fishes. Freshwater Biology 46:973.

Shetty, H. P. C., M. C. Nandeesha, and A. G. Jhingran. 1989. Impact of exotic aquatic species in Indian waters. Pages 45-55 *in* S. S. De Silva, editor. Exotic aquatic organisms in Asia. Proceedings of the workshop on introduction of exotic aquatic organisms in Asia. Asian Fisheries Society Special Publication 3.

Sirenko, L. A., P. S. Vovk, A. Ya. Malyarevskaya, and T. I. Birger. 1976. Control of eutrophication of the Dnieper reservoir by algae removal and herbivorous fishes introduction. Limnologica 10:603-606.

Slechtova, V., V. Slechta, D. D. Hiep, and M. Valenta. 1991. Biochemical genetic comparison of bighead (*Hypophthalmichthys molitrix*), silver carp (*Aristichthys nobilis*), and their hybrids reared in Czechoslovakia. Journal of Fish Biology 39(Supplement A):349-357.

Smith, D. W. 1985. Biological control of excessive phytoplankton growth and the enhancement of aquacultural production. Canadian Journal of Fisheries and Aquatic Sciences 42:1940-1945.

Spataru, P., and M. Gophen. 1985. Feeding behaviour of silver carp *Hypophthalmichthys molitrix* Val. and its impact on the food web in Lake Kinneret, Israel. Hydrobiologia 120:53-61.

Spataru, P., G. W. Wohlfarth, and G. Hulata. 1983. Studies on the natural food of different fish species in intensively manured polyculture ponds. Aquaculture 35:283-298.

Starling, F. L. R. M., and A. J. A. Rocha. 1990. Experimental study of the impacts of planktivorous fishes on plankton community and eutrophication of a tropical Brazilian reservoir. Pages 581-591 *in* R. D. Gulati, E. H. R. R. Lammens, M. L. Meijer, and E. van Donk, editors. Biomanipulation–tool for water management. Kluwer Academic Publishers, Dordrecht, Germany.

Stone, N., C. Engle, D. Heikes, and D. Freeman. 2000. Bighead carp. Southern Regional Aquaculture Center (SRAC), Stoneville, Mississippi, September 2000, Southern Regional Aquaculture Center Publication 438.

Sugunan, V. V. 1995. Reservoir fisheries of India. FAO Fisheries Technical Paper 345.

Sugunan, V. V. 1997. Fisheries management of small water bodies in seven countries in Africa, Asia, and Latin America. Food and Agriculture Organization of the United Nations, Fisheries Circular 993 FIRI/c933.

Sumantadinata, K., N. Taniguchi, and K. Sugama. 1990. The necessary conditions and the use of ultraviolet irradiated sperm from different species to induce gynogenesis of Indonesian common carp. Pages 539-542 *in* R. Hirano, and I. Hanu, editors. Proceedings of the second Asian fisheries forum. Asian Fisheries Society, Makati City, Philippines.

USACE (U.S. Army Corps of Engineers). 2012. Environmental DNA calibration study: interim technical review report.

Vörös, L., I. Oldal, M. Présing, and K. V. Balogh. 1997. Size-selective filtration and taxon-specific digestion of plankton algae by silver carp (*Hypophthalmichthys molitrix* Val.). Hydrobiologia 342/343:223-228.

Voropaev, H. V. 1978. Biology and fishery importance of hybrids between bighead and silver carp. Szarvas Fishery Research Institute, Szarvas, Hungary.

Williams, A. 2003. Flyin' fish everywhere. St. Louis Post-Dispatch (September 4).

Williamson, C. J., and J. E. Garvey. 2005. Growth, mortality, and fecundity of newly established silver carp in the middle Mississippi River. Transactions of the American Fisheries Society 134(6):1423-1430.

Xie, P., and Y. Chen. 2001. Invasive carp in China's Plateau lakes. Science 224:999-1000.

Yang, Y., X. Huang, and J. Liu. 1999. Long-term changes in zooplankton and water quality in a shallow, eutrophic Chinese lake densely stocked with fish. Hydrobiologia 391:195-203.