Koi (*Cyprinus rubrofuscus*)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, September 2011
Revised, September 2019
Web Version, 1/7/2020

Photo: Chinese Academy of Fishery Sciences. Licensed under CC BY-NC 3.0. Available: https://www.fishbase.de/photos/PicturesSummary.php?ID=59920&what=species. (September 2018).

1 Native Range and Status in the United States

Native Range

From Huckstorf (2012):

"The species has an east Asian distribution. It is distributed from the Amur to Red River drainages (Kottelat 2006) in Mongolia, Russia (Amur), eastern China, Lao PDR, and Viet Nam."

Status in the United States

Daniel et al. (2019) report nonindigenous occurrences of *Cyprinus rubrofuscus* from the following U.S. states and HUCs during the stated timeframes: Delaware, 2014-2018 (Broadkill-Smyrna); Florida, 1997-2019 (Florida Southeast Coast, Hillsborough, Kissimmee, Lower Ochlockonee, Oklawaha, Upper St. Johns); Kentucky, 2019; Louisiana, 2004-2018 (Liberty Bayou-Tchefuncta, Toledo Bend Reservoir); Maine, 2008 (Saco); Massachusetts, 2016 (Cape Cod); Minnesota, 2004-2016 (Lake Superior, Twin Cities); Nevada, 2016 (Las Vegas Wash); New Jersey, 2006-2009 (Crosswicks-Neshaminy, Mullica-Toms); New York, 2011 (Niagara); North Carolina, 2019 (Haw); Pennsylvania, 2007-2016 (Crosswicks-Neshaminy, Schuylkill); South Dakota, 2003 (Middle Cheyenne-Spring).

Domesticated Koi (scientific name not specified) are in trade in the United States.

From Koi To The World (2019):

"Lot Of (15) Assorted 5-8" Koi […] $ 300.00"

Means of Introductions in the United States

From Mitrica (2015):

"In the Colorado Lake, 3,000 Koi fish (Japanese carp) are now swarming the water, wiping out native species and dramatically altering the environment."

"It's not clear why, when and how the fish popped up in the lake – the explosion of these exotic fish which are not native to North America seems to have occurred three years ago, and authorities suspect that a local pet store is responsible. The fact that all the fish seem to be some three years old seems to be telling for that aspect."

""Based on their size, it looks like they're 3-year-olds, which were probably produced from a small handful of fish that were illegally introduced into the lake," Ben Swigle, a fish biologist at the Colorado Parks and Wildlife (CPW), told Live Science."

Remarks

All scientific name synonyms of *C. rubrofuscus* listed below were used to search for information for this report. *Cyprinus rubrofuscus*, Koi, is commonly confused with Common Carp, *Cyprinus carpio*. Literature discussing domesticated, ornamental Koi will often refer to it using the scientific name *Cyprinus carpio.* While every effort was made to limit the information in this report to that applicable to *C. rubrofuscus*, it was not always possible to determine with certainty which species was being referenced in literature discussing ornamental Koi.

From Daniel et al. (2019):

"Koi (*Cyprinus rubrofuscus*) are ornamental varieties of domesticated carp that are often erroneously identified as European Carp (*C. carpio*) (Kottelat and Freyhof 2007)."

"The koi has gone through a lot of taxonomic changes due to extensive cultivation and breeding history (Gross et al 2002; Zhou et al 2003a), and its origins are uncertain, leaving its taxonomic status ambiguous (Dong et al. 2015). Gross et al (2002) found koi to be a distinct monophyletic group resulting from domestication, but more closely related to East Asian carp groups, and recognized as the subspecies *Cyprinus carpio haematopterus*; this was also the conclusion and taxonomic assignment in similar studies from the same time period that used allozyme data (Kohlmann and Kersten 1999; Zhou et al 2013b). Literature from a decade later has also recognized koi as carp subspecies *Cyprinus carpio haematopterus* (Kim et al 2018; Zoran et al 2017). Matsui et al (2008) recongnized [*sic*] koi as a carp subspecies *Cyprinus carpio koi*. Athough [*sic*] Zhou et al (2003b) used the subspecies name *rubrofuscus* to describe other carp strains, Eschmeyer's Catalog of Fishes, as well as the Integrated Taxonomic Information System (ITIS), recognizes the species *Cyprinus rubrofuscus* as of June 2019 (Fricke et al 2019), putting a lot of the other subspecies assigned to the koi as synonyms (Dong et al. 2015)."

From Huckstorf (2012):

"*Cyprinus rubrofuscus* is the species commonly identified as the common carp, *C. carpio*, a species native to eastern Europe and central Asia. Contrary to what is often believed, the European carp is not introduced in Europe from Asia (Kottelat 1997, Kottelat 2001). *Cyprinus carpio* has been introduced worldwide, but many cultivated stocks in Asia are in fact *C. rubrofuscus*, a species native to Eastern Asia (China, and probably Japan and Viet Nam). The molecular data of Zhou et al. (2004) support this conclusion although these authors did not discuss the taxonomy aspect of their results."

From Naseka and Bogutskaya (2004):

"The Amur carp is widely treated as subspecies *C. carpio haematopterus* Temminck & Schlegel in the Russian literature. However, the name *Cyprinus haematopterus* Temminck & Schlegel, 1846[…] is permanently invalid as a junior primary homonym of *Cyprinus haematopterus* Rafinesque, 1820 (Eschmeyer, 1998). The earliest available name for the Amur (Asian) carp is *Cyprinus rubrofuscus* La Cepède, 1803[…], and this taxon has been commonly considered a subspecies, *C. carpio rubrofuscus*, in the recent Chinese literature (Chen & Huang, 1977; Zhu, 1995; etc.). Kottelat (2001a, 2001b) considers it to be a distinct species."

From Huckstorf (2012):

"Synonym(s):
Cyprinus carpio Linnaeus, 1758 ssp. *murgo* Dybowski, 1869
Cyprinus flammans Richardson, 1846
Cyprinus fossicola Richardson, 1846
Cyprinus nigroauratus Lacepède, 1803
Cyprinus annacarolina Lacepède, 1803
Cyprinus carpio Linnaeus, 1758 ssp. *yuankiang* Wu et al., 1963
Cyprinus floripenna van Hasselt, 1823
Cyprinus haematopterus Temminck & Schlegel, 1846
Cyprinus hybiscoides Richardson, 1846

Cyprinus sculponeatus Richardson, 1846
Cyprinus viridiviolaceus Lacepède, 1803"

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 *Cyprinus*
Species *Cyprinus rubrofuscus* Lacepède, 1803"

From Fricke et al. (2019):

"Current status: Valid as *Cyprinus rubrofuscus* Lacepède 1803. Cyprinidae: Cyprininae."

Size, Weight, and Age Range

From Daniel et al. (2019):

"Size: 30 to 60 cm long (Tomelleri and Eberle 1990)"

"Koi are long-lived and have a typical life span of around 40 years, but the oldest-known koi lived to be 230 years old. They reach sexual maturity around age 4 and breed yearly thereafter (Smithsonian National Zoo and Conservation Biology Institute 2019)."

Environment

From Froese and Pauly (2018):

"Freshwater; brackish; benthopelagic."

"Found in freshwater, but tolerant to slightly brackish water [Bogutskaya et al. 2008]."

Climate/Range

From Froese and Pauly (2018):

"Tropical"

Distribution Outside the United States

Native

From Huckstorf (2012):

"The species has an east Asian distribution. It is distributed from the Amur to Red River drainages (Kottelat 2006) in Mongolia, Russia (Amur), eastern China, Lao PDR, and Viet Nam."

Introduced

From Magalhães and Jacobi (2013a):

"Among the 65 non-native aquarium fish currently found in Brazilian inland waters are seven cyprinids, […] [including] koi carp *Cyprinus rubrofuscus* Lacepéde 1803, […]"

From Freyhof and Kottelat (2008):

"[…] *C. rubrofuscus* (often erroneously referred to as *C. carpio haematopterus*) is cultivated in several eastern European countries and has been introduced to Russia and Ukraine. It is not known whether it has become established there."

Yang et al. (2011) find genetic evidence of *C. rubrofuscus* (as *C. carpio haematopterus*) in Xingyun Lake, central Yunnan Province, China.

From Centre for Invasive Species Solutions (2017):

"Carp populations in the upper Murrumbidgee catchment (Lake Burrinjuck in New South Wales and Lake Burley Griffin in the Australian Capital Territory), the Upper Lachlan catchment, several coastal catchments in New South Wales, lakes Crescent and Sorell in Tasmania and wetlands near Perth in Western Australia have some koi ancestry. Some established wild populations in coastal New South Wales are made up entirely of highly coloured koi strain fish."

From The University of Waikato (2019):

"The species is thought to have been introduced to New Zealand waters in the 1960s. […] Feral breeding stocks were first noticed in the Waikato River in 1983. They are now very common throughout the lower Waikato River regions – spreading into streams, lakes and wetlands."

"Koi carp are widespread in the Waikato and Auckland and are spreading further north. They have also been found in Wanganui, Hawke's Bay and Wellington but have not yet been found in the South Island."

Means of Introduction Outside the United States

From Magalhães and Jacobi (2013b):

"*Cyprinus rubrofuscus* (common variety) that escaped from fish farms has great importance in commercial fishing in several lotic and lentic environments in the Doce River basin (Vieira, 2010). The same trend of spread may occur with *Cyprinus rubrofuscus* - koi if released by hobbyists in the studied rivers. Feral koi carp released by aquarium amateurs has established itself and dispersed in a number of rivers and lakes of New Zealand (Tempero et al., 2006)."

From Freyhof and Kottelat (2008):

"In western Europe, Japanese ornamental varieties (kois) possibly derived from *C. rubrofuscus* or of hybrid origin occasionally escape from ponds."

From Yang et al. (2011):

"According to historical records from the Xingyun Lake Protection Bureau, a fish farm near the lake [Xingyun Lake, Yunnan Province, China] introduced this strain of carp from northern China."

From Centre for Invasive Species Solutions (2017):

"There have […] been multiple releases of the Japanese 'koi strain' of carp [in Australia], all relatively recently (1976—2008). It is likely that many of these releases originated from locally cultured fish rather than direct introductions from Japan."

From The University of Waikato (2019):

"The species is thought to have been introduced to New Zealand waters in the 1960s. They may have been released accidently from ponds during flooding. Some may have been released for fishing purposes."

From Hanchet (1990):

"The introduction of koi into New Zealand waters is undocumented, but they were probably brought into the country in a consignment of goldfish (*Carassius auratus*), from which they are difficult to distinguish as juveniles (McDowall 1979). Since koi arrived in New Zealand, they have been bred and introduced into many farm ponds and dams, mainly in the north of the North Island."

Short Description

From Freyhof and Kottelat (2008):

"Wild *C. rubrofuscus* are distinguished from wild *C. carpio* by having 29-33 + 2-3 lateral line scales (vs. 33-37 + 2-3), 18-22½ branched dorsal rays (vs. 17-20½), body silvery with red pelvic, anal and lower caudal lobe (vs. grey to bronze)."

From Froese and Pauly (2018):

"Body silvery with red pelvic, anal and lower caudal lobe (Xiangkhouang stock) or grey (Louang Phabang stock, Laos). Last simple anal ray bony and serrated posteriorly; with 4 barbels; branched dorsal rays 18-22.5 [Kottelat 2001a]."

From Daniel et al. (2019):

"Koi are a domesticated ornamental carp taxa that vary widely in coloration with combinations of bright gold, orange, silver, white, and black colors patterns (Kottelat and Freyhof 2007). Koi are characterized by their deep body, two barbels on each side of its upper jaw, and serrated dorsal spine (Nelson 1984)."

Biology

From The University of Waikato (2019):

"Waikato koi rarely exceed 9 years of age. Females average 5.2 years and males 4.6 years of age. An average fish weighs 3 kg. Females produce 100 000 eggs per kg of body weight. A typical female can produce 300 000 eggs annually (or more if they spawn more than once). Koi carp spawn throughout the summer. As they gather for spawning or feeding in the shallow margins of the river, koi biomass can reach 4000 kg/ha."

"Koi carp feed like vacuum cleaners – moving along the bottoms of streams, lakes and rivers. Koi carp are opportunistic feeders eating a wide variety of benthic organisms – plants and animals. They suck up and expel material from the bottom, filtering out edible material as they go. They grind their food to a pulp with powerful teeth located in their throats, making a noise that can be heard underwater through a hydrophone."

"Koi carp prefer still waters, spreading from rivers into lakes, streams or backwaters in rivers. They are highly tolerant of poor water quality – surviving well in degraded water and contributing to the decline."

Human Uses

From Huckstorf (2012):

"This species is a commercial fishery target. It is extensively used in aquaculture."

From Cornwell et al. (2013):

"Koi Carp *Cyprinus carpio* represent a major portion of U.S. ornamental fish aquaculture. Although other ornamental species have greater total sales, more farms raise Koi than any other ornamental fish species in the USA. In 2005, there were 193 farms in the USA culturing Koi, with sales totaling more than US$6.5 million (USDA 2006)."

Cornwell et al. (2013) report the scientific name of Koi Carp as *Cyprinus carpio*, but ornamental Koi are likely *Cyprinus rubrofuscus*.

Diseases

From Daniel et al. (2019):

"Koi carry and transmit the koi herpesvirus (KHV) disease, which can result in large die-offs of many carp groups (Matsui et al. 2008). The species is also capable of becoming infected with carp oedema virus (CEV), which causes koi sleepy disease (KSD) and results in sickness and the eventual death of the fish from anoxia, which can affect the ornamental koi industry, as there is a 100% motality rate for the disease (Kim et al. 2017)."

From Goodwin (2002):

"The United States is a major producer of fish species susceptible to SVCV [spring viremia of carp virus], including […] koi (a strain of common carp) […]."

From Cornwell et al. (2013):

"In this study, 80 Koi were exposed to VHSV [viral hemorrhagic septicemia virus] by intraperitoneal injection. Mortality was very low and occurred in the first 2 d of the experiment, suggesting that deaths could be due to handling stress and not VHSV infection. Nevertheless, the results of this experiment provide strong evidence that Koi have the potential to become infected with VHSV IVb. Two Koi showed mild clinical signs associated with VHSV infection. The virus quantity present in fish increased slightly but significantly between exposure and the first 2 weeks postexposure. In addition, infectious VHSV was isolated from many fish up to 28 DPE. Virus was detected by qRT-PCR up to 90 DPE […], albeit at very low levels, suggesting that Koi have the potential to be long-term carriers of VHSV viral genomic material, although it is not known at this point whether virus remaining at these later time points is viable, infectious virus."

Cornwell et al. (2013) report the scientific name of Koi Carp as *Cyprinus carpio* but they also note that commercially-bred ornamental Koi were tested for infection with VHSV, so these individuals were likely *Cyprinus rubrofuscus*.

OIE (2019) lists "Infection with koi herpesvirus," "Infection with spring viraemia of carp virus," and "Infection with viral haemorrhagic septicaemia virus" in its "OIE-Listed diseases, infections and infestations in force in 2019".

Threat to Humans

From Froese and Pauly (2018):

"Harmless"

3 Impacts of Introductions

From Magalhães and Jacobi (2013b):

"There are no studies showing the adverse ecological effects of introducing *Cyprinus rubrofuscus* - koi, […] by hobbyists in Minas Gerais or elsewhere in Brazil."

From The University of Waikato (2019):

"Koi carp feed like vacuum cleaners – moving along the bottoms of streams, lakes and rivers. Koi carp are opportunistic feeders eating a wide variety of benthic organisms – plants and animals. They suck up and expel material from the bottom, filtering out edible material as they go."

"This activity destroys native plant, fish, invertebrate and water bird habitat. It stirs up the substrate and can greatly increase the turbidity of the water. Waterways become muddy and unattractive. Aquatic plants are dislodged and are unlikely to re-establish. Oxygen is depleted."

From Rowe (2007):

"Changes in water clarity (secchi disc transparency) in relation to the presence/absence of introduced, exotic fish, including rudd (*Scardinius erythrophthalmus*), tench (*Tinca tinca*), perch (*Perca fluviatilis*), brown bullhead catfish (*Ameiurus nebulosus*), goldfish (*Carassius auratus*), and koi carp (*Cyprinus carpio*) were determined for 49 small, North Island, New Zealand lakes. There was a negative association between water clarity and the presence of exotic fish independent of lake depth. Moreover, a 'before-and-after' comparison and examination of case-studies indicated that introductions of exotic fish reduce water clarity. The number of species introduced affected the relationship between lake depth and water clarity but the specific role of each species could not be distinguished because most of the lakes (83%) contained more than one exotic fish species."

Rowe (2007) report the scientific name of Koi Carp as *Cyprinus carpio*, but ornamental Koi are likely *Cyprinus rubrofuscus*.

From Hanchet (1990):

"The impacts of koi on the New Zealand aquatic environment are extremely difficult to predict. Firstly, we have little information on whether their growth, reproduction, feeding habits, and general behaviour are similar to some of the more virulent strains of carp overseas […] Secondly, we have little information on the densities of koi attained in New Zealand, and at what densities any impacts to vegetation will eventuate. Furthermore, the effects of carp on many of our exotic plants (e.g., *Egeria densa*, *Lagarosiphon major*, and *Vallisneria gigantea*) and native plants (e.g., *Potamogeton* spp., *Myriophyllum* spp.) are unknown. Lastly, the principal, large, predatory fish in New Zealand (eels and trout) are largely absent from those areas in North America where carp have been a problem, and therefore their role in regulating koi numbers is unknown."

“In January 1988, MAF Fisheries [New Zealand’s Ministry of Agriculture and Fisheries] was aware of only three waterbodies where koi apparently have had a major impact on the aquatic environment. The first waterbody, called Harrison's Pond, is on a farm north of Auckland. The pond is 440 m long by 67 m wide, is 2 ha in area, and has an average water depth of 1 m (maximum depth, 3 m). It was sampled in August 1986 by MAF Fisheries, using gill nets and fyke nets. Nineteen koi, 49 eels, seven rudd, and two goldfish were caught (S. Pullan, pers. comm.). Details of the date and number of koi originally released into the pond are unknown. The presence of several size classes of koi in the catch suggests that these fish have successfully bred there. The pond had a surface temperature of l3.7°C, a Secchi disk reading of 475 mm, a mud substrate, and very sparse aquatic vegetation (algae, watercress, and willow weed). Mr Harrison (the landowner) stated that, since koi had been introduced, there had been a reduction in aquatic vegetation (quantity and species unknown) and that the ducks previously present had disappeared. The koi caught in Harrison's Pond were in poor condition compared to koi caught in the Waikato River. This suggests that there was a shortage of food in the pond and that the density of koi was probably high. No biomass estimates are available for this pond.”

“The second waterbody is a small pond on a farm in Taranaki (Pullan 1982). The pond has an area of about 0.2 ha with an average water depth of 2 m. It was surveyed by S. Pullan in December 1981, and, using gelignite, a total of 22 koi was removed. Ten koi survived the blasts, but eight of these fish were later removed (Pullan [1984]). The fish were on average 40-50 cm long, and weighed between 1.5 kg and 4.8 kg, giving an estimated density of 440 kg/ha. After the koi were removed, dense regrowth of vegetation occurred (S. Pullan, pers. comm.).”

“The third waterbody is also a small (0.05 ha) pond, about 1.0 - 1.5 m depth, near Ohaupo, south of Hamilton. The water has apparently become turbid, and lost its vegetation since koi were liberated (S. Pullan, pers. comm.). No attempt has been made to sample the waterbody, and so no estimate of fish density is available.”

4 Global Distribution

Figure 1. Known global distribution of *Cyprinus rubrofuscus*. Map from GBIF Secretariat (2019). Most occurrences represent ornamental Koi, not wild-type individuals. It could not be determined which occurrence points represent fish being raised in captivity and which are living in the wild.

5 Distribution Within the United States

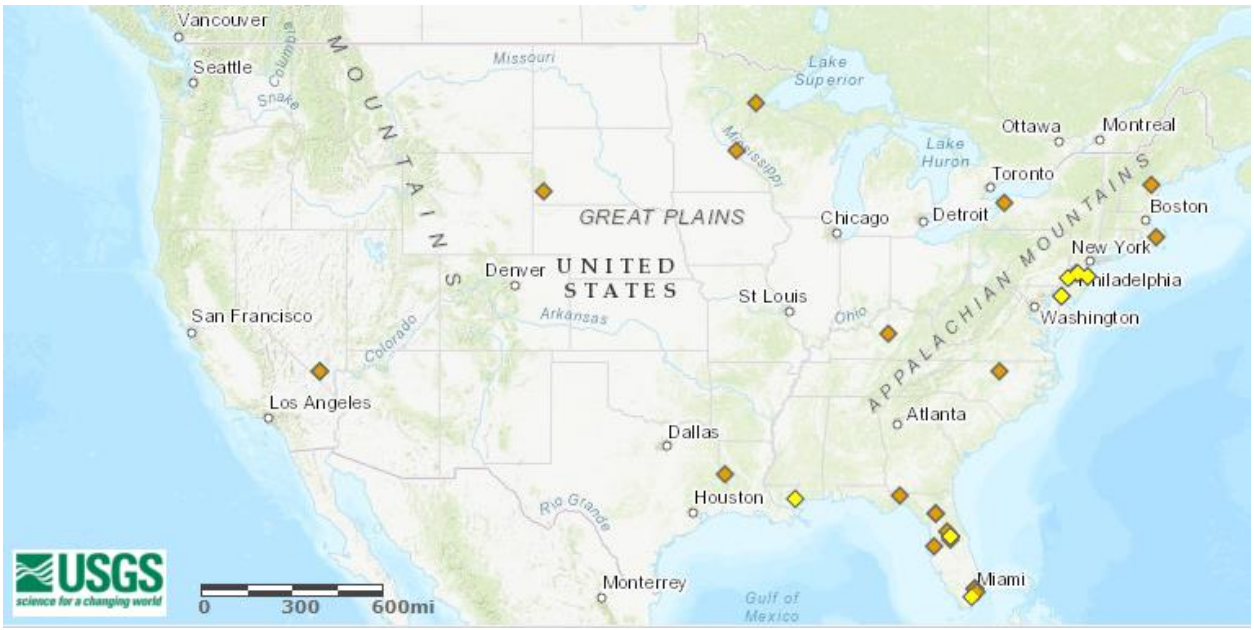

Figure 2. Known distribution of *Cyprinus rubrofuscus* in the United States. Map from Daniel et al. (2019). Yellow diamonds represent established populations; orange diamonds represent populations with a status of "collected," "eradicated," "extirpated," "failed," or "unknown."

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 0.957, which is a high climate match. A Climate 6 score of 0.103 or greater indicates a high match. The climate match was categorically high in all states in the contiguous United States, but there were several small areas of low match in the Pacific Northwest.

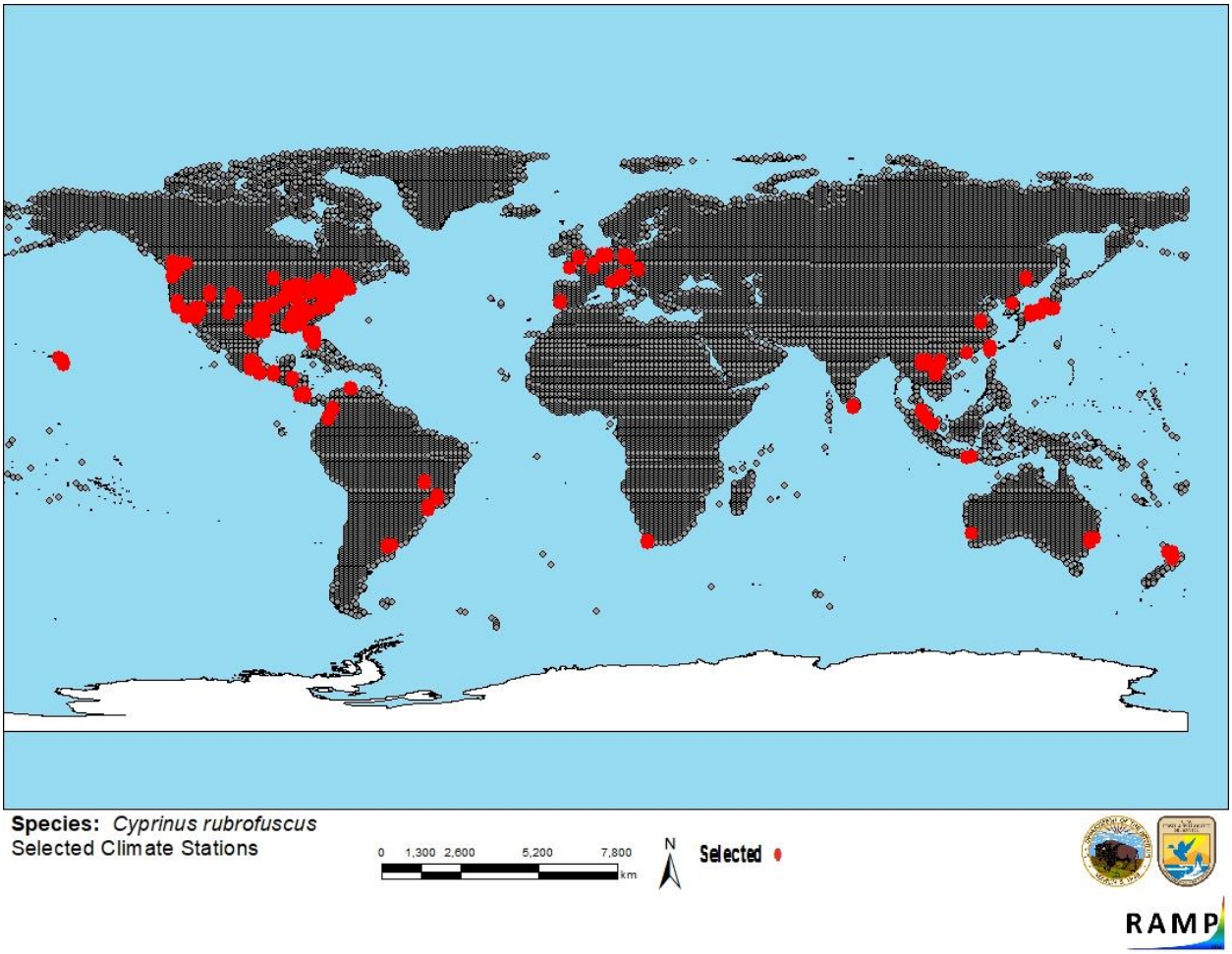

Figure 3. RAMP (Sanders et al. 2018) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Cyprinus rubrofuscus* climate matching. Source locations from GBIF Secretariat (2019).

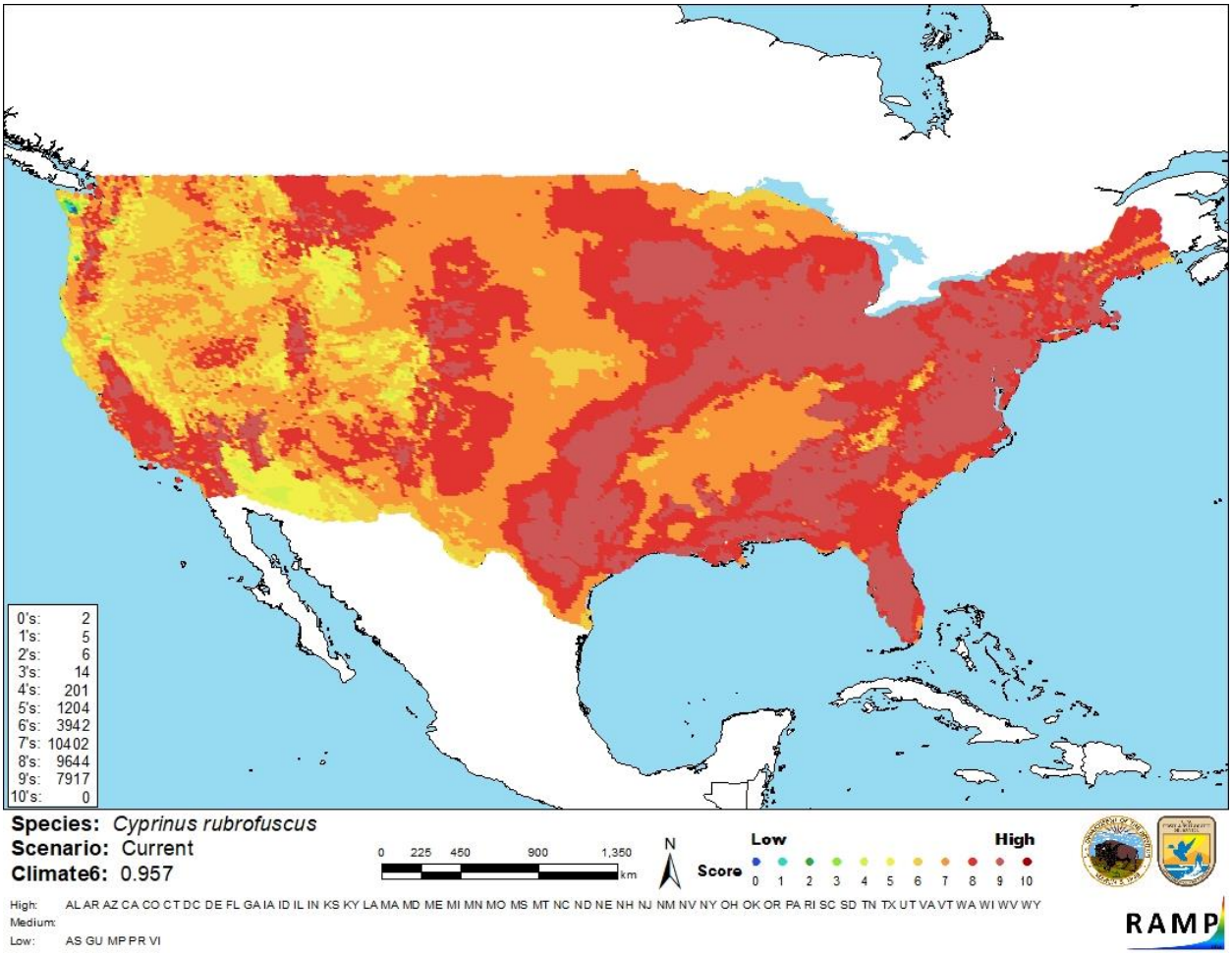

Figure 4. Map of RAMP (Sanders et al. 2018) climate matches for *Cyprinus rubrofuscus* in the contiguous United States based on source locations reported by GBIF Secretariat (2019). Counts of climate match scores are tabulated on the left. 0= Lowest match, 10=Highest match.

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

Despite the ubiquity of Koi in aquaculture, there is relatively little information available about the biology of this species in the wild. There is anecdotal evidence that the species has negative impacts on aquatic vegetation, but more robust research is necessary. Because the domesticated fish commonly referred to as Koi is often called *Cyprinus carpio* in scientific literature, as opposed to *Cyprinus rubrofuscus*, it cannot be determined which species is being referenced with

certainty. Further information clarifying the taxonomy of domesticated Koi is necessary to assess the risk *Cyprinus rubrofuscus* poses to the contiguous United States with certainty. Certainty of this assessment is low.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Cyprinus rubrofuscus, the Koi, is a freshwater carp species native to eastern Asia. Although domesticated Koi are often known by the scientific name *Cyprinus carpio*, also known as Common Carp, Koi are more likely bred from wild *Cyprinus rubrofuscus*. Domesticated Koi are bred for many highly ornamental characteristics and are available in shades of gold, silver, white, orange, and black. *C. rubrofuscus* has been widely introduced outside of its native range. It is not clear what impacts it is having where introduced, so the history of invasiveness is classified as "none documented." This species is reported to have negative impacts in New Zealand, but the evidence is either anecdotal or any impacts of *C. rubrofuscus* are confounded with the impacts of other nonnative species. This species has a very high climate match with the contiguous United States; however, confidence in the results of the climate matching analysis is reduced because it could not be determined which occurrence points represented domesticated fish and which were feral. Certainty of this assessment is low. The overall risk assessment category is Uncertain.

Assessment Elements

- **History of Invasiveness (Sec. 3): None Documented**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): Low**
- **Important additional information: Susceptible to three OIE-reportable diseases.**
- **Overall Risk Assessment Category: Uncertain**

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.

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