# Red Piranha (*Pygocentrus nattereri*)

## Ecological Risk Screening Summary

**U.S. Fish and Wildlife Service, February 2011**
**Revised, December 2017**
**Web Version, 5/29/2018**

Photo: G. Moine. Licensed under Creative Commons (CC BY 2.0). Available: https://commons.wikimedia.org/w/index.php?title=File:Gregory_Moine_-_Red_bellied_Piranha_(by).jpg&oldid=188117641. (December 2017).

# 1 Native Range and Status in the United States

## Native Range

From Nico and Neilson (2017):

"Tropical America. Widely distributed in lowland areas of central and southern South America east of the Andes, including the Amazon [Venezuela, Colombia, Ecuador, Peru, Brazil, Bolivia] and Parana [Brazil, Paraguay, Uruguay, Argentina] basins and various coastal drainages of the Guianas and Brazil (Fink 1993)."

From Froese and Pauly (2017):

"South America: Amazon River basin [Venezuela, Colombia, Ecuador, Peru, Brazil, Bolivia], Paraguay-Paraná River basin [Brazil, Paraguay, Uruguay, Argentina], northeastern Brazilian coastal rivers and Essequibo River basin [Venezuela, Guyana] (Jégu 2003). Reported from the Uruguay River, Brazil (Zaniboni Filho et al. 2004)."

## Status in the United States

From Nico and Neilson (2017):

"Status: Failed in all states."

"A single specimen (recorded as *Serrasalmus nattereri*) was collected from a golf course pond in Ventura County, California in 1988 (museum specimen). A single fish was taken from a borrow pit connected to Snapper Creek in Miami, Dade County, Florida, ca. 1974 (Courtenay et al. 1974). One specimen was taken from Lake Mabo in Boca Raton, Palm Beach County, on 4 April 1979 (as a result, the lake was treated with rotenone to kill all fishes present) (Courtenay and Hensley 1979: Courtenay, personal communication; museum specimen). There is also a record of one specimen taken from a canal west of Ft. Lauderdale in Broward County (no date given) (Courtenay and Hensley 1979). Piranhas were first reported in Hawaii in Wahiawa Reservoir, a 350-acre, privately owned irrigation reservoir on Oahu, in June 1992 (Devick 1992); a mature female was taken on 23 February 1993, but there was no indication that the species had become established (Radtke 1995; W. S. Devick, personal communication). Local aquarists in Lawrence, Kansas have been reported releasing specimens into local ponds (E. Wiley, personal communication). There are four records of individual fish taken in Massachusetts from various localities: one fish (124 mm SL) from Lexington Reservoir, Middlesex County, on 3 August 1981 (Hartel 1992; Cardoza et al. 1993); one fish (146 mm SL) from Island Grove Pond in Abington, Plymouth County, in August 1984 (Hartel 1992; Cardoza et al. 1993); one fish from a pond near Westminster, Worcester County, on 22 July 1985 (Cardoza et al. 1993); and one fish (tentative identification) from Horn Pond in Woburn, Middlesex County, during the summer of 1993 (Cardoza et al. 1993). One specimen was found dead in Michigan on shore of a lake near Ann Arbor, ca. 1977 (Courtenay and Hensley 1979; W. C. Latta, personal communication) and reported in Lakes Huron, St. Clair, and Erie (Cudmore-Vokey and Crossman 2000). Single specimens have been taken in Minnesota from Duban Lake in Rice County in July 1993 (museum specimen) and from Simley Pond in Dakota County in August 1998 (museum specimen). In Ohio, a single fish was taken from Rocky River near London, Madison County, in early August 1975; a second specimen was apparently observed at the same site during the same period as was the first (Stroud 1976; D. Moreno, personal communication). Three moribund fish were found in January 2000, in the Lincoln County drain near the town of North Platte, Nebraska (Schainost, personal communication). In Oklahoma, one fish (170 mm SL) was found dead in Theta pond on the campus of Oklahoma State University in Stillwater, Payne County, on 12 November 1993 (museum specimen). One, or possibly more reports came from an unspecified locality or localities in Pennsylvania (Courtenay et al. 1984, 1991; Courtenay and Stauffer 1990). A single piranha (119 mm TL, 119 g) taken in Texas from Boerne City Reservoir in Kendall County (Howells et al. 1991). A single fish (150 mm) was taken in Virginia from Indian Lake

(borrow pit) in the Virginia Beach area, on 22 August 1987 (Stone 1987; Jenkins and Burkhead 1994, identified as *Pygocentrus* sp.; Southwick, personal communication)."

"This species is the most commonly seen piranha in the aquarium trade. […] Import is prohibited in many southern states (e.g., Florida and Texas)."

According to Bennett et al. (1997), states that specifically prohibit the sale, possession, or transport of piranhas within their borders include: Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Illinois, Kentucky, Louisiana, Massachusetts, Mississippi, Nevada, New Mexico, New York, Oklahoma, Oregon, Texas, Vermont, Virginia, and Washington.

## Means of Introductions in the United States

From Nico and Neilson (2017):

"Probable aquarium releases."

## Remarks

From Nico and Neilson (2017):

"Synonyms and Other Names: *Pygocentrus altus* Gill 1870, *Serrasalmo ternetzi* Steindachner 1908, *Serrasalmus nattereri* (Kner 1858); red-bellied piranha."

"Single or several *P. nattereri* have been found in ponds, lakes, rivers, and borrow pits. In northern states, reports are typically of fish taken by hook and line during the summer or found dead during the cooler months. The reaction by some state agencies has been to rotenone the entire lake where the piranha was taken. This fish has small chance of surviving cold periods. A fish taken from the Elk River, Alabama, previously reported in a newspaper account as a red piranha (Middleton 1988), has been shown to be the pacu *Piaractus brachypomus* (museum specimen). The piranha taken from Duban Lake, Minnesota, was originally misidentified by local biologists as being a pacu. Reports of piranhas taken from the Tamiami Canal in south Florida during the period 1969-1979 were unconfirmed (Courtenay and Hensley 1979)."

From Bennett et al. (1997):

"Considering the number of states that permit free trade of piranha, the difficulty of policing states that restrict trade, and the frequency with which piranhas are found outside of captivity, it is perhaps amazing that only two breeding populations have been confirmed during the 45 years these fish have been imported to the USA."

The "two breeding populations" mentioned by Bennett et al. (1997) occurred in Hawaii and Florida, respectively, and both have been eradicated.

# 2 Biology and Ecology

## Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2017):

"Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Deuterostomia
Phylum Chordata
Subphylum Vertebrata
Infraphylum Gnathostomata
Superclass Actinopterygii
Class Teleostei
Superorder Ostariophysi
Order Characiformes
Family Characidae
Genus *Pygocentrus* Müller and Troschel, 1844
Species *Pygocentrus nattereri* Kner, 1858"

"Taxonomic Status: valid"

## Size, Weight, and Age Range

From Froese and Pauly (2017):

"Max length : 50.0 cm SL male/unsexed; [Britski et al. 2007]; max. published weight: 3.9 kg [IGFA 2001]"

## Environment

From Froese and Pauly (2017):

"Pelagic; freshwater; pH range: 5.5 - 7.5; dH range: ? – 20."

"[…] 23°C - 27°C [Riehl and Baensch 1996; assumed to be recommended aquarium water temperature]"

From Bennett et al. (1997):

"Red-bellied piranhas became progressively more active and aggressive with increasing water temperatures. Fish acclimated to 35°C frequently engaged in overt agonistic behavior, leaving some fish with missing portions of caudal fins or with semicircular wounds from bites. […] Fish acclimated to 20.5°C remained active but were more tolerant of tankmates. At 15°C, fish remained tightly schooled and displayed a marked reduction in general activity. Below 10.2°C, fish began to lose equilibrium, and at 10.0°C, approximately half of the fish, though still alive, were lying on the bottom of the tank. […] Feeding behavior was also markedly influenced by acclimation temperature. Between 14°C and 35°C, red-bellied piranhas successfully pursued and

consumed live goldfish. As temperatures decreased to less than 14°C, piranhas in the 10°C acclimation group appeared lethargic and were unable to catch the more cold-tolerant goldfish; however, these piranhas continued to accept adult brine shrimp until temperatures decreased to less than 12°C."

## Climate/Range

From Froese and Pauly (2017):

"Subtropical; […] 9°N - 34°S"

## Distribution Outside the United States

### Native

From Nico and Neilson (2017):

"Tropical America. Widely distributed in lowland areas of central and southern South America east of the Andes, including the Amazon [Venezuela, Colombia, Ecuador, Peru, Brazil, Bolivia] and Parana [Brazil, Paraguay, Uruguay, Argentina] basins and various coastal drainages of the Guianas and Brazil (Fink 1993)."

From Froese and Pauly (2017):

"South America: Amazon River basin [Venezuela, Colombia, Ecuador, Peru, Brazil, Bolivia], Paraguay-Paraná River basin [Brazil, Paraguay, Uruguay, Argentina], northeastern Brazilian coastal rivers and Essequibo River basin [Venezuela, Guyana] (Jégu 2003). Reported from the Uruguay River, Brazil (Zaniboni Filho et al. 2004)."

### Introduced

From Knight (2010):

"Ornamental fishes ranging from the tiny guppy fish (*Poecilia reticulata*) to the large and aggressive Red Piranha (*Pygocentrus nattereri*) have been recorded in southern India (Bijukumar 2000)."

From Xiong et al. (2015):

"Three of these species (*C. macropomum, P. brachypomus, and P. nattereri*) were introduced into Southern China for aquaculture […]"

"Established [in China]"

From Latini and Petrere (2004):

"The Parque Estadual do Rio Doce, an important reserve within the Atlantic Forest biome, is located in the middle River Doce, southeastern Brazil. […] red piranha, *Pygocentrus nattereri*

Kner, were introduced into lakes neighbouring this Park, later reaching the lakes within the reserve area (Sunaga & Verani 1985, 1987; Godinho & Formagio 1992)."

From Nico and Neilson (2017):

"Red Piranha have been reported in Lake Huron, Ontario (Cudmore-Vokey and Crossman 2000)."

Additionally, Froese and Pauly (2017) report introduction of *P. nattereri* to Bangladesh, Barbados, and the Philippines. The species is reported as probably not established in Bangladesh, while the establishment status is reported as uncertain for the other two countries.

## Means of Introduction Outside the United States

From Knight (2010):

"[…] there are many other species of non-native fish that have started establishing local populations throughout peninsular India thanks to the flourishing aquarium trade. Ornamental fishes ranging from the tiny guppy fish (*Poecilia reticulata*) to the large and aggressive Red Piranha (*Pygocentrus nattereri*) have been recorded […]"

From Xiong et al. (2015):

"[…] introduced into Southern China for aquaculture […]"

From Latini and Petrere (2004):

"In Brazil, fish translocation was common during the 1960s and 1970s, mainly from the Amazon Basin to the north-east and south-east of the country (Agostinho, Júlio & Petrere 1994; Agostinho 1996; Agostinho & Júlio 1996)."

## Short Description

From Froese and Pauly (2017):

"Dorsal spines (total): 0; Dorsal soft rays (total): 16 - 18; Anal spines: 0; Anal soft rays: 27 – 30"

From Putz (2002):

"Generally *P. nattereri* is reddish-orange ventrally and silver-gray dorsally. The fins vary in color as well, with a black dorsal fin, black anal fin, and reddish-orange pectoral fins. The lateral color of the fish is a gray to silver-gray. (Fink, 1993)"

## Biology

From Froese and Pauly (2017):

"Common in creeks and interconnected ponds in Matto Grosso, Brazil, where it influences distribution and feeding of other fish [Sazima and Machado 1990] and in areas of high primary production in Rio Machado and Rio Negro [Goulding 1980]. Adults feed mainly at dusk and dawn. Feeds on insects, worms and fish [Mills and Vevers 1989]. Medium-sized to large individuals (15-24 cm length) forage mainly at dawn, late afternoon and night up to about 2200H, whereas smaller fish (8-11 cm) are active mainly during the day [Sazima and Machado 1990]. Teeth replacement on alternating sides of jaw allows continuous feeding. Its powerful dentition can inflict serious bites. Has a highly evolved auditory capacity and a 'lurking', then 'dashing' behavior during daytime. Shows hierarchies within small schools [Pauly 1994]. Available information on body composition of 'piranha caju' flesh is 8.2% fat, 15.0% protein and 4.4% ash [Junk 1976]."

"Eggs are laid on tree roots trailing in the water and are guarded; the reproductive success may vary strongly from year to year depending on how the savanna was flooded [Lowe-McConnell 1964]. The eggs are large, adhere to plants and are not attacked by the parents. They hatch in 9 to 10 days [Mills and Vevers 1989]."

From Nico and Neilson (2017):

"*Pygocentrus nattereri* is a schooling predator that consumes live fishes whole or by removing portions of fin, scales, or muscle. It also feeds on crustaceans, insects, molluscs, and plant material (Sazima and Machado 1990). Additionally, this species is known to scavenge, feeding on dead and/or decaying fishes, birds, mammals, and occasionally human corpses (Sazima and Guimarães 1987; Sazima and Machado 1990)."

"Spawning season occurs between [*sic*] approximately October to February and is associated with changes in environmental cues including photoperiod and/or rainfall (Duponchelle et al. 2007; Queiroz et al. 2010). Spawning occurs in small nests dug within grasses or other marginal vegetation (Uetanabaro et al 1993; Queiroz et al. 2010)"

## Human Uses

From Froese and Pauly (2017):

"Fisheries: minor commercial; aquarium: commercial"

## Diseases

From Froese and Pauly (2017)

"Ichthyobodo Infection, Parasitic infestations (protozoa, worms, etc.)
Bacterial Infections (general), Bacterial diseases
*Eustrongylides* Infestation 2 (Larvae), Parasitic infestations (protozoa, worms, etc.)
*Procamallanus* Infection 10, Parasitic infestations (protozoa, worms, etc.)"

From Gomez et al. (2006):

"Betanodaviruses are the causative agents of viral nervous necrosis (VNN) in cultured marine fish. […] The brains of the fish and other tissues of the invertebrates were examined by reverse transcriptase-polymerase chain reaction (RT-PCR) and nested PCR to detect betanodavirus. Positive nested PCR results were obtained from […] 2 freshwater fish species (South American leaf fish *Monocirrhus polyacanthus* and red piranha *Pygocentrus nattereri*). […] These subclinically infected aquarium fish and invertebrates may constitute an inoculum source of betanodaviruses for cultured fishes in the Korean Peninsula."

From Evely et al. (2011):

"Fish tuberculosis is caused by several species of *Mycobacterium*; the most common of which is *Mycobacterium marinum* (Decostere et al. 2004). *Mycobacterium fortuitum* has been less frequently documented and is most commonly seen in freshwater fish, while *Mycobacterium chelonae* infections have primarily been identified in Pacific cold water salmonid species (Decostere et al. 2004). […] To the authors knowledge, this is the first case report of *M. chelonae* infection in a piranha [*Pygocentrus nattereri*] and the first report of ocular localization of mycobacteriosis without systemic lesions."

Eiras et al. (2016) list *Pygocentrus nattereri* as a host of the following fish-infecting nematodes with zoonotic potential: *Contyracaecum* sp. (larva), *Eustrongylides ignotus* Jägerskiöld, 1909 (larva), *Eustrongylides* sp. (larva).

No OIE-reportable diseases were documented for *Pygocentrus nattereri*.

## Threat to Humans

From Nico and Neilson (2017):

"Although *P. nattereri* is considered one of the more aggressive piranha species, many experts consider its danger to humans greatly exaggerated. Nevertheless, considerable care must be taken in handling live individuals."

From Froese and Pauly (2017):

"Traumatogenic [Robins et al. 1991]"

From Putz (2002):

"*Pygocentrus nattereri* is considered one of the more dangerous and aggressive species of piranha. (Fuller, et al., 1999)"

*Pygocentrus nattereri* is a host of several fish-infecting nematodes with zoonotic potential (Eiras et al. 2016).

# 3 Impacts of Introductions

From Singh and Lakra (2011):

"During our survey study, we have captured some live specimens of red-belied [*sic*] piranha *Pygocentrus nattereri* from Periyar river of Kerala [India]. This fish also existed in the Dimbhe reservoir near Pune, Maharashtra [India] and there are incidences of some people bitten when they entered into the reservoir for their day to day work."

From Guerrero (2014):

"Among its [*Pygocentrus nattereri*'s] negative impacts is its ability to cause human injuries through bites or stings (Fuller et al. 1999). The reputation of the piranha as a 'man-eater' is said to be exaggerated and 'it is unlikely to become widespread outside its natural habitat' ([Vicentin] et al. 201[3]; Bleher pers. comm.)."

From Nico and Neilson (2017):

"Impact of Introduction: Unknown."

From Cagauan (2007):

"Since its introduction in 1970-1979, [there has been] no available information on its establishment and invasive impacts [in the Philippines]."

From Latini and Petrere (2004):

"The introduction of these species [*Pygocentrus nattereri* and others] in lakes of the [River Doce State] Park [in southeastern Brazil] affected the native fish community, causing the disappearance of some species and a reduction in the abundance of young individuals of others, coupled with reduction in mean weight of these individuals (Sunaga & Verani 1991; Godinho, Fonseca & Araújo 1994)."

"[…] in the lakes with alien species, the most heterogeneous habitats do not apparently serve as refugia for the native fish populations. These facts suggest that the importance of macrophyte mats as refugia to native fishes should be related with bionomics and behaviour of native and alien species that comprise the impacted community. If an alien species efficiently uses these mats, e.g. *P. nattereri*, there would be a smaller chance for a native species, e.g. the chameleon cichlid, *Cichlasoma facetum* (Jenyns), to efficiently use the same area as refugia."

From Fragoso-Moura et al. (2016):

"This study discusses the effects of non-native fish species in the largest conservation unit of Atlantic Forest in Minas Gerais [Brazil] […] A total of 17 fish species was collected (2006-2010) of which five were introduced species. Among the small to medium size native species (30 to 2000 mm standard length) seven had disappeared, two are new records and one was

recaptured. The non-native species *Cichla kelberi* (peacock bass) and *Pygocentrus nattereri* (red piranha) are within the most abundant captured species."

"[…] for *C. kelberi* and *P. nattereri* there are better documented introduction records. According to Godinho et al. (1994) both were introduced in the middle Rio Doce [Brazil] in the 1960's in the surrounding lakes of the Rio Doce State Park and the important impact on native species is mainly attributed to these two species (Godinho, 1996). An example of this impact on local biodiversity is the disappearance of *Oligosarcus solitarius* Menezes, 1987, an endemic species of the region, in lakes where the presence of *C. kelberi* and *P. nattereri* was identified (Vieira, 1994). Moreover, other small sized species, major food sources for piscivorous species, like *M. doceana*, *Geophagus brasiliensis* (Quoy & Gaimard, 1824) and *Australoheros* sp., were also directly affected and not recorded in Lake Carioca since 1992 to the present date."

"*Hoplias* gr. *malabaricus*, a native piscivorous species, changes its diet to shrimps in some lakes inside and surrounding the Rio Doce State Park with *C. kelberi* and *P. nattereri* (Pompeu and Godinho, 2001)."

From Bennett et al. (1997):

"Although red-bellied piranhas may temporarily colonize parts of southern Alabama, Georgia, Louisiana, and Mississippi, cyclic recurrence of lethal low temperatures make it unlikely that persistent populations could become established in these states. […] But it is equally possible that one or more unusually mild winters would allow red-bellied piranhas to overwinter and perhaps even reach population levels where they would pose a risk to native ecosystems. Inevitably, however, severe winter conditions would return and water temperatures would fall to lethal levels. Even in Arizona, California, Florida, and Texas, where thermal conditions are more conducive to red-bellied piranha establishment […], the fish's northern distribution extremes could be expected to show considerable year-to-year variation."

According to Bennett et al. (1997), states that specifically prohibit the sale, possession, or transport of piranhas within their borders include: Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Illinois, Kentucky, Louisiana, Massachusetts, Mississippi, Nevada, New Mexico, New York, Oklahoma, Oregon, Texas, Vermont, Virginia, and Washington.

# 4 Global Distribution

**Figure 1.** Known global distribution of *Pygocentrus nattereri*, reported from South America. Map from GBIF Secretariat (2017). Occurrences in North America are excluded from this map and from the climate matching analysis because they do not represent established populations. Although noted as established in China (see Distribution Outside the United States, above), no georeferenced occurrences are available for that country.

# 5 Distribution Within the United States

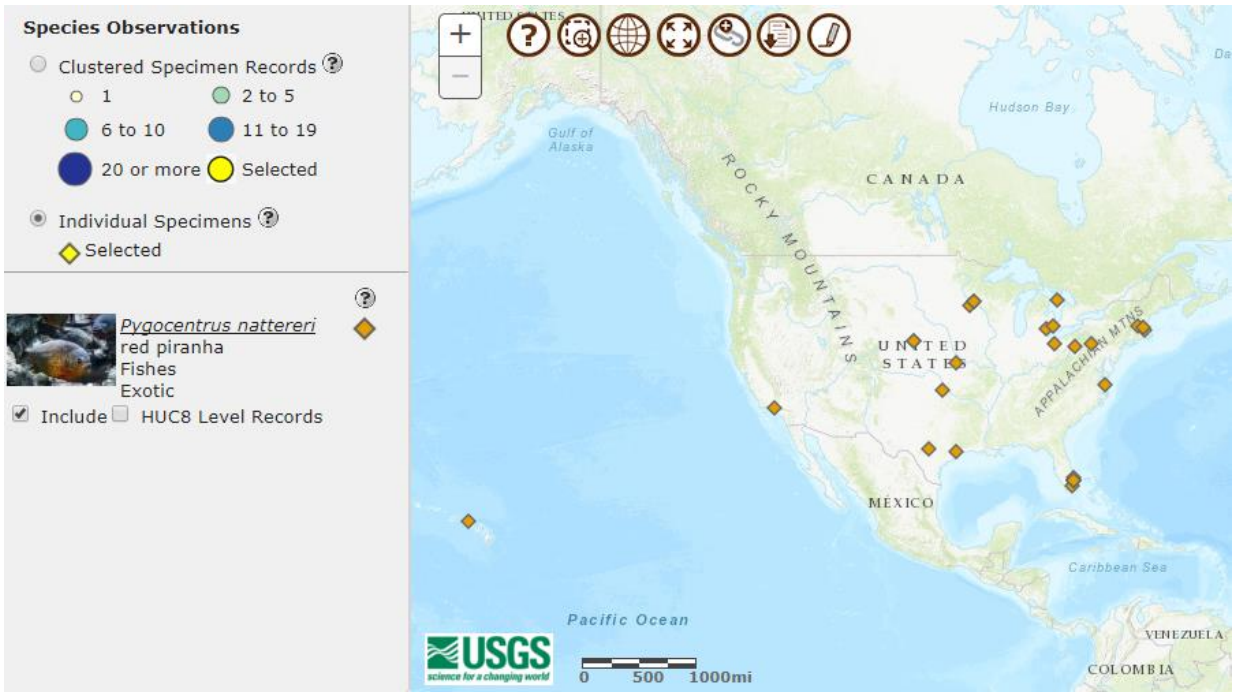


**Figure 2.** Known occurrences of *Pygocentrus nattereri* in the United States. None of the mapped occurrences represent established populations, so none of these points were used in the climate matching analysis. Map from Nico and Neilson (2017).

# 6 Climate Matching

## Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014; 16 climate variables; Euclidean Distance) for *Pygocentrus nattereri* in the contiguous United States is medium overall, represented by a Climate6 proportion of 0.065. Proportions between 0.005 and 0.103 are classified as medium match. Locally, peninsular Florida and large areas of the Gulf Coast showed high matches, while much of the remainder of the southeastern U.S. showed medium matches. Low matches were found in the northeast, north-central, and western portions of the contiguous U.S.

The climate matching source locations do not include any locations in China, where the species is established outside its native range (Xiong et al. 2015), because no georeferenced occurrences were available.

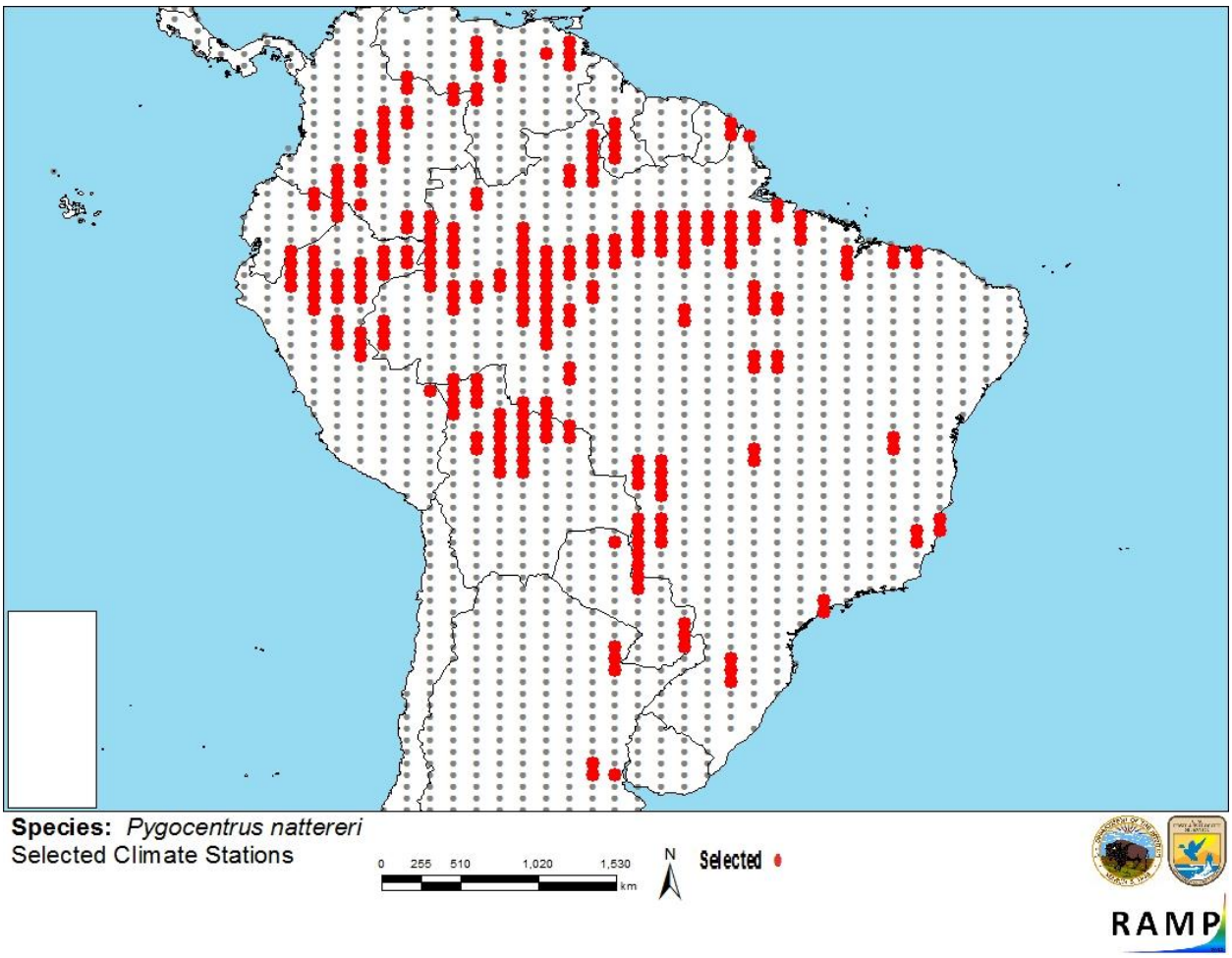


**Figure 3.** RAMP (Sanders et al. 2014) source map showing weather stations in South America selected as source locations (red) and non-source locations (gray) for *P. nattereri* climate matching. Source locations from GBIF Secretariat (2017).

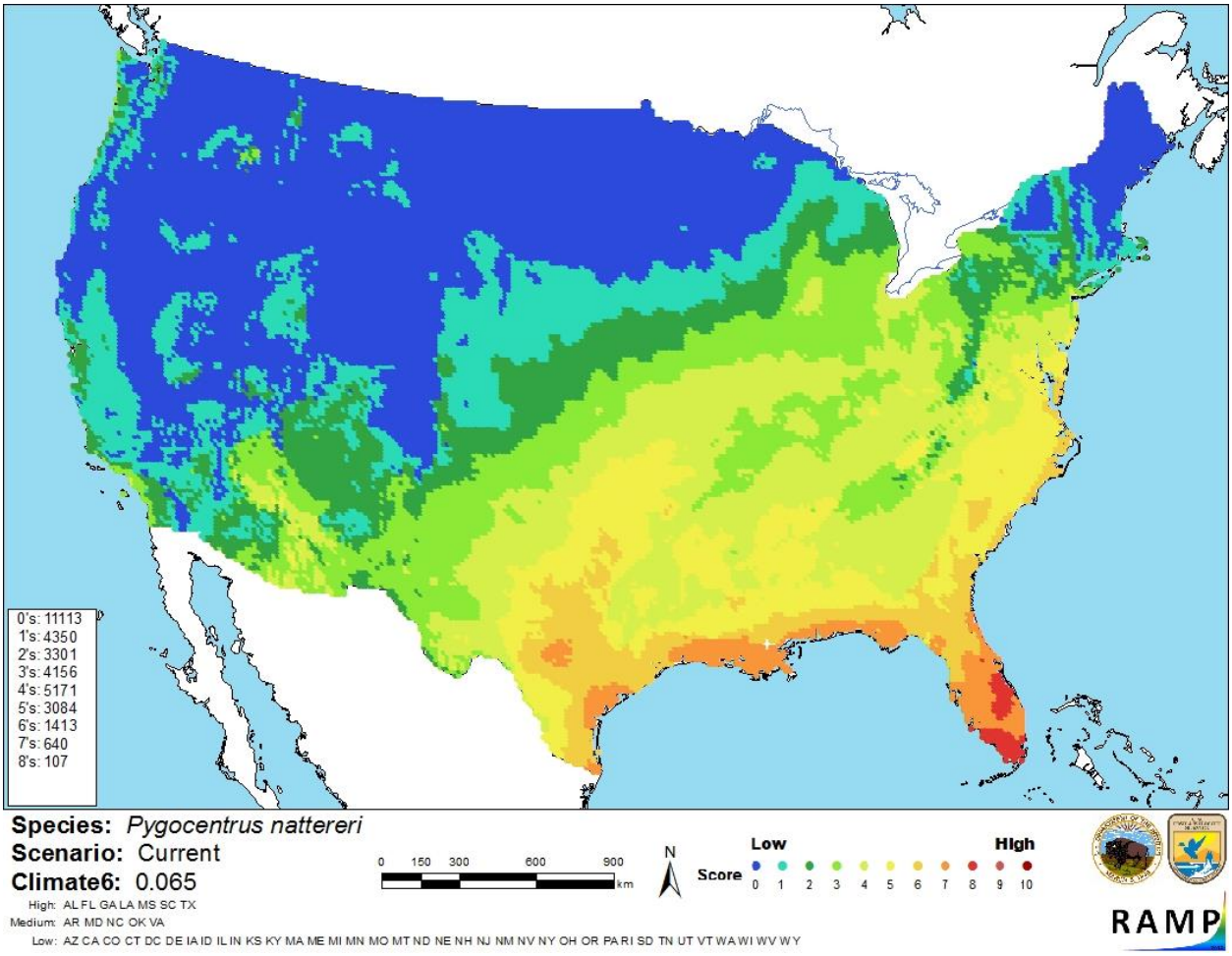


**Figure 4.** Map of RAMP (Sanders et al. 2014) climate matches for *P. nattereri* in the contiguous United States based on source locations reported by GBIF Secretariat (2017). 0=Lowest match, 10=Highest match.

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

A considerable amount of information on the biology, ecology, and distribution of *Pygocentrus nattereri* is available for review. Despite numerous specimens having been captured outside their native range, there are a limited number of established non-native populations. Literature sources vary in the severity of impact described for these populations and in the level of certainty that impacts are occurring. Given these inconsistencies, certainty of this assessment is medium.

# 8 Risk Assessment

## Summary of Risk to the Contiguous United States

*Pygocentrus nattereri* is a species of piranha native to the Amazon, Paraguay-Paraná, and Essequibo river basins in South America, as well as north-coastal rivers in Brazil. *P. nattereri* is a host of several fish-infecting nematodes with zoonotic potential. This aggressive species of piranha has a medium climate match with the contiguous United States, but would likely face difficulties overwintering in most regions. Numerous *P. nattereri* specimens have been taken from waterbodies across the contiguous United States, but all populations have failed or been eradicated. These introductions most likely resulted from aquarium releases; approximately half of U.S. states allow for trade and possession of this species by hobbyists. In India, *P. nattereri* introduction has led to reports of human injury. In Brazil, introductions of *P. nattereri* and *Cichla kelberi* (peacock bass) have been associated with disappearance of native species from several water bodies, although the distinct contributions of *P. nattereri* and *C. kelberi* to these changes have not been quantified. Given the history of negative impacts of introduction in other parts of the world and the medium climate match to the contiguous United States, the overall risk assessment category for *P. nattereri* is high.

## Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): Medium**
- **Certainty of Assessment (Sec. 7): Medium**
- **Remarks/Important additional information: *P. nattereri* is a host of several fish-infecting nematodes with zoonotic potential.**
- **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.**


Bennett, W. A., R. J. Currie, P. F. Wagner, and T. L. Beitinger. 1997. Cold tolerance and potential overwintering of the red-bellied piranha *Pygocentrus nattereri* in the United States. Transactions of the American Fisheries Society 126(5):841-849.

Cagauan, A. G. 2007. Exotic aquatic species introduction in the Philippines for aquaculture – a threat to biodiversity or a boon to the economy? Journal of Environmental Science and Management 10(1):48-62.

Eiras, J. C., G. C. Pavanelli, R. M. Takemoto, M. U. Yamaguchi, L. C. Karkling, and Y. Nawa. 2016. Potential risk of fish-borne nematode infections in humans in Brazil – current status based on a literature review. Food and Waterborne Parasitology 5:1-6.

Evely, M. M., J. M. Donahue, S. F. Sells, and A. T. Loynachan. 2011. Ocular mycobacteriosis in a red-bellied piranha, *Pygocentrus nattereri* Kner. Journal of Fish Diseases 34:323-326.

Fragoso-Moura, E. N., L. T. Oporto, P. M. Maia-Barbosa, and F. A. R. Barbosa. 2016. Loss of biodiversity in a conservation unit of the Brazilian Atlantic Forest: the effect of introducing non-native fish species. Brazilian Journal of Biology 76(1):18-27.

Froese, R., and D. Pauly, editors. 2017. *Pygocentrus nattereri* Kner, 1858. FishBase. Available: http://www.fishbase.us/summary/SpeciesSummary.php?ID=4501&AT=red+piranha. (December 2017).

GBIF Secretariat. 2017. GBIF backbone taxonomy: *Pygocentrus nattereri* Kner, 1858. Global Biodiversity Information Facility, Copenhagen. Available: https://www.gbif.org/species/2352479. (December 2017).

Gomez, D. K., D. J. Lim, G. W. Baeck, H. J. Youn, N. S. Shin, H. Y. Youn, C. Y. Hwang, J. H. Park, and S. C. Park. 2006. Detection of betanodaviruses in apparently healthy aquarium fishes and invertebrates. Journal of Veterinary Science 7(4):369-374.

Guerrero, R. D. III. 2014. Impacts of introduced freshwater fishes in the Philippines (1905–2013): a review and recommendations. Philippine Journal of Science 143:49-59.

ITIS (Integrated Taxonomic Information System). 2017. *Pygocentrus nattereri* Kner, 1858. Integrated Taxonomic Information System, Reston, Virginia. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=641816#null. (December 2017).

Knight, J. D. M. 2010. Invasive ornamental fish: a potential threat to aquatic biodiversity in peninsular India. Journal of Threatened Taxa 2:700-704.

Latini, A. O., and M. Petrere. 2004. Reduction of a native fish fauna by alien species: an example from Brazilian freshwater tropical lakes. Fisheries Management and Ecology 11(2):71-79.

Nico, L., and M. Neilson. 2017. *Pygocentrus nattereri* Kner, 1858. U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=429. (December 2017).

Putz, B. 2002. *Pygocentrus nattereri*. Animal Diversity Web. Available: http://animaldiversity.org/accounts/Pygocentrus_nattereri/. (December 2017).

Sanders, S., C. Castiglione, and M. Hoff. 2014. Risk Assessment Mapping Program: RAMP. U.S. Fish and Wildlife Service.

Singh, A. K., and W. S. Lakra. 2011. Ecological impacts of exotic fish species in India. Aquaculture Asia Magazine 16(2):23-25.

Xiong, W., X. Sui, S. H. Liang, and Y. Chen. 2015. Non-native freshwater fish species in China. Reviews in Fish Biology and Fisheries 25(4):651-687.

# 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.**

Agostinho, A. A. 1996. O lado oculto da introdução de peixes. Boletim Informativo da Abrapoa 7:9-11.

Agostinho, A. A., and H. F. Júlio. 1996. Ameaça ecológica: peixes de outras águas. Ciéncia Hoje 21:36-44.

Agostinho, A. A., H. F. Julio, and M. Petrere, Jr. 1994. Itaipu Reservoir (Brazil): impacts of the impoundment on the fish fauna and fisheries. Pages 171-184 *in* I. G. Cowx, editor. Rehabilitation of freshwater fisheries. Fishing News Books, Blackwell Science, Oxford, U.K.

Bijukumar, A. 2000. Exotic fishes and freshwater fish diversity. Zoos' Print Journal 15(11): 363-367.

Britski, H. A., K. Z. de S. de Silimon, and B. S. Lopes. 2007. Peixes do Pantanal: manual de identificação, 2nd edition, revised and expanded. Embrapa Informação Tecnológica, Brasília, Brazil.

Cardoza, J. E., G. S. Jones, T. W. French, and D. B. Halliwell. 1993. Exotic and translocated vertebrates of Massachusetts, 2nd edition. Fauna of Massachusetts Series 6. Publication 17223-110-200-11/93-C.R. Massachusetts Division of Fisheries and Wildlife, Westborough, Massachusetts.

Courtenay, W. R., Jr., and D. A. Hensley. 1979. Survey of introduced non-native fishes. Phase I report. Introduced exotic fishes in North America: status 1979. Report submitted to National Fishery Research Laboratory, U.S. Fish and Wildlife Service, Gainesville, Florida.

Courtenay, W. R., Jr., D. A. Hensley, J. N. Taylor, and J. A. McCann. 1984. Distribution of exotic fishes in the continental United States. Pages 41-77 *in* W. R. Courtenay, Jr., and J. R. Stauffer, Jr., editors. Distribution, biology and management of exotic fishes. Johns Hopkins University Press, Baltimore, Maryland.

Courtenay, W. R., Jr., D. P. Jennings, and J. D. Williams. 1991. Appendix 2: exotic fishes. Pages 97-107 *in* C. R. Robins, R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott, editors. Common names and scientific names of fishes from the United States and Canada, 5th edition. American Fisheries Society, Bethesda, Maryland.

Courtenay, W. R., Jr., H. F. Sahlman, W. W. Miley II, and D. J. Herrema. 1974. Exotic fishes in fresh and brackish waters of Florida. Biological Conservation 6(4):292-302.

Courtenay, W. R., Jr., and J. R. Stauffer, Jr. 1990. The introduced fish problem and the aquarium fish industry. Journal of the World Aquaculture Society 21(3):145-159.

Cudmore-Vokey, B., and E. J. Crossman. 2000. Checklists of the fish fauna of the Laurentian Great Lakes and their connecting channels. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2500.

Decostere, A., K. Hermans, and F. Haesebrouch. 2004. Piscine mycobacteriosis: a literature review covering the agent and the disease it causes in fish and humans. Veterinary Microbiology 99:159-166.

Devick, W. S. 1992. The great piranha hunt. Hawaii Fishing News 17(10):6-7.

Duponchelle, F., F. Lino, N. Hubert, J. Panfili, J.-F. Renno, E. Baras, J. P. Torrico, R. Dugue, and J. Nuñez. 2007. Environment-related life-history trait variations of the red-bellied piranha *Pygocentrus nattereri* in two river basins of the Bolivian Amazon. Journal of Fish Biology 71:1113-1134.

Fink, W. L. 1993. Revision of the piranha genus *Pygocentrus* (Teleostei, Characiformes). Copeia 1993(3):665-687.

Fuller, P., L. Nico, and J. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Bethesda, Maryland.

Godinho, A. L. 1996. Peixes do Parque Estadual do Rio Doce. IEF/UFMG, Belo Horizonte, Brazil.

Godinho, A. L., M. T. Fonseca, and M. L. Araújo. 1994. The ecology of predator fish introductions: the case of Rio Doce valley lakes. Pages 77-83 *in* R. M. Pinto-Coelho, A. Giani, and E. von Sperling, editors. Ecology and human impact on lakes and reservoirs in Minas Gerais with special reference to future development and management strategies. SEGRAC, Belo Horizonte, Brazil.

Godinho, A. L., and P. S. Formagio. 1992. Efeitos da introdução de Cichla ocellaris e *Pygocentrus* sp. sobre a comunidade de peixes da Lagoa Dom Helvécio. Encontro Anual de Aqüicultura de Minas Gerais 10:93-102.

Goulding, M. 1980. The fishes and the forest: explorations in Amazonian natural history. University of California Press, Berkeley.

Hartel, K. 1992. Non-native fishes known from Massachusetts freshwaters. Occasional Reports of the Museum of Comparative Zoology Fish Department 2:1-9.

Howells, R. G., R. L. Benefield, and J. M. Mambretti. 1991. Records of pacus (*Colossoma* spp.) and piranhas (*Serrasalmus* spp.) in Texas. Texas Parks and Wildlife, Management Data Series 70, Austin, Texas.

IGFA (International Game Fish Association). 2001. Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, Florida.

Jégu, M. 2003. Serrasalminae (pacus and piranhas). Pages 182-196 *in* R. E. Reis, S. O. Kullander, and C. J. Ferraris, Jr., editors. Checklist of the freshwater fishes of South and Central America. EDIPUCRS, Porto Alegre, Brazil.

Jenkins, R. E., and N. M. Burkhead. 1994. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Junk, W. J. 1976. Biologia de água doce e pesca interior. Page 105 *in* Relatorio anual de INPA. Instituto Nacional de Pesquisas da Amazonia, Manaus, Brazil.

Lowe-McConnell, R. H. 1964. The fishes of the Rupununi Savana district of British Guiana, South America, part 1. Ecological groupings of fish species and effects of the seasonal cycle on the fish. Zoological Journal of the Linnean Society 45(304):103-144.

Middleton, K. 1988. Man-eating fish found in river. Athens News Courier (September 1) 105(177):1-2.

Mills, D., and G. Vevers. 1989. The Tetra encyclopedia of freshwater tropical aquarium fishes. Tetra Press, New Jersey.

Pauly, D. 1994. Quantitative analysis of published data on the growth, metabolism, food consumption, and related features of the red-bellied piranha, *Serrasalmus nattereri* (Characidae). Environmental Biology of Fishes 41:423-437.

Pompeu, O. S., and A. L. Godinho. 2001. Mudança na dieta da traíra *Hoplias malabaricus* (Bloch) (Erythrinidae, Characiformes) em lagoas da bacia do rio Doce devido à introdução de peixes piscívoros. Revista Brasileira de Zoologia 18(4):1219-1225.

Queiroz, H. L., M. B. Sobanski, and A. E. Magurran. 2010. Reproductive strategies of red-bellied piranha (*Pygocentrus nattereri* Kner, 1858) in the white waters of the Mamirauá flooded forest, central Brazilian Amazon. Environmental Biology of Fishes 89:11-19.

Radtke, R. L. 1995. Forensic biological pursuits of exotic fish origins: piranha in Hawaii. Environmental Biology of Fishes 43:393-399.

Riehl, R., and H. A. Baensch. 1996. Aquarien Atlas, volume 1, 10th edition. Mergus Verlag GmBH, Melle, Germany.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. World fishes important to North Americans. Exclusive of species from the continental waters of the United States and Canada. American Fisheries Society Special Publication 21.

Sazima, I., and S. de A. Guimarães. 1987. Scavenging on human corpses as a source for stories about man-eating piranhas. Environmental Biology of Fishes 20(1):75-77.

Sazima, I., and F. A. Machado. 1990. Underwater observations of piranhas in western Brazil. Environmental Biology of Fishes 28:17-31.

Stone, S. 1987. 6-inch piranha found in pit at Indian Lakes. Virginia Pilot and Ledger Star (August 23).

Stroud, R. A. 1976. Ohio piranha. Sport Fishing Institute Bulletin 272:3.

Sunaga, T., and J. R. Verani. 1985. Preliminary report of comparative study on fish community of the Rio Doce Valley lakes. Pages 167-174 *in* Y. Saijo, and J. G. Tundisi, editors. Limnological studies in Rio Doce Valley lakes and Pantanal wetland, Brazil, volume 1. Nagoya University Press, Nagoya, Japan.

Sunaga, T., and J. R. Verani. 1987. Second report of comparative study on fish community of the Rio Doce Valley lakes. Pages 129-135 *in* Y. Saijo, and J. G. Tundisi, editors. Limnological studies in Rio Doce Valley lakes and Pantanal wetland, Brazil, volume 2. Nagoya University Press, Nagoya, Japan.

Sunaga, T., and J. R. Verani. 1991. The fish communities of the lakes in Rio Doce Valley, Northeast, Brazil. Verhandlungen der Internationalen Vereinigung für Theoretiche und Angewandte Limnologie 24:2563-2566.

Uetanabaro, M., T. Wang, and A. S. Abe. 1993. Breeding behaviour of the red-bellied piranha, *Pygocentrus nattereri*, in nature. Environmental Biology of Fishes 38:369-371.

Vieira, F. 1994. Estrutura de comunidade e aspectos da alimentação e reprodução dos peixes em dois lagos do médio Rio Doce. Master's thesis. Universidade Federal de Minas Gerais, Belo Horizonte, Brazil. Available: http://www.icb.ufmg.br/pgecologia/dissertacoes/D019_Fabio_Vieira.pdf. (April 2013).

Vicentin, W., F. E. dos Santos Costa, and Y. R. Súarez. 2013. Population ecology of Red-bellied Piranha Pygocentrus nattereri Kner, 1858 (Characidae: Serrasalminae) in the Negro River, Pantanal, Brazil. Environmental Biology of Fishes 96:57.

Zaniboni Filho, E., S. Meurer, O. A. Shibatta, and A. P. de Oliverira Nuñer. 2004. Catálogo ilustrado de peixes do alto Rio Uruguai. Editora da UFSC, Tractebel Energia, Florianópolis, Brazil.