Arapaima (*Arapaima gigas*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, November 2021
Revised, December 2021
Web Version, 5/19/2022

Organism Type: Fish
Overall Risk Assessment Category: Uncertain

Photo: Citron. Licensed under Creative Commons BY-SA 3.0 Unported. Available: https://commons.wikimedia.org/wiki/File:Arapaima_gigas_captivity.jpg. (November 2021)

1 Native Range and Status in the United States

Native Range

From Fricke et al. (2021):

"Distribution: South America: Amazon River basin: Brazil, Colombia, Ecuador, Guyana (?) and Peru."

From Froese and Pauly (2021):

"South America: Amazon River basin."

"[In Peru:] Occurs mainly in Ucayali and Marañon Rivers, with the exception of Pacaya-Samiria [Tello and Sánchez 1995]."

Castello and Stewart (2010) present a map summarizing "best available information on geographic distribution of *Arapaima* genus," reporting the species from the Amazon River basin (Brazil, far southern Colombia, eastern Ecuador, northeastern Peru), the Essequibo River basin in Guyana, and the Tocantins River basin in Brazil.

Status in the United States

There are no reported wild established populations of *Arapaima gigas* in the United States. This species is in trade in the United States. For example:

From Predatory Fins (2021):

"Arapaima (Arapaima Gigas) […]
$195.00"

Predatory Fins is based in Boca Raton, Florida.

Procopio (2021) indicates two failed introductions of *Arapaima* sp. in the United States (Florida and Louisiana), however it is unknown which species was introduced and therefore will not be included in this assessment.

From Shaw (2020):

"On August 26, we turned to animal care and conservation leader Shedd Aquarium for assistance in the rescue and rehabilitation of 102 internationally protected juvenile arapaima (*Arapaima gigas*) that were confiscated from O'Hare International Airport following an attempted illegal importation for the pet trade industry. The species is one of the world's largest freshwater fishes and is listed as protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) at the Appendix II level."

From Oklahoma Secretary of State (2019):

"(a) Until such time as is necessary for the Department of Wildlife Conservation to obtain adequate information for the determination of other harmful or potentially harmful exotic species, the importation into the State and/or the possession of the following exotic fish or their eggs is prohibited: […] (3) Boney-tongue group: *Osteoglossum* spp., and *Arapaima* spp."

From Texas Parks and Wildlife (2021):

"The organisms listed here are legally classified as exotic, harmful, or potentially harmful. No person may possess or place them into water of this state except as authorized by the department. Permits are required for any individual to possess, sell, import, export, transport or propagate listed species for zoological or research purposes; for aquaculture […] or for aquatic weed control […]. […] *Arapaima gigas*"

From Arizona Office of the Secretary of State (2013):

"**I.** Fish listed below are considered restricted wildlife: […] 4. The species *Arapaima gigas*."

The Florida Fish and Wildlife Conservation Commission has listed the *Arapaima gigas* as a conditional species. Conditional nonnative species (FFWCC 2021) "are considered to be dangerous to the ecology and/or the health and welfare of the people of Florida. These species are not allowed to be personally possessed, although exceptions are made by permit from the Executive Director for research, commercial use (with security measures to prevent escape or release) or public exhibition purposes."

Means of Introductions in the United States

There are no reported wild established populations of *Arapaima gigas* in the United States.

Remarks

This ERSS was previously published in August 2019. Revisions were completed to incorporate new information and conform to updated standards.

According to Fricke et al. (2021), *Arapaima gigas* was originally described as *Sudis gigas* (Schinz 1822) and has been known previously as *Clupisudis gigas* (Schinz 1822). The following are synonyms of *Arapaima gigas*: *Vastres arapaima*, *Vastres cuvieri*, and *Sudis gigas*. Information searches to inform this report were conducted for each synonym.

From Quieroz (2000):

"In Guyana this fish is called 'arapaima' […] In the eastern parts of Peru and Colombia, the species is known as 'paiche' […] In northern Brazil the common name is […] 'pirarucu'[…]"

From Froese and Pauly (2021):

"International trade restricted (CITES II, since [1975]). The active fishing of this fish has reduced both the population size, and occurrence of large individuals, especially around the populated regions of the Amazon [Ferraris 2003]."

"Threatened due to over harvesting [Stone 2007]."

From Procopio (2021):

"Until the work of Stewart (2013a), the genus *Arapaima* was thought to be monotypic, with *Arapaima gigas* considered as the only valid species (Castello and Stewart 2010; Hill and Lawson 2015). His reclassification of *A. agassizii* (Stewart 2013a), and description of new species (Stewart 2013b) uncovered hidden diversity within the genus, identifying a total of 5 distinct species. These species include *A. gigas*, *A. mapae*, *A. arapaima*, *A. agassizii*, and *A. leptosome* [*A. leptosoma*]. Stewart (2013a) and (2013b) present a detailed diagnosis of major morphological features that distinguish these 5 distinct Arapaima species."

From Farias et al. (2019):

"One of the most prominent uncertainties surrounding *Arapaima* is the number of species present in this genus and their distribution. Contrary to the assertions of Stewart [2013a,b], we find no evidence for multiple species of *Arapaima* existing or co-existing in the Amazon basin and satellite river basins."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

According to Fricke et al. (2021), *Arapaima gigas* (Schinz 1822) is the current valid name for this species.

From ITIS (2021):

Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Deuterostomia
Phylum Chordata
Subphylum Vertebrata
Infraphylum Gnathostomata
Superclass Actinopterygii
Class Teleostei
Superorder Osteoglossomorpha
Order Osteoglossiformes
Suborder Osteoglossoidei
Family Osteoglossidae
Subfamily Heterotidinae
Genus *Arapaima*
Species *Arapaima gigas* (Schinz, 1822)

Size, Weight, and Age Range

From Froese and Pauly (2021):

"Maturity: Lm ?, range 145 - 154 cm
Max length : 450 cm TL male/unsexed [about 14.8 feet]; [Axelrod et al. 1991]; common length :

200 cm [6.6 feet] TL male/unsexed; [Wheeler 1977]; max. published weight: 200.0 kg [about 440 lbs] [Wheeler 1977]"

Environment

From Froese and Pauly (2021):

"Freshwater; demersal; pH range: 6.0 - 6.5; dH range: 10 - ? […] 25°C - 29°C [Baensch and Riehl 1985; assumed to be the recommended aquarium temperature]"

From Lawson et al. (2015):

"This study is the first known experimental test of low-temperature tolerance for Arapaima. Our findings suggest Arapaima will not survive temperatures at or below 16°C."

Climate

From Froese and Pauly (2021):

"Tropical; […] 5°N - 11°S"

Distribution Outside the United States

Native

From Fricke et al. (2021):

"Distribution: South America: Amazon River basin: Brazil, Colombia, Ecuador, Guyana (?) and Peru."

From Froese and Pauly (2021):

"South America: Amazon River basin."

"[In Peru:] Occurs mainly in Ucayali and Marañon Rivers, with the exception of Pacaya-Samiria [Tello and Sánchez 1995]."

Castello and Stewart (2010) present a map summarizing "best available information on geographic distribution of *Arapaima* genus," reporting the species from the Amazon River basin (Brazil, far southern Colombia, eastern Ecuador, northeastern Peru), the Essequibo River basin in Guyana, and the Tocantins River basin in Brazil.

Introduced

From Fricke et al. (2021):

"Introduced in Java (Indonesia)."

According to Froese and Pauly (2021), *Arapaima gigas* has been introduced in Malaysia, Thailand, Mexico, Cuba, China, the Philippines, and Singapore. The status of *A. gigas* in the

wild is listed as probably established in Thailand; unknown in Malaysia, China, and the Philippines; probably not established in Singapore; and not established in Mexico and Cuba.

From Froese and Pauly (2021):

"Introduction [to Mexico] was unsuccessful due to cold climate."

"Large individuals sighted in Bedok Reservoir and some ponds in eastern Singapore. Possibly also in flooded quarry pits on Pulau Ubin."

From Fadjar et al. (2019):

"We present the first record of *Arapaima gigas* (Schinz, 1822) in Brantas River, Sidoarjo, East Java, Indonesia with diagnostic meristic and morphometrics of the specimens analyzed following Stewart method. Herein, it recorded from the Brantas River basin. This record based [sic] on the finding of one live specimen on the tributary of Brantas River basin, and in situ observation of juveniles and adults in the river) [sic]."

From Marková et al. (2020):

"In total, 27 individuals of giant arapaima were recorded in Indonesian freshwaters. Two of them were found in Sumatra and the others in Java […]"

"No nesting activity or fry and juveniles were found in Indonesian wild but, since eggs were found in the adult female, successful reproduction and subsequent establishment cannot be excluded."

From Miranda-Chumacero et al. (2012):

"According to people who participated in the activity, in 1979 about 1,000 arapaima fry were introduced into the Sandoval Lagoon [Peru] (Roger Pinedo, pers. comm. 2010). […] By the mid 1980s, arapaima was reported outside the lagoons in Peru, and at the beginning of the 1990s the species was first reported in Bolivian waters."

From Van Damme et al. (2015):

"*Arapaima* cf. *gigas* was first found in the upper headwaters of the Madera [Peru] in the 1960s […] Over the last half century, the species has spread downstream into Bolivian waters (Madre de Dios watershed)."

Means of Introduction Outside the United States

From Froese and Pauly (2021):

"There have been reports that this species has been released into natural waters by pet owners, […]"

Froese and Pauly (2021) also lists aquaculture as a reason for introduction.

From Fadjar et al. (2019):

“However, there have been no definite reports of how arapaima fish can enter the Brantas River [Indonesia]. We speculate that pirarucu was released into Brantas River by native people for an unclear purpose.”

From Marková et al. (2020):

“Based on personal investigation in the field, there are some local giant arapaima keepers who intentionally release the fishes into the wild in Indonesia […]”

From Miranda-Chumacero et al. (2012):

“Live arapaimas were transferred (from a place close to Iquitos [Peru]) for a fish-farming program in the Sandoval and Valencia lagoons (Peruvian side of the Madre de Dios River basin), close to the city of Puerto Maldonado in southeastern Peru, near the border of Bolivia (Wust 2001).”

“According to people who participated in the activity, in 1979 about 1,000 arapaima fry were introduced into the Sandoval Lagoon [Peru] (Roger Pinedo, pers. comm. 2010). The introduction occurred when the Madre de Dios River flooded and the rising water reached aquaculture ponds containing arapaima. As a result, the arapaima escaped into the broader watershed. By the mid 1980s, arapaima was reported outside the lagoons in Peru, and at the beginning of the 1990s the species was first reported in Bolivian waters.”

Short Description

From Queiroz (2000):

“This red colour [on *A. gigas*] is present for most of pirarucus [sic] life, and refers to spots of red pigmentation at the posterior border of scales, especially in some parts of the bodies of adults, as tail, dorsal, caudal and anal fins, and the middle posterior part, above and below lateral line.”

“Pirarucus [sic] have a big sub-cylindrical and laterally enlarged body that becomes progressively thin from the dorsal origin. The head is small and the inter-orbital space is plan [sic], with many bony plaques.”

“The scales are cicloid, large and thick. Their anterior part is striated and translucent, while their posterior part is granular and dark. In this darker part can be found a reddish hind border. The mosaic-like imbrication of scales (Jordan, 1905) put these reddish borders together, and the effect is a number or [sic] red spots organised in diagonal red stripes in those mentioned parts of pirarucu bodies. Pectoral and ventral fins are apart, but dorsal and anal fins are stand [sic] very close to the caudal fin, and sometimes there may be a communication among these three fins (Bard & Imbiriba, 1986).”

“From the very early stages of life, pirarucus have a dark brown coloration. This persists until the end of their first year. Then, coloration turns light brown with darker patches in head and dorsal area, while the ventral area is kept almost white. As the animals approach their maturity, the red spots start to develop, mostly in the posterior part of the bodies.”

Biology

From Froese and Pauly (2021):

“Often referred to as the largest freshwater fish. Builds a nest of about 15 cm depth and 50 cm width in sandy bottoms. Spawns in April and May and guards the eggs and the young. Obligate air breather. The fish rises to the surface of the water and inspires air in a noisy, distinctive gulp, which is reported to carry for long distances [Ferraris 2003]. Migrates into higher floodplain habitats with rising water and moves back eventually to lacustrine habitats during low water level [Castello 2008].”

From Castello (2008):

“Fontanele (1948) concluded that the nests are ‘cooking-pan’ like holes in the substrata, which the fish dig with their mouths. The nests measure c. 500 mm in diameter, and occur in shallow areas (c. 1 m in depth) away from floating vegetation (Fontanele, 1948). Based on a survey of 11 nests, Queiroz (2000) concluded that the nests were built in lakes, occur at average densities of 2·1 nests km^{-1} along margins and banks, and have diameters ranging from 190 to 670 mm. Mean depth of the nests was 120 mm (Queiroz, 2000).”

“A summary of the existing information on the main reproductive and migratory activities of the giant pirarucu during an annual flood cycle suggests most giant pirarucu inhabit lakes but can be found also in rivers and connecting channels during low water levels, roughly from September to January every year (Castello, in press; pers. obs.). At that time, the adults form pairs. Both sexes of adult giant pirarucu collaborate to build their nest in the margins and banks of lakes, temporary lakes and connecting channels during rising water levels (Queiroz, 2000). They take from 3 to 5 days to build their nests, spawn immediately after the nests are ready, and the young hatch from 3 to 5 days after the adults spawn (Fontanele, 1948). After the larvae hatch, most females leave (pers. obs.), and some may reproduce again in the same season (Queiroz, 2000). The males protect the young by staying close to them, usually no farther than 1 m away. The males protect and guide the young by swimming slowly through the food-rich environments of flooded forest during the following weeks. The male giant pirarucu care for their young for c. 3 months (Castello, in press). As water levels decline, the adult giant pirarucu separate from their young, and they all migrate to communicating channels and lakes.”

From Queiroz (2000):

“The analysis of pirarucu feeding baits demonstrated that pirarucus are specialised [sic] carnivores, living mainly on fishes. Other invertebrate species are also important in their diet.”

Human Uses

From Froese and Pauly (2021):

"Fisheries: commercial; aquaculture: commercial; gamefish: yes; aquarium: public aquariums"

"Much appreciated food fish. Overfished in 1998. Catch prohibited from November to March [in Brazil] [Ferreira et al. 1998]."

"Minimum size of capture is 1 m [in Peru]. However, this restriction is hardly enforced [Wheeler 1977]."

Diseases

No OIE-reportable diseases (OIE 2021) were found to be associated with *Arapaima gigas*.

From Froese and Pauly (2021):

"Mexiconema Infestation, Parasitic infestations (protozoa, worms, etc.)
Terranova Infection 2, Parasitic infestations (protozoa, worms, etc.)
Goezia Disease 6, Parasitic infestations (protozoa, worms, etc.)
Goezia Disease 6, Parasitic infestations (protozoa, worms, etc.)
Camallanus Infection 15, Parasitic infestations (protozoa, worms, etc.)
Nilonema Infection, Parasitic infestations (protozoa, worms, etc.)
Rumai Infection, Parasitic infestations (protozoa, worms, etc.)
Gnathostoma Infestation 3, Parasitic infestations (protozoa, worms, etc.)"

According to Bailly (2017), *Arapaima gigas* can be the host to the following parasites: *Caballerotrema arapaimense*, *Caballerotrema brasiliense*, *Caballerotrema piscicola*, *Dawestrema cycloancistrium*, *Dolops discoidalis*, and *Nesolecithus janickii*.

In addition to the parasites and diseases listed above, Poelen et al. (2014) lists the following as parasites of *Arapaima gigas*: *Pucciniastrum*, *Calyptospora* sp., *Caballerotrema brasiliensis*, *Dawestrema cycloacistrioides*, *Schizocoerus liguloideus*, *Polyacanthorhynchus macrorhynchus*, *Dawestrema cycloancistrioides*, *Schizochoerus liguloides*, *Dawestrema punctata*, *Camallanus tridentatus*, *Caballerotrema*, and *Salmonella enterica* subsp. *arizonae*.

Threat to Humans

From Froese and Pauly (2021):

"Harmless"

3 Impacts of Introductions

Although *Arapaima gigas* has been recorded as introduced outside of its native range, there is limited information available on the impacts of these introductions and some information focuses only on potential impacts and not observed impacts.

From Fadjar et al. (2019):

"Another study reports that the introduction of arapaima has caused severe environmental impacts such as causing a reduction of native fish populations, including many fish of high commercial value (Van [Damme] 2006)."

"The potential for negative ecosystem impacts of the *Arapaima gigas* invasion as Nonnative [sic] fish species in Brantas river seems likely, considering the large body size, life history, and feeding ecology of this species, but has not yet been demonstrated (Van [Damme] et al. 2015). […] Economically it will have a negative impact, such as reducing the stock of fisherman catches in the river and can [sic] eliminate fish resources needed by the community. Notwithstanding, to our knowledge, there is no assessment evaluating the consequences of *Arapaima gigas* introduction on the native fauna of Brantas River."

From Procopio (2021):

"In Bolivia, *Arapaima gigas* is suspected of having negatively impacted native fish populations, causing the decline of commercially valuable species (Van Damme 2006; Miranda-Chumacero et al. 2012; Hill and Lawson 2015). Fadjar et al. (2019) hypothesized that the establishment of *A. gigas* in the Brantas River, Indonesia, would result in negative economic and environmental impacts, but emphasized that a study examining this had not been completed."

From Van Damme et al. (2015):

"Despite the size of the fish, and its reported role as a top predator, fisheries information is not conclusive on a possible negative impact on other commercial species [in Bolivia] (but see Miranda-Chumacero et al. 2013). However, support for this hypothesis is confounded by changes in targets by the commercial fleet as they shift from a more multi-species catch of migratory catfish species (predominantly *Pseudoplatystoma* spp.) and characid species (*C. macropomum*, *Piaractus brachypomus* (Cuvier, 1818)) to a more specialized fishing of *A.* cf. *gigas*. Some indigenous communities report that the paiche is reducing their catches of small characids, and, since *A*. cf. *gigas* is not traditionally utilized, see it as a pest that needs to be eliminated."

From Miranda-Chumacero et al. (2012):

"All that is known about the impact of arapaima on fish communities is limited to an intentional introduction to control piranha proliferation in lakes in the southeastern Brazil. Although this strategy was successful, it also drastically reduced the number of native fish species in these water bodies (Oliveira 1944; Fontenele 1948; Helder Quiroz and Kelven Lopes, pers. comm.)."

From Hill and Lawson (2015):

"We used a screening tool, the Fish Invasiveness Screening Kit (FISK), coupled with a detailed literature review to evaluate the risks of the genus Arapaima across Florida, where there is

growing interest in its culture as a food fish. We found a medium risk of invasiveness overall […]"

"Anecdotal evidence of negative impacts on native fishes in Bolivia (Miranda-Chumacero et al. 2012). Anecdotal reference to Portuguese language reports from the 1950s about impacts in reservoirs in northeast Brazil (see Quieroz 2000)."

4 History of Invasiveness

Arapaima gigas has become established in the wild in Bolivia and Peru outside its native range. The species is probably established in Thailand and may be established in Indonesia, Malaysia, China, and the Philippines. Introductions have failed or likely failed in Singapore, Mexico, and Cuba. *A. gigas* is present in the aquarium trade, although there was no information found on the number of individuals in trade. Some introductions have occurred for aquacultural purposes. Possession of *A. gigas* is prohibited in Oklahoma, Texas, Arizona, and Florida.

Information in the English language scientific literature was inadequate to draw conclusions about the potential of *A. gigas* to negatively affect humans, wildlife, or wildlife resources. Multiple authors report that it has affected native fish species in its introduced range, but the authors of this report were unable to find any robust investigations of these claims. More detail may be available in Portuguese or Spanish language publications; these publications were inaccessible to the authors of this report. The history of invasiveness for *A. gigas* is classified as Data Deficient.

5 Global Distribution

Figure 1. Known global distribution of *Arapaima gigas*. Observations are reported from North America, South America, and Thailand. Map from GBIF Secretariat (2021). Points located in North America, Thailand, southern Bolivia, the Paraná River basin in southern Brazil, and central Colombia were not used to select source points in the climate match because they do not represent confirmed established populations of *A. gigas*. There are also reports of *A. gigas* in Indonesia but no sources have confirmed an established population, therefore no occurrences in Indonesia were included in the climate matching analysis.

6 Distribution Within the United States

Figure 2. Known distribution of *Arapaima gigas* in the United States. Map from BISON (2021). These points do not represent established wild populations; they are museum specimens (BISON 2021). No wild populations have been reported in the United States.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Arapaima gigas* was low for the majority of the contiguous United States. Areas of medium match were found in the Southeast and medium-low matches were scattered through the Southwest and along the Pacific coast. Areas of medium-high match were located along the Gulf Coast from Texas to Florida and along the Atlantic Coast from Florida to southern Virginia. The overall Climate 6 score (Sanders et al. 2021; 16 climate variables; Euclidean distance) for the contiguous United States was 0.017, medium (scores between 0.005 and 0.103 are classified as medium). The following States had high individual Climate 6 scores: Florida and Louisiana. The following States had medium individual Climate 6 scores: Alabama, Georgia, Mississippi, North Carolina, South Carolina, and Texas. All remaining States had a low individual Climate 6 score.

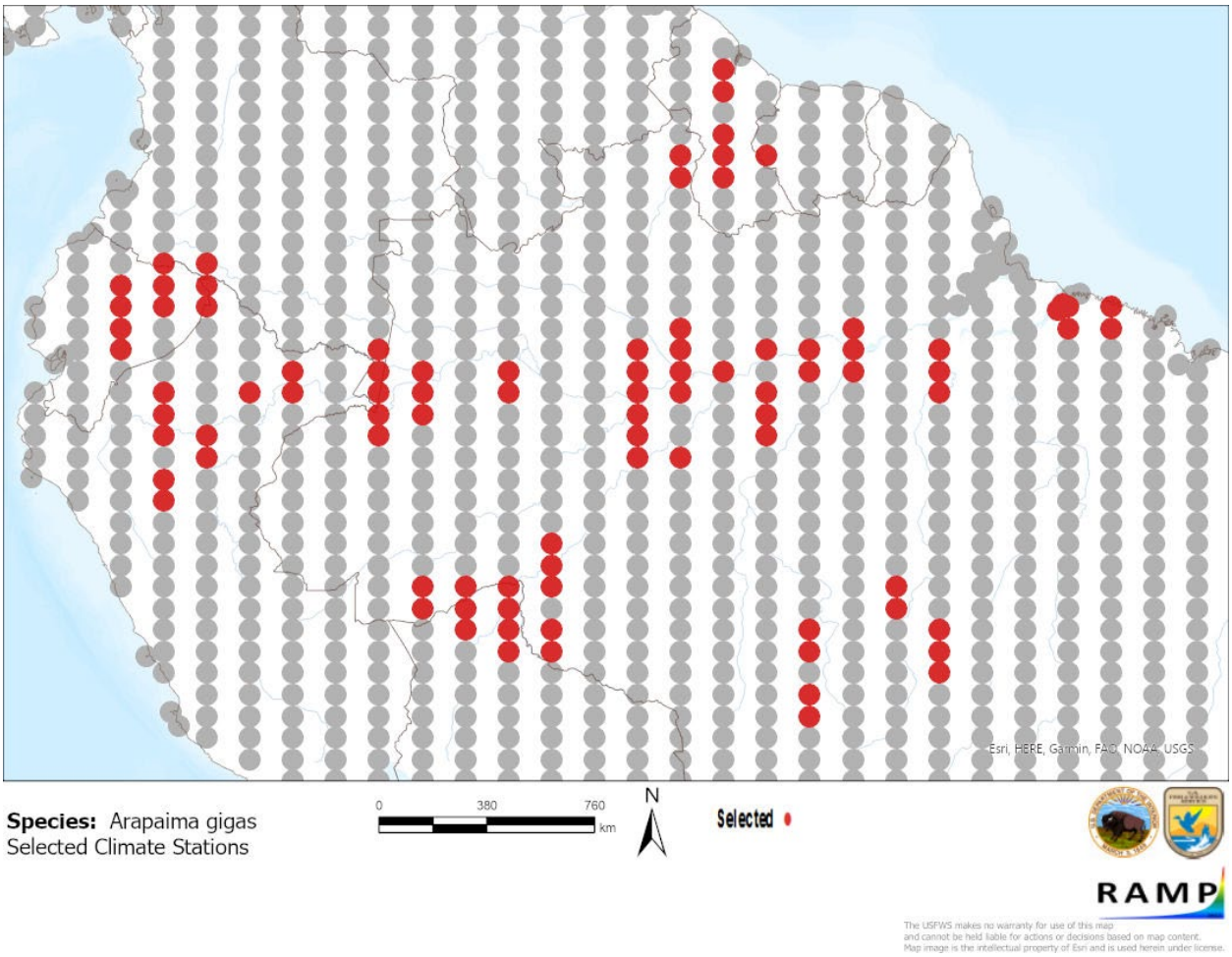

Figure 3. RAMP (Sanders et al. 2021) source map showing weather stations in South America selected as source locations (red; Guyana, Brazil, Colombia, Peru, Ecuador, and Bolivia) and non-source locations (gray) for *Arapaima gigas* climate matching. Source locations from GBIF Secretariat (2021). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

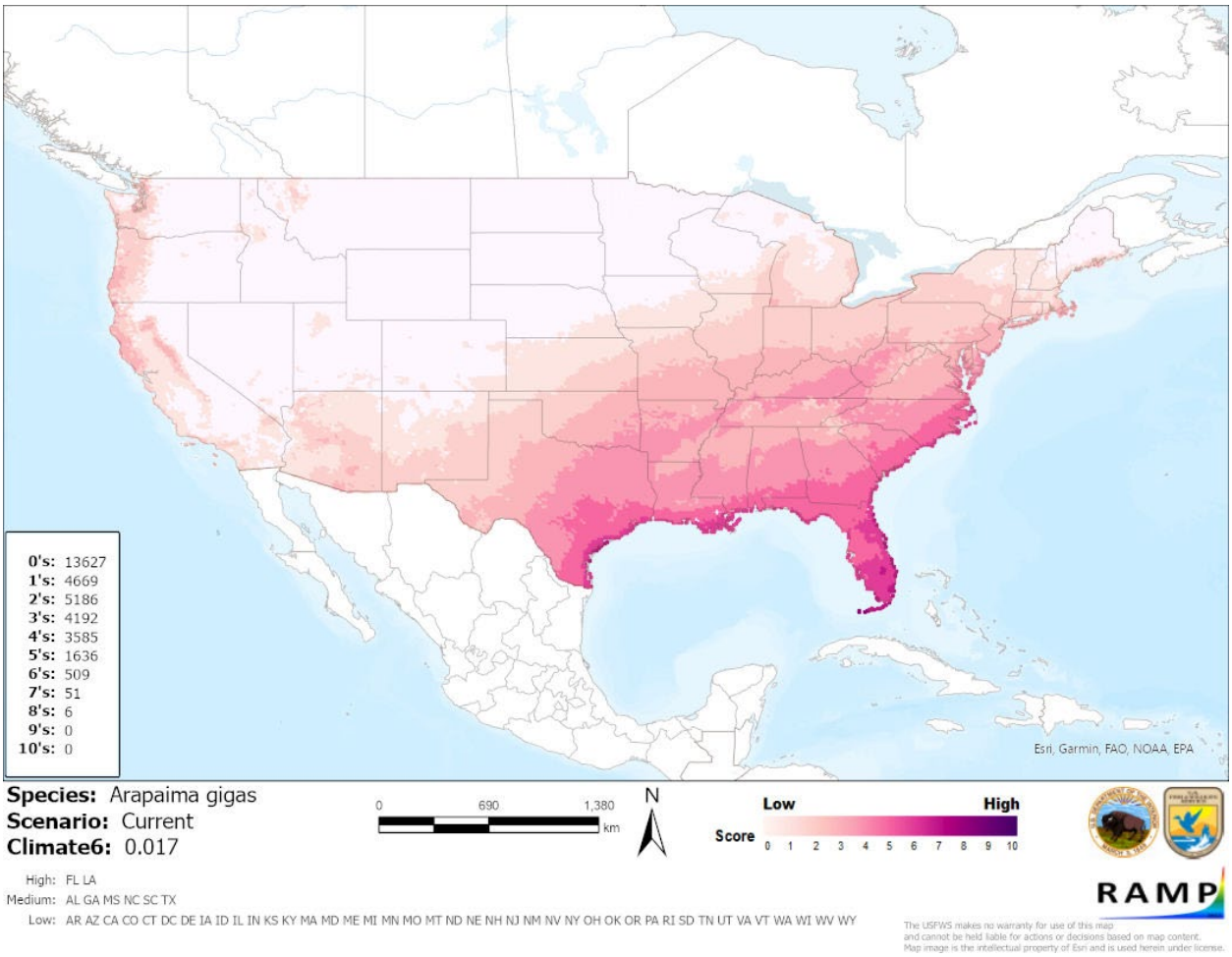

Figure 4. Map of RAMP (Sanders et al. 2021) climate matches for *Arapaima gigas* in the contiguous United States based on source locations reported by GBIF Secretariat (2021). Counts of climate match scores are tabulated on the left. 0/Light Pink = Lowest match, 10/Dark Purple = Highest match.

The High, Medium, and Low Climate match Categories are based on the following table:

Climate 6: (Count of target points with climate scores 6-10)/ (Count of all target points)	Overall Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

8 Certainty of Assessment

The certainty of assessment for *Arapaima gigas* is low. There is some information available describing this species and its biology. Although this species has become established outside its native range and some authors mentioned impacts of introduction, supporting data were not available in English language publications and therefore the potential for impacts of introduction

to the United States could not be evaluated for this risk screening summary. Additional uncertainty is introduced because upper and lower lethal temperatures cannot be incorporated into RAMP. The known lower lethal temperature limit of 16°C (Lawson et al. 2015) would likely preclude establishment in many areas estimated as medium or high match by RAMP's algorithm (Sanders et al. 2021). RAMP measures similarity between source locations and target locations on 16 bioclimatic variables and does not have a mechanism to account for upper or lower lethal temperature limits.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Arapaima gigas is a large freshwater fish that is native to the Amazon River basin. *A. gigas* is an obligate air breather that can reach up to 200 kg in weight and 450 cm in length. This species has been declining in its native range due to fishing pressure. *A. gigas* is also used in aquaculture and the pet trade, but its international trade is restricted through the Convention on International Trade in Endangered Species (CITES). Possession of *A. gigas* is prohibited in the U.S. States of Oklahoma, Texas, Arizona, and Florida. *A. gigas* has been introduced outside its native range in Peru, Bolivia, Indonesia, Malaysia, Thailand, Mexico, Cuba, China, the Philippines, and Singapore; it is confirmed to have become established in Bolivia and Peru, is probably established in Thailand, and may be established in Indonesia, Malaysia, China, and the Philippines. There have been reports of *A. gigas* in the United States, but all specimens were from museums or confiscated at airports. There have been reports of impacts of introduction in Bolivia, but data to support these reports were not found in English language publications. The history of invasiveness is classified as Data Deficient. The climate match for the contiguous United States is medium overall, with the highest matches occurring along the Gulf and southern Atlantic coastlines. The certainty of assessment is low due to lack of information on impacts and the inability of the climate matching analysis to account for the known lower lethal temperature limit for the species. The overall risk assessment category for *Arapaima gigas* is Uncertain.

Assessment Elements

- **History of Invasiveness (Sec. 4): Data Deficient**
- **Overall Climate Match Category (Sec. 7): Medium**
- **Certainty of Assessment (Sec. 8): Low**
- **Remarks, Important additional information: No additional remarks**
- **Overall Risk Assessment Category: Uncertain**

10 Literature Cited

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 11.

Arizona Office of the Secretary of State. 2013. Live wildlife. Arizona Administrative Code, Game and Fish Commission, Title 12, Chapter 4, Article 4.

Bailly N. 2017. *Arapaima gigas*. World Register of Marine Species. Available: http://www.marinespecies.org/aphia.php?p=taxdetails&id=1042347 (November 2021).

BISON. 2021. Biodiversity Information Serving Our Nation. U.S. Geological Survey. Available: https://bison.usgs.gov (November 2021).

Castello L. 2008. Nesting habitat of *Arapaima gigas* (Schinz) in Amazonian floodplains. Journal of Fish Biology 72:1520–1528.

Castello L, Stewart DJ. 2010. Assessing CITES non-detriment findings procedures for *Arapaima* in Brazil. Journal of Applied Ichthyology 26:49-56.

Fadjar M, Islamy RA, Herawati EY. 2019. First record of *Arapaima gigas* (Schinz, 1822) (Teleostei: Osteoglossomorpha), in the Brantas River, Sidoarjo, East Java, Indonesia. Biodiversitas Journal of Biological Diversity 20(12):3527–3531.

Farias IP, Willis S, Leão A, Verba JT, Crossa M, Foresti F, Porto-Foresti F, Sampaio I, Hrbek T. 2019. The largest fish in the world's biggest river: Genetic connectivity and conservation of *Arapaima gigas* in the Amazon and Araguaia-Tocantins drainages. PLoS ONE 14(8):e0220882.

[FFWCC] Florida Fish and Wildlife Conservation Commission. 2021. Conditional nonnative species list. Tallahassee: Florida Fish and Wildlife Conservation Commission. Available: https://myfwc.com/wildlifehabitats/nonnatives/conditional-species-list/ (November 2021).

Fricke R, Eschmeyer WN, van der Laan R, editors. 2021. Eschmeyer's catalog of fishes: genera, species, references. California Academy of Science. Available: http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp (November 2021).

Froese R, Pauly D, editors. 2021. *Arapaima gigas* (Schinz, 1822). FishBase. Available: https://www.fishbase.se/summary/Arapaima-gigas.html (November 2021).

GBIF Secretariat. 2021. GBIF backbone taxonomy: *Arapaima gigas* (Schinz, 1822). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5212877 (May 2022).

Hill JE, Lawson KM. 2015. Risk screening of Arapaima, a new species proposed for aquaculture in Florida. North American Journal of Fisheries Management 35:885–894.

[ITIS] Integrated Taxonomic Information System. 2021. *Arapaima gigas* (Schinz, 1822). Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=650008#null (November 2021).

Lawson LL, Tuckett QM, Lawson KM, Watson CA, Hill JE. 2015. Lower lethal temperature for arapaima *Arapaima gigas*: potential implications for culture and establishment in Florida. North American Journal of Aquaculture 77:497-502.

Marková J, Jerikho R, Wardiatno Y, Kamal MM, Magalhães ALB, Bohatá L, Kalous L, Patoka J. 2020. Conservation paradox of giant arapaima *gigas* (Schinz, 1822) (Pisces: Arapaimidae): endangered in its native range in Brazil and invasive in Indonesia. Knowledge and Management of Aquatic Ecosystems 421:47.

Miranda-Chumacero G, Wallace R, Calderón H, Calderón G, Willink P, Guerrero M, Siles TM, Lara K, Chuqui D. 2012. Distribution of arapaima (*Arapaima gigas*) (Pisces: Arapaimatidae) in Bolivia: implications in the control and management of a non-native population. BioInvasions Records 1(2):129-138.

[OIE] World Organisation for Animal Health. 2021. Animal diseases. Available: https://www.oie.int/en/what-we-do/animal-health-and-welfare/animal-diseases/ (November 2021).

Oklahoma Secretary of State. 2019. List of restricted exotic species. Oklahoma Administrative Code, Title 800, Chapter 20-1-2.

Poelen JH, Simons JD, Mungall CJ. 2014. Global Biotic Interactions: an open infrastructure to share and analyze species-interaction datasets. Ecological Informatics 24:148–159.

Predatory Fins. 2021. Arapaima (*Arapaima Gigas*). Predatory Fins, Boca Raton, Florida. Available: https://www.predatoryfins.com/products/arapaima-arapaima-gigas (December 2021).

Procopio J. 2021. *Arapaima* sp. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=3148 (November 2021).

Queiroz HL. 2000. Natural history and conservation of pirarucu, *Arapaima gigas*, at the Amazonian Várzea: red giants in muddy waters. Ph.D. thesis. St. Andrews, UK: University of St. Andrews.

Sanders S, Castiglione C, Hoff M. 2021. Risk Assessment Mapping Program: RAMP. Version 4.0. U.S. Fish and Wildlife Service.

Shaw T. 2020. Wildlife trafficking: what happens to confiscated animals? U. S. Fish and Wildlife Service Inside Region 3. Available: https://www.fws.gov/midwest/insider3/January16Story6.htm (November 2021).

Texas Parks and Wildlife. 2021. Invasive, prohibited and exotic species. Austin: Texas Parks and Wildlife. Available:

https://tpwd.texas.gov/huntwild/wild/species/exotic/prohibited_aquatic.phtml (November 2021).

Van Damme PA, Méndez CC, Zapata M, Carvajal-Vallejos FM, Carolsfeld J, Olden JD. 2015. The expansion of *Arapaima* cf. *gigas* (Osteoglossiformes: Arapaimidae) in the Bolivian Amazon as informed by citizen and formal science. Management of Biological Invasions 6:375–383.

11 Literature Cited in Quoted Material

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.

Axelrod HR, Burgess WE, Pronek N, Walls JG. 1991. Dr. Axelrod's atlas of freshwater aquarium fishes. Sixth edition. Neptune City, New Jersey: T.F.H. Publications.

Baensch HA, Riehl R. 1985. Aquarien atlas. Volume 2. Melle, Germany: Mergus, Verlag für Natur-und Heimtierkunde GmbH.

Bard J, Imbiriba EP. 1986. Psicultura do Pirarucu, *Arapaima gigas*. Boletim Embrapa-Cepatu 52:1–17.

Castello L, Stewart DL. 2010. Assessing CITES non-detriment findings procedures for Arapaima in Brazil. Journal of Applied Ichthyology 26(1):49–56.

Ferraris CJ Jr. 2003. Arapaimatidae (Bonytongues). Page 31 in Reis RE, Kullander SO, Ferraris CJ Jr., editors. Checklist of the freshwater fishes of South and Central America. Porto Alegre, Brasil: EDIPUCRS.

Ferreira EJG, Zuanon JAS, dos Santos GM. 1998. Peixes comerciais do médio Amazonas. Brasília, Brazil: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis.

Fontanele O. 1948. Contribuicxao para o conhecimento da biologica do pirarucu, *Arapaima gigas* (Cuvier), em cativeiro (Actinopterygii, Osteoglossidae). Revista Brasileira de Biologia 8:445–459.

Jordan DS. 1905. A guide to the Study of Fishes. Volume II. Westminster, London: Archibald Constable & Co. Ltd.

Oliveira CE. 1944. Notas sobre pirarucus (*Arapaima gigas*). A Voz do Mar 23(191):169.

Stewart DJ. 2013a. Re-description of the *Arapaima agassizii* (Valenciennes), a rare fish from Brazil (Osteoglossomorpha: Osteoglossidae). Copeia 1:38–51.

Stewart DJ. 2013b. A new species of *Arapaima* (Osteoglossomorpha: Osteoglossidae) from the Solimões River, Amazonas State, Brazil. Copeia 3:470–476.

Stone R. 2007. The last of the leviathans. Science 316:1684–1688.

Tello S, Sánchez H. 1995. Unpublished. [Source material did not give full citation for this reference.]

Van Damme PA. 2006. Propuesta de estrategia y proyecto demanejo y Desarrollo pesquero para el norte amazónico (Bolivia). Propuesta enviada a la FAO, Rome. [In Spanish.]

Wheeler A. 1977. Das grosse Buch der Fische. Stuttgart, Germany: Eugen Ulmer GmbH and Co.

Wust WH. 2001. El paiche, al rescate del rey. Santa Cruz, Bolivia: Revista Etecé.