U.S. Fish & Wildlife Service

Asian Swamp Eel (*Monopterus albus*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, December 2022
Revised, January 2023
Web Version, 4/10/2025

Organism Type: Fish
Overall Risk Assessment Category: High

Photo: EarthEngine. Licensed under CC BY-SA 3.0. Available: https://commons.wikimedia.org/wiki/File:Monopterus_albus_7.jpg (December 2022).

1 Native Range and Status in the United States

Native Range

From Fuller et al. (2022):

"Native Range: Asia, from northern India and Burma to China, perhaps Asiatic Russia, Japan, and the Indo-Malayan Archipelago (Bailey and Gans 1998); possibly northeastern Australia (Merrick and Schmida 1984). Because of taxonomic confusion and the probability of crytic [sic] undescribed taxa included within the nomen *M. albus* (Collins et al. 2002), this range description for the species *M. albus* is probably overly broad."

From Ame et al. (2021):

"Native
Extant (resident)
Brunei Darussalam; Cambodia; China; Hong Kong; India; Indonesia; Japan; Korea, Democratic People's Republic of; Korea, Republic of; Lao People's Democratic Republic; Malaysia; Myanmar; Philippines; Singapore; Taiwan, Province of China; Thailand; Viet Nam"

"Possibly Extant (resident)
Bangladesh […]"

"This species occurs in Asia from India, throughout South-east Asia (Talwar and Jhingran 1991), China (Kottelat 1998, Walker and Yang 1999, Ma et al. 2003), Japan (Masuda et al. 1984) and the Korean Peninsula (Kim et al. 2005). It is found all over the Philippines but most of its population is distributed in central and northern Luzon [Philippines]. It is probably found in Bangladesh."

Status in the United States

From Nico et al. (2019):

"Wild *M. albus*/*javanensis* are firmly established in several places in the USA (Collins et al. 2002). Included are populations in the states of Hawaii (Island of Oahu, present since before 1900), Georgia (Chattahoochee River drainage, since the early 1990s), Florida (multiple drainages in the Tampa, Miami, and Homestead areas, all since the late 1990s), and New Jersey (Silver Lake area, since about 2008) (Starnes et al. 1998; Yamamoto and Tagawa 2000; Collins et al. 2002; Nico et al. 2011). Molecular data indicate the six different introduced populations represent as many as three cryptic species, with each geographically-separated population being composed of one of the three identified clades (Collins et al. 2002)."

From Fuller et al. (2022):

"Genetic analysis indicates that there have been multiple introductions from different geographic areas (Collins et al. 2002). The Atlanta population is from Japan or Korea; Florida populations in Tampa and North Miami are from Southern China while the population in Homestead is from Indo-China, the Malay Peninsula, or the East Indies (Collins et al. 2002)."

From Nico et al. (2019):

"Live *M. albus*/*javanensis* were only found in one market, a large grocery store in Atlanta where it was observed in both 2003 and 2004. Air cargo labels on containers indicated the 2003 stock had been shipped from Vietnam to Atlanta […]"

"Based on LEMIS [U.S. Fish and Wildlife Service Law Enforcement Management Information System] records, we estimated that 832,897 live swamp eels were imported into the USA and its territories during July 1996–January 2017. Most, 829,601 (99.6%), were filed as *Monopterus albus* (or *Fluta alba*). Remaining entries included an estimated 3,206 individuals recorded as *Monopterus species* […] LEMIS data indicate the numbers of live swamp eels imported was greatest during the years 2000 to 2007, followed by a substantial drop (Figure 9 [in source material]). However, we still regularly encountered swamp eels for sale in US food markets even after 2007 (Figures 8 and 9 [in source material]). Although the LEMIS filings recorded almost all imported swamp eels imported over the period 1996–2017 as "*M. albus*", our 2001–2017 market surveys revealed that almost all imports were *A. cuchia* [*Amphipnous cuchia*; synonym of *Ophichthys cuchia*]. Predominance of *A. cuchia* in US markets corresponds to LEMIS records indicating that most imports originated in Bangladesh."

"Members of the *M. albus*/*javanensis* complex and "*Synbranchus marmoratus*" intermittently appear in the pet trade, sometimes within the USA (Fenner 1998; Howells and Rao 2003; Moreau and Coomes 2007; Jayalal and Ramachandran 2012)."

Regulations

Monopterus albus is regulated in Colorado (CPW 2022), Hawaii (HDOA 2019), Maryland (Code of Maryland Regulations 2022), Nevada (Nevada Board of Wildlife Commissioners 2022), New Jersey (NJFW 2022), New York (New York DEC 2022), North Carolina (North Carolina DEQ 2022), and Virginia (Virginia DWR 2022). It is regulated at the family level (Synbranchidae) in Louisiana (Louisiana Revised Statutes 2022), Tennessee (TWRA 2022), Texas (TPW 2022), and Utah (Utah DWR 2020). Please refer back to state agency regulatory documents for details on the regulations, including restrictions on activities involving this species. While effort was made to find all applicable regulations, this list may not be comprehensive. Notably, it does not include regulations that do not explicitly name this species or its genus or family, for example, when omitted from a list of authorized species with blanket regulation for all unnamed species.

Means of Introductions within the United States

From Fuller et al. (2022):

"Its introduction into Florida was probably the result of either an aquarium release, a fish farm escape or release, or release of specimens from the live food-fish market. The Tampa population is near a former fish farm. Colorful specimens may indicate selective breeding for the aquarium trade. They are a popular ethnic food item and may have been released by that trade. The eel was probably introduced into Georgia as an aquarium release. In Georgia, adults were first collected in 1994, although they were likely present since 1990 or before (Starnes et al. 1998; Turkewitz 2006). It was presumably brought to Hawaii by Asian immigrants as a food fish (Devick [1991]). Brock (1960) stated that it was established in Hawaii prior to 1900. Devick ([1991]) listed it as one of six fish species that were successfully introduced into Hawaii in the 19th century. However, Cobb (1902) and Jordan and Evermann (1902, 1905) made no mention of finding the species in their turn-of-the-century surveys of Hawaiian fishes."

From Nico et al. (2019):

"The origin of certain wild *M. albus*/*javanensis* populations in Florida are conceivably related to the aquarium industry, a suspicion based on existence of ornamental fish farms in the state as well as on observations that two of the three wild populations in Florida include highly colorful phenotypes."

Remarks

A previous version of this ERSS was published in April 2018. Revisions were completed to incorporate new information and conform to updated standards.

Recently, authors have determined that *Monopterus albus*, as historically defined, most likely represents a species complex containing an uncertain number of species. In the absence of a widely accepted taxonomic revision of the species complex, this screening treats *M. albus* as a single species. Information regarding the taxonomic issue and species complex is presented below.

From Britz et al. (2021):

"Originally described as *Muraena alba* by the Russian ichthyologist Basilius Zuiew (1793) [Vasilij Fyodorovich Zuev'], the name *Monopterus albus* has long been used for a species of swamp eel (Synbranchidae) with a reportedly widespread occurrence in Asia (Rosen & Greenwood 1976, Kottelat 2013). In recent years molecular studies have shown that *Monopterus albus* of authors is a species complex and several authors have recommended that up to three (Collins et al. 2002, Matsumoto et al. 2010, Kottelat 2013, Nico et al. 2019) or even five (Arisuryanti 2016) different species can be recognized. Kottelat (2013) referred to the eastern Asian clade of Matsumoto et al. (2010) as *Monopterus albus* and the Southeast Asian clade as *Monopterus javanensis* La Cepède, 1800, noting that no name is available for the clade on the Ryukyu Islands."

From Fuller et al. (2022):

"The taxonomy of the genus *Monopterus* is in need of systematic review. *Monopterus albus* was initially thought to be a single species, but subsequent study has shown four known populations of this "species" (in Florida and Georgia) may actually be three genetically distinct (yet morphologically similar/identical) species or taxa, each from a different area of Asia (Collins et al. 2002)."

"Genetic analysis indicates that there have been multiple introductions from different geographic areas (Collins et al. 2002). The Atlanta population is from Japan or Korea; Florida populations in Tampa and North Miami are from Southern China while the population in Homestead is from Indo-China, the Malay Peninsula, or the East Indies (Collins et al. 2002)."

From Matsumoto et al. (2010):

"The analyses showed clearly that this species can be genetically delineated into three clades based on geographical populations [China–Japan (Honshu + Kyushu), Ryukyu Islands, and Southeast Asia clades], with each clade exhibiting its own reproductive behavior. Therefore, "*M. albus*" is believed to be composed of at least three species. The Southeast Asia clade with the highest genetic diversity may include more species. The Ryukyu clade was estimated to have diverged more than 5.7 million years ago, suggesting that the Ryukyuan "*M. albus*" is native. In contrast, in the China–Japan clade, all haplotypes from Japan were closely related to those from China, suggesting artificial introduction(s)."

From Nico et al. (2019):

"We refer to the widespread *Monopterus* species complex of eastern and southeastern Asia as *Monopterus albus*/*javanensis*. Such a designation is based primarily on genetic research revealing that the swamp eel commonly referred to as either *Monopterus albus* (Zuiew, 1793) or *Monopterus javanensis* Lacepede, 1800 is actually composed of multiple (perhaps five or more), genetically-distinct, cryptic forms (Collins et al. 2002; Matsumoto et al. 2010; Cai et al. 2013; Arisuryanti 2016)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2022):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Deuterostomia
      Phylum Chordata
        Subphylum Vertebrata
          Infraphylum Gnathostomata
            Superclass Actinopterygii
              Class Teleostei
                Superorder Acanthopterygii
                  Order Synbranchiformes
                    Suborder Synbranchoidei
                      Family Synbranchidae
                        Genus *Monopterus* Lacepède, 1800
                          Species *Monopterus albus* (Zuiew, 1793)

According to Fricke et al. (2022), *Monopterus albus* is the current valid name for this species.

Size, Weight, and Age Range

From Froese and Pauly (2022):

"Max length : 100.0 cm SL [standard length] male/unsexed; [Davidson 1975]; common length : 40.0 cm SL male/unsexed; [Allen et al. 2002]"

From Fuller et al. (2022):

"Up to 100 cm (39 inches)"

Environment

From Froese and Pauly (2022):

"Freshwater; brackish; demersal; potamodromous [Riede 2004]; depth range 3 - ? m [Davidson 1975]. […] 25°C - 28°C [Baensch and Riehl 1985; assumed to be recommended aquarium temperature range]"

From Fuller et al. (2022):

"Swamp eel populations in Florida show significant extended tolerance to moderate salinity levels (up to 14-16 ppt), suggesting that coastal and estuarine areas are potential pathways for dispersal (Schofield and Nico 2009)."

"Laboratory studies show that swamp eels stopped feeding at 14-16ºC [water temperature] and died at 8-9ºC (Shafland et al. 2010). This temperature coincides with a range that would not extend farther north than Jacksonville, Florida (Shafland and Pestrak 1982)."

Climate

From Froese and Pauly (2022):

"Tropical; […] 34°N - 6°S"

From Fuller et al. (2022):

"However, the Georgia population has survived air temperatures below freezing and ice cover over their pond habitat (Starnes et al. 1998) for many years indicating that it is different genetically (as determined by Collins et al. 2002)."

From Nico et al. (2019):

"One or more members of the *M. albus*/*javanensis* complex are known to survive in temperate climatic zones where winter air temperatures fall to or below freezing, as evidenced by their natural occurrence in China north to about 45.2°N latitude (Fan 1990) and the persistence of introduced populations in Japan north to about 34.8°N latitude (Matsumoto et al. 1998) and in New Jersey (USA) in a lake situated at 39.8°N latitude (LG Nico, pers. obs.)."

Distribution Outside the United States

Native

From Fuller et al. (2022):

"Native Range: Asia, from northern India and Burma to China, perhaps Asiatic Russia, Japan, and the Indo-Malayan Archipelago (Bailey and Gans 1998); possibly northeastern Australia (Merrick and Schmida 1984). Because of taxonomic confusion and the probability of crytic [sic] undescribed taxa included within the nomen *M. albus* (Collins et al. 2002), this range description for the species *M. albus* is probably overly broad."

From Ame et al. (2021):

"Extant (resident)
Brunei Darussalam; Cambodia; China; Hong Kong; India; Indonesia; Japan; Korea, Democratic People's Republic of; Korea, Republic of; Lao People's Democratic Republic; Malaysia; Myanmar; Philippines; Singapore; Taiwan, Province of China; Thailand; Viet Nam

Possibly Extant (resident)
Bangladesh […]

This species occurs in Asia from India, throughout South-east Asia (Talwar and Jhingran 1991), China (Kottelat 1998, Walker and Yang 1999, Ma et al. 2003), Japan (Masuda et al. 1984) and the Korean Peninsula (Kim et al. 2005). It is found all over the Philippines but most of its population is distributed in central and northern Luzon [Philippines]. It is probably found in Bangladesh."

Introduced

From Nico et al. (2019):

"Non-native occurrences have been reported for sites in Asia (China, Japan, Philippines), Australia"

"The "*Monopterus albus*" population present in northwest China's Xinjiang Province (Hami Prefecture) is considered descended from an introduction in 1875 or 1876"

"Swamp eels of the *M. albus/javanensis* complex found in southwestern regions of the islands of Honshu and Kyushu [Japan] are considered introduced (Okada 1966; Matsumoto et al. 1998, 2010). Non-native status is supported by genetic analyses indicating a close relationship to populations inhabiting Asia's northeastern mainland (Matsumoto et al. 2010). […] Other populations found in Japan's main islands may be offspring of separate introductions (Okada 1966). The Nara population has expanded its range since initial introduction and is now widespread in the Kizu, Yamata, and Yoshino river systems (Matsumoto et al. 1998)."

"Swamp eels identified as "*M. albus*" and brought to the Philippines from Malaysia for aquaculture purposes are known to be reproducing and dispersing in the wild (Guerrero 2014)."

"Swamp eels referred to as "*M. albus*" inhabit Taiwan but their status and origin are unclear, with some arguing it to be native and others the result of introduction (perhaps post-1940) (Matsumoto et al. 2010)."

"The situation in Indonesia is similar to Taiwan. Arisuryanti (2016) conducted a genetic analysis of members of the *M. albus/javanensis* complex and found that Indonesia included two cryptic species, referred to as clade A and B. It was speculated that "clade B" may not be native to Indonesia but introduced from countries to the north. Alternatively, Arisuryanti (2016) posited that the "clade B" swamp eels could be native to Indonesia and possibly the source of introduction to other countries, perhaps via fish trading and marketing. The researcher commented that verification of native versus non-native status was difficult because all samples were obtained from farmers, fishermen, and markets."

"There are a few, scattered reports of fish identified as "*M. albus*" from Australia, all from the coastal region of Queensland. Several authors treat these "records" as introductions (Whitley 1960; Lake 1971; Merrick and Schmida 1984). […] In contrast, Rosen and Greenwood (1976) suggested its occurrence in Australia may be natural. Recent ichthyologists still express uncertainty as to whether "*M. albus*" is of native or non-native status in Australia (Allen et al. 2002; Pusey et al. 2004). Some Australian records reported as *Monopterus albus*—particularly those unsupported by vouchers—are suspected of being misidentifications of swamp eels of the genus *Ophisternon*, which are generally considered to be native to the country (Pusey et al. 2004)."

Means of Introduction Outside the United States

From Nico et al (2019):

"[…] the fish were purportedly transported from Hunan Province (Yangtze River Basin) [China] by members of General Zuo Zongtang's army [to Xinjiang Province, northwest China] (Li 1985; Wang et al. 1994)."

"Japan […] The source of populations in Honshu's Nara region are purported to be descended from some 10 fish that a missionary brought from the Korean Peninsula around 1900 and released into a pond near the Uda River (Okada 1966, citing Imatani 1958)."

"Swamp eels identified as "*M. albus*" and brought to the Philippines from Malaysia for aquaculture purposes […] Although dates and number of separate introductions are unknown, all presumably occurred after about 2000. In northern Luzon Island, residents believe the invaders—known locally as "kiwit"—were introduced into Nagadacan rivers by a US Peace Corps volunteer in 2008, supposedly to serve as a food source for local people (Gascon 2011)."

"Cai et al. (2013) speculated that drops in sea level over the past 800,000 years may have allowed for the natural exchange of swamp eels between Taiwan and mainland China; however, they could not rule out possible past human-mediated transfers between the two regions."

"Without providing sources, Whitley (1960) commented: "Some Oriental ricefield [sic] eels were introduced into Australia by Chinese in the early days but evidently died out." Similarly, Pusey et al. (2004) speculated that *M. albus* may have been imported into Australia by the Chinese during the goldrushes that took place in northern Queensland during the late 1800s."

Short Description

From Froese and Pauly (2022):

"Anguilliform body; no scales; no pectoral and pelvic fins; dorsal, caudal and anal fins confluent and reduced to a skin fold; gill openings merged into single slit underneath the head (Kottelat 1998). Rice paddy eels are red to brown with a sprinkling of dark flecks across their backs; large mouths and small eyes (Yamamoto and Tagawa 2000)."

From Fuller et al. (2022):

"Asian Swamp Eel is morphologically similar to two North American native fishes: American Eel (*Anguilla rostrata*) and lampreys (*Ichthyomyzon*, *Lampetra*, *Lethenteron*, or *Petromyzon* spp.). Asian Swamp Eels can be distinguished from American Eels by the presence/absence of pectoral fins (present in *A. rostrata*; absent in *Monopterus* sp.). Asian Swamp Eels may be distinguished from lampreys by the morphology of the gill opening (a single V-shaped opening in swamp eels; 7 small, pore-like gill openings in lampreys) and mouth/teeth (lampreys lack jaws and have an ovoid oral disc with embedded teeth). Asian Swamp Eels are also morphologically similar to two native salamanders (*Siren* and *Amphiuma* spp.), but can be distinguished by the presence/absence of legs/limbs (front and hind legs present in *Amphiuma*, front legs only in *Siren*, no legs/limbs in *Monopterus*)."

"Most individuals in Florida are olive-drab brown in color with yellow-orange bellies […] However, some specimens are brightly colored with variations of orange, pink, and a calico pattern (Shafland et al. 2010)."

Biology

From Froese and Pauly (2022):

"Obligate air-breathing (Müller et al. 2022); Found in hill streams to lowland wetlands (Vidthayanon 2002) often occurring in ephemeral waters (Allen et al. 2002). Adults are found in medium to large rivers, flooded fields and stagnant waters including sluggish flowing canals (Taki 1978, Rainboth 1996), in streamlets and estuaries (Menon 1999). Benthic (Mundy 2005), burrowing in moist earth in dry season surviving for long periods without water (Davidson 1975). Occasionally dug out in old taro fields, in Hawaii, long after the field has been drained; more frequently observed in stream clearing operations using heavy equipment to remove large amounts of silt and vegetation where the eels are hidden (Yamamoto and Tagawa 2000)."

"Male builds a large free-floating bubblenest among the submerged vegetation close to the shoreline; eggs are spat into the nest after being laid; male guards the nest and continues to guard the young after hatching till they are on their own (Yamamoto and Tagawa 2000). Spawning occurs in shallow water (Baensch and Riehl 1985). Sex reversal is completed in 8-30 weeks (Chan et al. 1972)."

From Fuller et al. (2022):

"Swamp eels are generally found in slowly moving freshwater regions. They are noctural [sic], and will often burrow into soft sediments or occupy crevices and small spaces (Shafland et al. 2010). In their native range, Asian Swamp Eel consumes a wide variety of invertebrate and vertebrate prey including fish (Yang et al. 1997; Cheng et al. 2003; Hill and Watson 2007). Hill and Watson's (2007) investigation into the diet of an introduced population near Tampa, Florida, revealed prey items such as amphipods, crayfish, fish, fish eggs, insects, oligochaetes, organic material, plant material and a tadpole. Shafland et al. (2010) found primarily fish (in 56% of stomachs), crustaceans (32%) (mostly crayfish), and insects (27%). Fish species included Swamp Darter (*Etheostoma fusiforme*), Bluefin Killifish (*Lucania goodei*), Eastern Mosquitofish (*Gambusia holbrooki*), other swamp eels, Fat Sleeper (*Dormitator maculatus*), Largemouth Bass (*Micropterus salmoides*), Mayan Cichlid (*Cichlasoma urophthalmus*), Tadpole Madtom (*Noturus gyrinus*), Bluegill (*Lepomis macrochirus*), Jaguar Guapote (*Parachromis managuensis*), African Jewelfish (*Hemichromis letourneuxi*), Black Acara (*Cichasoma bimaculatum*), and Spotted Sunfish (*Lepomis punctatus*). Swamp eels had also eaten mollusks, frogs, a turtle, fish eggs, and a snake's head."

"This species is a sequential hermaphrodite: all individuals are born and mature as females and some later transform into males (Liem 1963; Shafland et al. 2010). Populations studied in south Florida tend to be heavily skewed towards females (90-98%; Shafland et al. 2010). In Snake Creek, individuals transitioning ranged in size from 694-782 mm TL [total length], whereas the smallest male observed at another location was 434 mm TL. The smallest mature female was 318 mm TL and the smallest mature male was 434 mm TL (Shafland et al. 2010). A mature female averaged 439 (range 268-642) eggs (Shafland et al. 2010)."

"This species can breathe air, using atmospheric oxygen absorbed via a vascularized breathing apparatus at the rear of their mouths (Shafland et al. 2010)."

"Long and LaFleur (2011) used otoliths to estimate average daily growth rates and hatching dates for juvenile swamp eels in the Chattahoochee River, Georgia population, with an estimated growth rate of 0.2 cm/day."

"Although there are reports of this species moving over land, Shafland et al. (2010) found no evidence of that after studying them for many years. They are also reputed to be able to live out of water for a considerable length of time (Day 1958)."

Human Uses

From Froese and Pauly (2022):

"Fisheries: commercial; aquaculture: commercial; aquarium: commercial"

"Marketed fresh and can be kept alive for long periods of time as long as the skin is kept moist (Rainboth 1996). Good flesh (Davidson 1975). Important fisheries throughout Southeast Asia (Vidthayanon 2002)."

From Ame et al. (2021):

"It is important in fisheries throughout South-east Asia, both commercial and subsistence."

From GISD (2022):

"According to Bricking (2002), in Asia, *M. albus* are considered a food fish, and a delicacy. They are also found in markets as food in the United States, as well as in pet supply stores, although they are not as well known."

From Guerrero (2014):

"The rice paddy eel, *Monopterus albus*, earlier reported to be a "pest" in Northern Luzon is now a major export commodity and may no longer be considered invasive."

From Nico et al. (2019):

"However, in China, Thailand, and other countries, prayer release is common and "eels" (all or mostly *M. albus*/*javanensis*) are frequently used in the ritual (Barrow 2011; Edmunds 2011; Liu et al. 2013; Basha and Dunlea 2017; Cooper 2018; Figure 11 [in source material])."

Diseases

No information was found associating *Monopterus albus* with any diseases listed by the World Organisation for Animal Health (2022).

According to Poelen et al. (2014), *Monopterus albus* hosts the following parasites: *Anguillicola globiceps*, *Azygia anguillae*, *Dentiphilometra monopteri*, *Diplostomum* spp., *Eustrongylides ignotus*, *Genarchopsis goppo*, *Gnathostoma hispidum*, *Gnathostoma malaysiae*, *Gnathostoma spinigerum*, *Hamacreadium interruptus*, *Hamacreadium mutabile*, *Neophyllodistomum* spp., *Pallisentis celatus*, *Phyllodistomum* spp., *Polyonchobothrium* spp., *Prosorchis tianjinensis*, *Proterometra guangzhouensis*, and *Tetracampos magnum*.

From Froese and Pauly (2022):

"Trypanosoma Infection, Parasitic infestations (protozoa, worms, etc.)
Pallisentis Infestation, Parasitic infestations (protozoa, worms, etc.)
Dentiphilometra Infestation, Parasitic infestations (protozoa, worms, etc.)
Proleptinae Disease (general sp. larvae), Parasitic infestations (protozoa, worms, etc.)
Eustrongylides Disease (larvae), Parasitic infestations (protozoa, worms, etc.)"

From Fuller et al. (2022):

"Nico et al. (2011) examined the occurrence of internal parasites in both imported, wild-caught swamp eels from a U.S. retail food market and from an introduced population in Florida, finding parasites in nearly all specimens and highlighting the potential of *Monopterus* as a vector for introduction of macroparasites."

Threat to Humans

From Froese and Pauly (2022):

"Harmless"

From Cole et al. (2014):

"Gnathostomiasis is a major foodborne parasitic zoonosis and a notable public health problem in areas where raw or undercooked freshwater fish are consumed by humans. […] Infected persons can exhibit intermittent migratory subcutaneous swellings, which often recur over several years because of larval migrans. In some instances, larvae migrate into deeper tissues, causing visceral gnathostomaisis [sic], which can be fatal if the larvae invade the central nervous system [Waikagul and Diaz Chamacho 2007]. […] Our data show that live swamp eels [*Monopterus* spp.] imported to the United States from gnathostome-endemic areas could serve as a source of infection to humans in the United States."

3 Impacts of Introductions

The following information was reported under the names *M. albus* or *M. albus*/*javanensis*. However, if the species complex taxonomic issue gets further clarity in the future (see section 1), some of the populations referred to below may be identified as a different species.

From Pintar et al. (2023):

"[…] Asian Swamp Eels (*Monopterus albus*/*javanensis*) are drought-resistant fish first reported from Florida in 1997 and the Everglades in 2007. Using a 26-year dataset that included a 13-year baseline period prior to swamp eel arrival in Taylor Slough, we assessed population changes of common small fishes and decapods that are important prey for larger vertebrate predators. After invasion, populations of two crayfishes collapsed by >95 %, two fishes declined by >80 %, two fishes had intermediate declines of 44–66 %, and three species remained unchanged. Species most strongly reduced were those dependent on predator-free habitats at the onset of the wet season, indicating drought-resistant swamp eels have introduced novel predator effects and disrupted the hydrology-mediated production of aquatic animals that are prey for many larger predators."

"No native taxa were expected to decline precipitously after accounting for these hydrological influences on population dynamics in the post-swamp-eel invasion period and none revealed such declines in nearby habitats lacking swamp eels (Appendix S2 [in source material]). Therefore, all signs indicate that swamp eels caused the collapse of these formerly abundant taxa, whose loss implies marked re-organization of the Taylor Slough food web and food-production system for apex predators including wading birds and alligators."

"Assessment of our common nine species in Taylor Slough using electrofishing catch-per-unit-effort of swamp eels (9 of 13 plots in Taylor Slough were electrofished), other non-native fishes, and large native fishes corroborate the effects of swamp eels documented here for all of the species that experienced population declines and suggest no other taxa have played major roles in the declines of any of our nine assessed species in Taylor Slough (Appendix S1; Table S3 [in source material])."

"Our conclusions from Taylor Slough are supported by data from three other regions of the Everglades. The marshes of the eastern Panhandle region of Everglades National Park (Fig. 1 [in source material]) are where swamp eels were first detected outside of canals in 2007, but intensive sampling there did not begin until 2008 (Fig. S2 [in source material]). Panhandle data show near complete collapses of populations of *P. alleni*, *J. floridae*, and *F. confluentus* (Fig. S3 [in source material]; *P. fallax* were always uncommon), but these data were excluded from statistical analyses because we lacked any baseline period prior to swamp eel arrival."

"Despite limited prior work suggesting that swamp eels had little potential for ecological or economic impacts (Hill and Watson, 2007; Shafland et al., 2010), our results do not bode well for the freshwater trophic functions and goals of restoration of the Everglades in light of the recent rapid expansion of swamp eels."

From Guerrero (2014):

"The rice paddy eel (*M. albus*) has been reported to infest rice paddies in the Cagayan Valley [the Philippines]. Locally known as "kiwet," it feeds on small fish, frogs and shrimp, and burrows into the bunds of the paddies causing water loss (Lazaro 2013, Valencia 2013)."

From Gonzales (2014):

"Farmers [in the Philippines] observed that these [*Monopterus albus*] survive long period of drought by burrowing in the moist earth such as dikes and rice fields. The burrowed holes destroy the rice dikes affecting irrigation during the vegetative stage of rice resulting to water loss that affects nutrient management. Farmers first reported the rice paddy eel as a pest to the Bureau of Fisheries and Aquatice [sic] Resources (BFAR) in Tuguegarao, Cagayan two years ago complained that these swamp eels were eating fingerlings in fishponds. PhilRice declared then the rice paddy eels as "an indirect pest" during the last dry season of 2010 [Icamina 2011]. Rice farmers in some parts of Nueva Ecija and 2 other provinces reported that *Monopterus albus* appeared in their farms and damaged their irrigation dikes."

From Nico et al. (2019):

"Japan […] Their burrowing activities damage rice field dikes causing water loss; they also invade aquaculture ponds and prey on fishes (Matsumoto 1997, 1998)."

"Philippines […] Rice farmers in northern Luzon attest swamp eels to be common and a pest largely because their burrowing activities damage dikes and terraces, leading to water, soil, and nutrient loss. Some impacted areas are within the Rice Terraces of the Philippine Cordilleras, a UNESCO World Heritage Site (Gascon 2011; Roque 2011; Abella et al. 2014)."

From Hill and Watson (2007):

"Despite our expectations […] our sampling results suggest that the Asian swamp eel is not a serious pest species for tropical ornamental aquaculture and represents less of a predation risk than anticipated. Although Asian swamp eels were found in production ponds on farms, the results of considerable sampling effort indicate the density was apparently low. Moreover, over half of the sampled Asian swamp eels had empty stomachs and the remaining stomachs contained relatively low numbers and weight of prey. Of the observed prey, only a small number was ornamental fish. Therefore, the expected negative effect of this introduced species in aquaculture ponds should be small (the product of a low apparent per capita consumption of ornamental fishes and a low apparent density of predators)."

From Fuller et al. (2022):

"Shafland et al. (2010) studied swamp eel populations established in south Florida and reported no deleterious ecological effects, although it should be noted that the investigators focused on populations inhabiting canals and associated waterways, habitats already highly disturbed. In addition, their study was largely interested in possible harm caused by swamp eels to sport fishes. Nico et al. (2011) examined the occurrence of internal parasites in both imported, wild-caught swamp eels from a U.S. retail food market and from an introduced population in Florida, finding parasites in nearly all specimens and highlighting the potential of *Monopterus* as a vector for introduction of macroparasites. Asian Swamp Eels are a known host of multiple *Gnathostoma* spp. nematodes, and are a potential [sic] source of gnathostomiasis in humans (Cole et al. 2014)."

The importation, possession, or trade *Monopterus albus* is regulated by the following states (see section 1): Colorado (CPW 2022), Hawaii (HDOA 2019), Louisiana (Louisiana Revised Statutes 2022), Maryland (Code of Maryland Regulations 2022), North Carolina (North Carolina DEQ 2022), New Jersey (NJFW 2022), Nevada (Nevada Board of Wildlife Commissioners 2022), New York (New York DEC 2022), Tennessee (TWRA 2022), Texas (TPW 2022), Utah (Utah DWR 2020), and Virginia (Virginia DWR 2022).

4 History of Invasiveness

The History of Invasiveness for *Monopterus albus* is classified as High. This species has documented introductions and established populations beyond its native range in the United States, Australia, and parts of Asia. There are negative impacts of introduced populations documented from peer-reviewed literature for this species, specifically in Florida where there were significant declines in the abundance of native fishes and decapods following the introduction of *M. albus*. Damages to rice agriculture were reported from areas with introduced populations in southeastern Asia. Increasingly, sources are referring to introductions formerly identified as *M. albus* as the species complex *M. albus/javanensis* or *Monopterus* spp., more broadly. If the *Monopterus albus* species complex issues are clarified in the future, some of these nonnative population and impacts may be attributed to a different *Monopterus* species.

5 Global Distribution

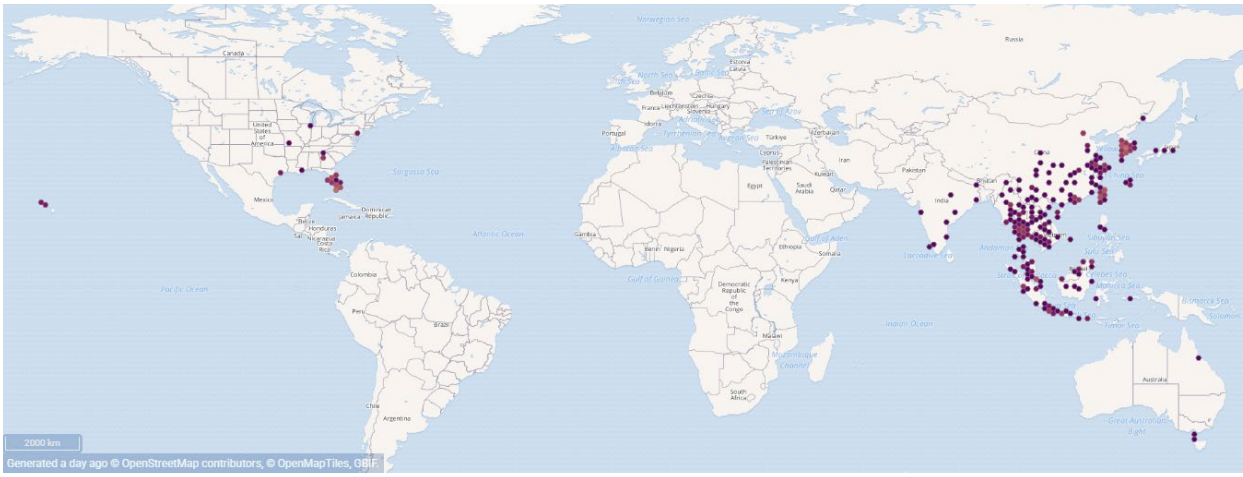

Figure 1. Reported global distribution of *Monopterus albus*. Map from GBIF Secretariat (2023). Observations are reported from eastern and southeastern Asia, India, United States (including Hawaii) and Australia. The southernmost points in Australia and those in Russia and India do not represent any known established populations and were excluded from the climate matching analysis. Points from Texas, Missouri, and Illinois in the United States were also excluded from the climate matching analysis as they were found to be from live markets, pet stores, or law enforcement collections.

6 Distribution Within the United States

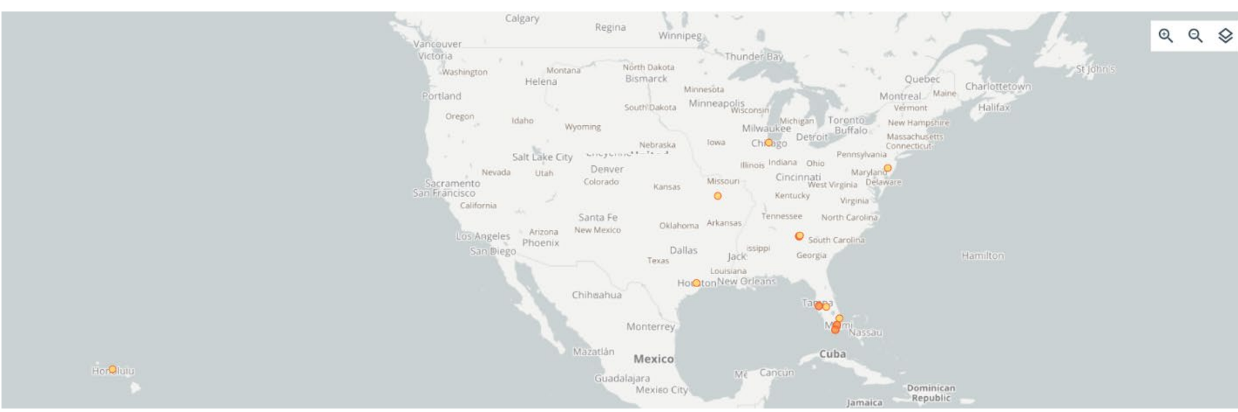

Figure 2. Reported distribution of *Monopterus albus* in the United States. Map from GBIF-US (2022). Observations are reported from Florida, Georgia, New Jersey, Illinois, Missouri, Texas, and Hawaii. Points from Texas, Missouri, and Illinois in the United States were excluded from the climate matching analysis as they were found to be from live markets, pet stores, or law enforcement collections.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Monopterus albus* was generally medium to high for the eastern contiguous United States. Areas of high match were found along the Mid-Atlantic Coast, through the Appalachian Range and into the Southeast including Florida. Medium matches were found in the Northeast, portions of the Midwest, and across most of the Great Plains. The Pacific Coast, Great Basin, Western Mountains, and Colorado Plateau all had low matches. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.651, indicating that Yes, there is establishment concern for this species. The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). Establishment concern is warranted for Climate 6 scores greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024). There are indications that the different lineages within the species complex referred to as *Monopterus albus* have differing environmental and climatic tolerances (see section 1 and Nico et al. 2019, Fuller et al. 2022 in section 2). Therefore, the results of this climate matching analysis may overestimate climate suitability of some individual lineages within the species complex.

Projected climate matches in the contiguous United States under future climate scenarios are available for *Monopterus albus* (see Appendix). These projected climate matches are provided as additional context for the reader; future climate scenarios are not factored into the Overall Risk Assessment Category.

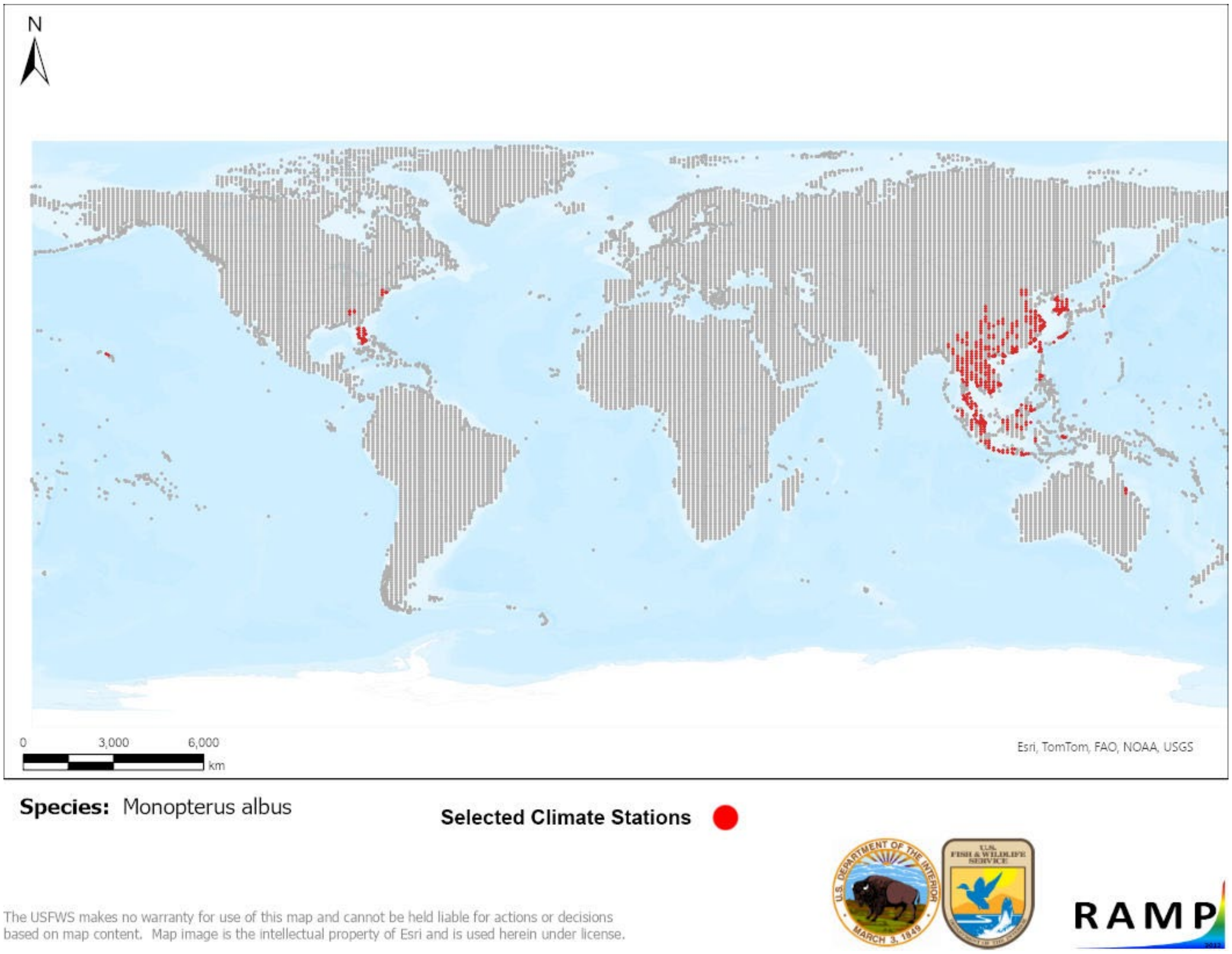

Figure 3. RAMP (Sanders et al. 2023) source map showing weather stations across Asia, Australia and the United States selected as source locations (red; United States, Australia, China, Japan, South Korea, India, Vietnam, Thailand, Indonesia, Malaysia, Philippines, Brunei, Laos, Cambodia, Taiwan, potentially other countries in Southeast Asia) and non-source locations (gray) for *Monopterus albus* climate matching. Source locations from GBIF Secretariat (2023). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

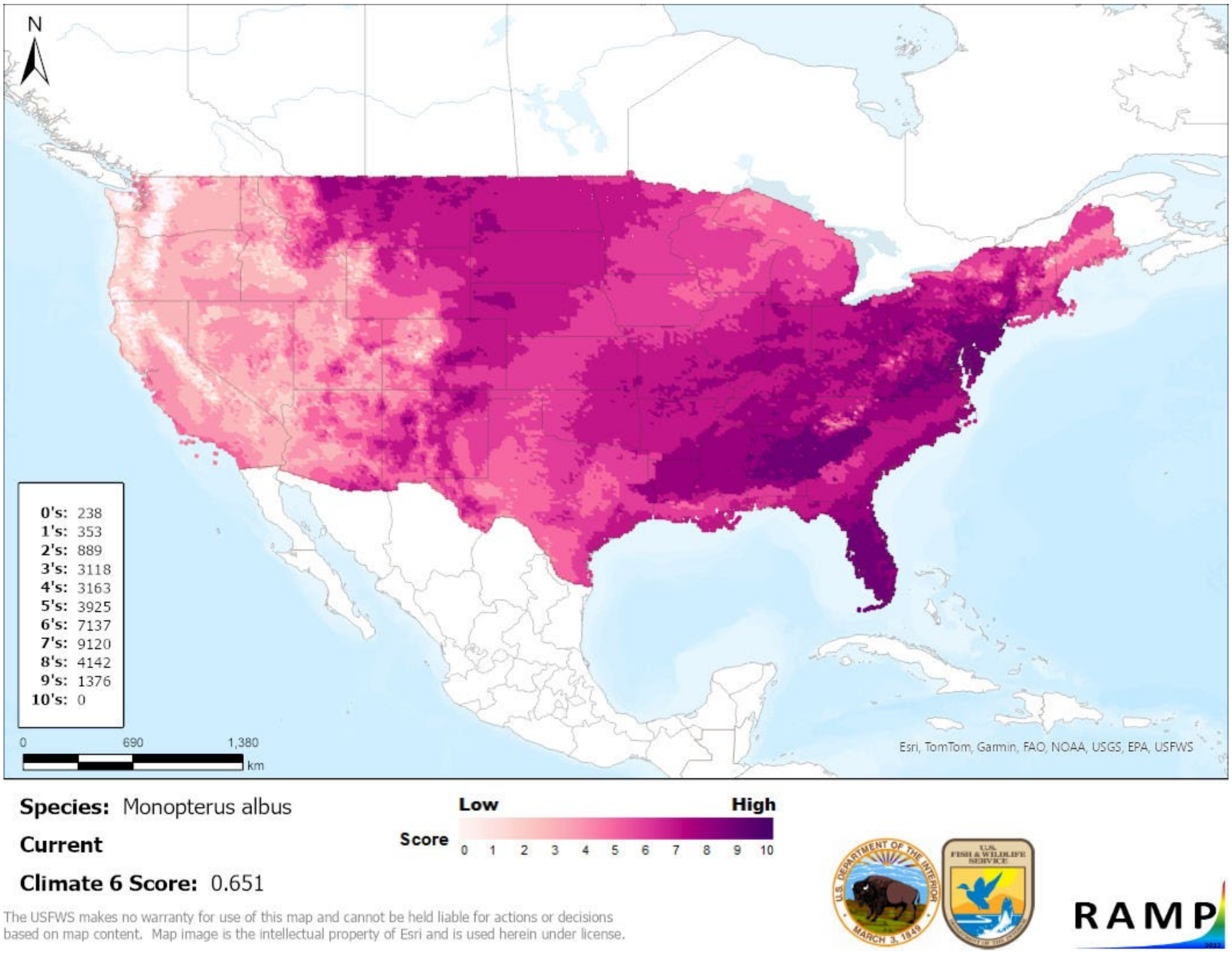

Figure 4. Map of RAMP (Sanders et al. 2023) climate matches for *Monopterus albus* in the contiguous United States based on source locations reported by GBIF Secretariat (2023). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment for *Monopterus albus* is classified as Medium. Information was available on the biology, ecology, and distribution of this species. Records of introduction, establishment, and impacts from nonnative populations were found. However, uncertainty exists regarding taxonomic relationships between different established populations and the taxonomic identity of specimens in trade, often falsely labeled *M. albus*. This reduces confidence in the described native and introduced ranges as well as applicability of impact information to this nominal species. Because of these factors, the certainty of assessment is reduced to Medium.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Monopterus albus, Asian Swamp Eel, is a fish that is native to eastern and southeastern Asia. This obligate air-breathing, eel-like fish is drought tolerant and will burrow into mud to withstand low water conditions. *M. albus* is found in trade as a live food source, aquarium species, and is used in some cultural traditions. *M. albus* has known established populations within the United States that were introduced via live release from the aquarium trade or from fish markets. There are negative impacts of introduced populations documented from peer-reviewed literature for this species, specifically in Florida where significant declines in the abundance of native fishes and decapods were found following the introduction of *M. albus*. *M. albus* is regulated in multiple U.S. States. *M. albus* has also been introduced beyond its native range in Asia and there have been reports of negative economic impacts due to burrowing behavior that has damaged rice fields in the Philippines and Japan. The History of Invasiveness for *M. albus* is classified as High due to the multiple established nonnative populations that have led to negative impacts. The climate matching analysis for the contiguous United States indicates establishment concern for this species. Areas of high match were recorded in the eastern portion of the country. The Midwest had a mostly medium climate match and areas of low match were found along the West Coast. The Certainty of Assessment for this ERSS is classified as Medium. Although there is a good amount of reliable information for this species, uncertainty exists regarding taxonomic relationships between different established populations and the identity of specimens in trade. Molecular studies have shown that *M. albus* represents a species complex with up to five potential species that may be recognized with future work. The Overall Risk Assessment Category for *M. albus* in the contiguous United States is High.

Assessment Elements

- **History of Invasiveness (see section 4): High**
- **Establishment Concern (see section 7): Yes**
- **Certainty of Assessment (see section 8): Medium**
- **Remarks, Important additional information: No additional remarks.**
- **Overall Risk Assessment Category: High**

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

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Appendix

Summary of Future Climate Matching Analysis

Future climate projections represent two Shared Socioeconomic Pathways (SSP) developed by the Intergovernmental Panel on Climate Change (IPCC 2021): SSP5, in which emissions triple by the end of the century; and SSP3, in which emissions double by the end of the century. Future climate matches were based on source locations reported by GBIF Secretariat (2023).

Under the future climate scenarios (figure A1), on average, high climate match for *Monopterus albus* was projected to occur in the Northeast, Southern Atlantic Coast, and Southern Florida regions of the contiguous United States. Areas of low climate match were projected to occur in the Great Basin and Northern Pacific Coast regions. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.322 (model: UKESM1-0-LL, SSP5, 2085) to a high of 0.669 (model: IPSL-CM6A-LR, SSP3, 2055). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species under future scenarios. The Climate 6 score for the current climate match (0.651, figure 4) falls within the range of scores for future projections. The time step and climate scenario with the most change relative to current conditions was SSP5, 2085, the most extreme climate change scenario. Under one or more time step and climate scenarios, areas within the Northeast saw a large increase in the climate match relative to current conditions. Additionally, areas within the Colorado Plateau, Great Lakes, Northern Pacific Coast, and Western Mountains saw a moderate increase in the climate match relative to current conditions. Under one or more time step and climate scenarios, areas within the Appalachian Range, Mid-Atlantic, Northern Plains, and Southeast saw a large decrease in the climate match relative to current conditions. Additionally, areas within the Colorado Plateau, Great Basin, Gulf Coast, Northeast, Southern Atlantic Coast, Southern Florida, Southern Plains, and Western Mountains saw a moderate decrease in the climate match relative to current conditions. The magnitude of change from current conditions was more pronounced in time step 2085 than in time step 2055 under both scenarios, SSP3 and SSP5. The areas of moderate and large change also had a larger geographic extent under SSP5 than SSP3 in the 2085 time step. Additional, very small areas of large or moderate change may be visible on the maps (figure A3).

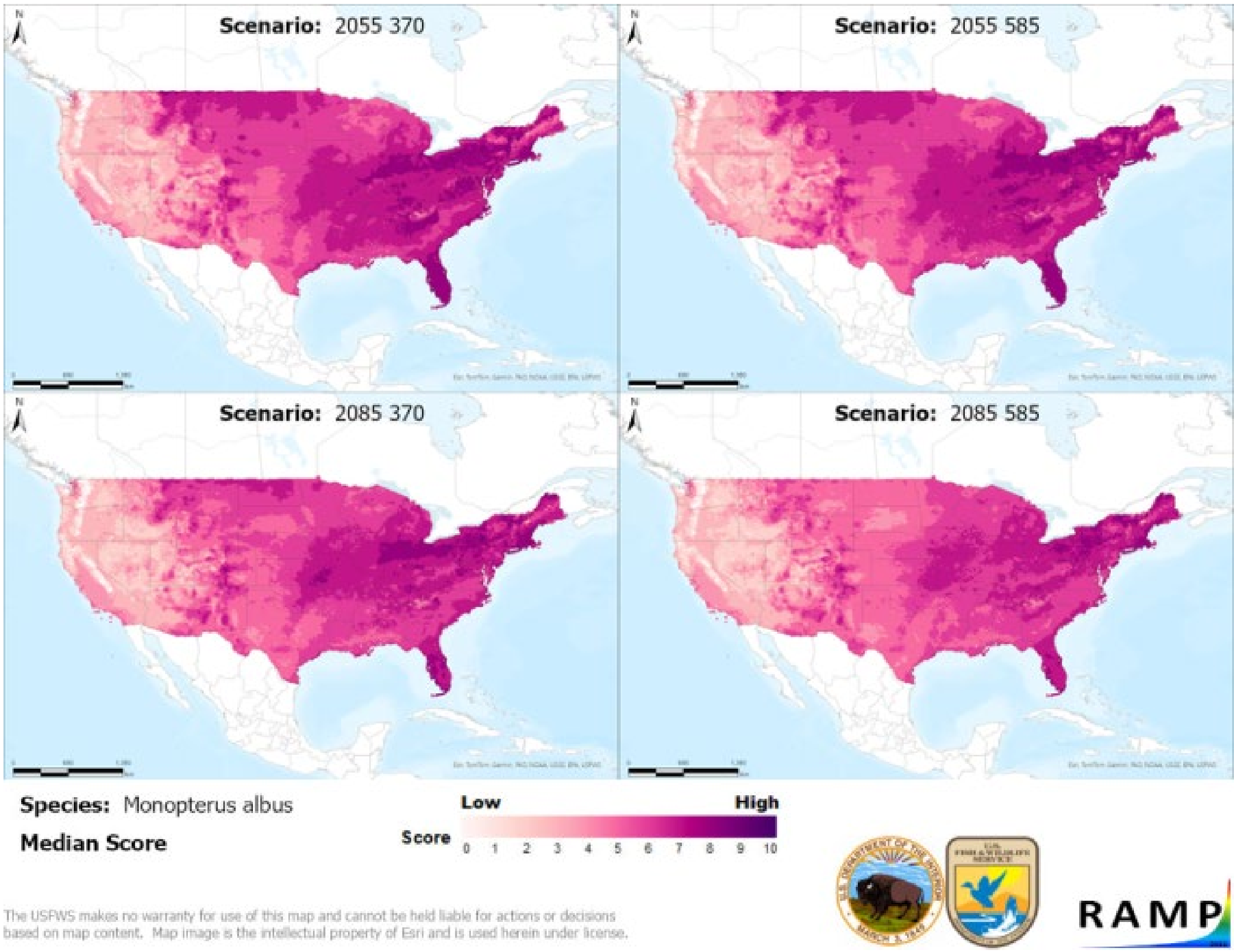

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Monopterus albus* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2023). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

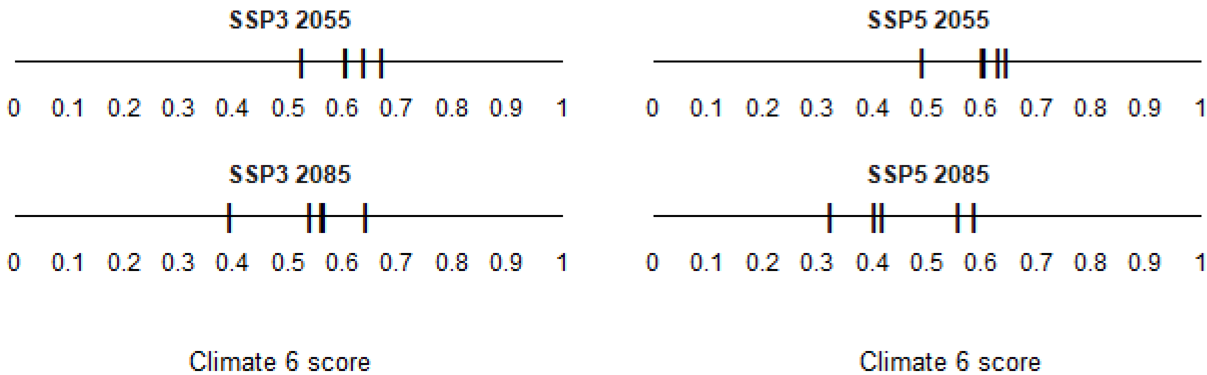

Figure A2. Comparison of projected future Climate 6 scores for *Monopterus albus* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0.

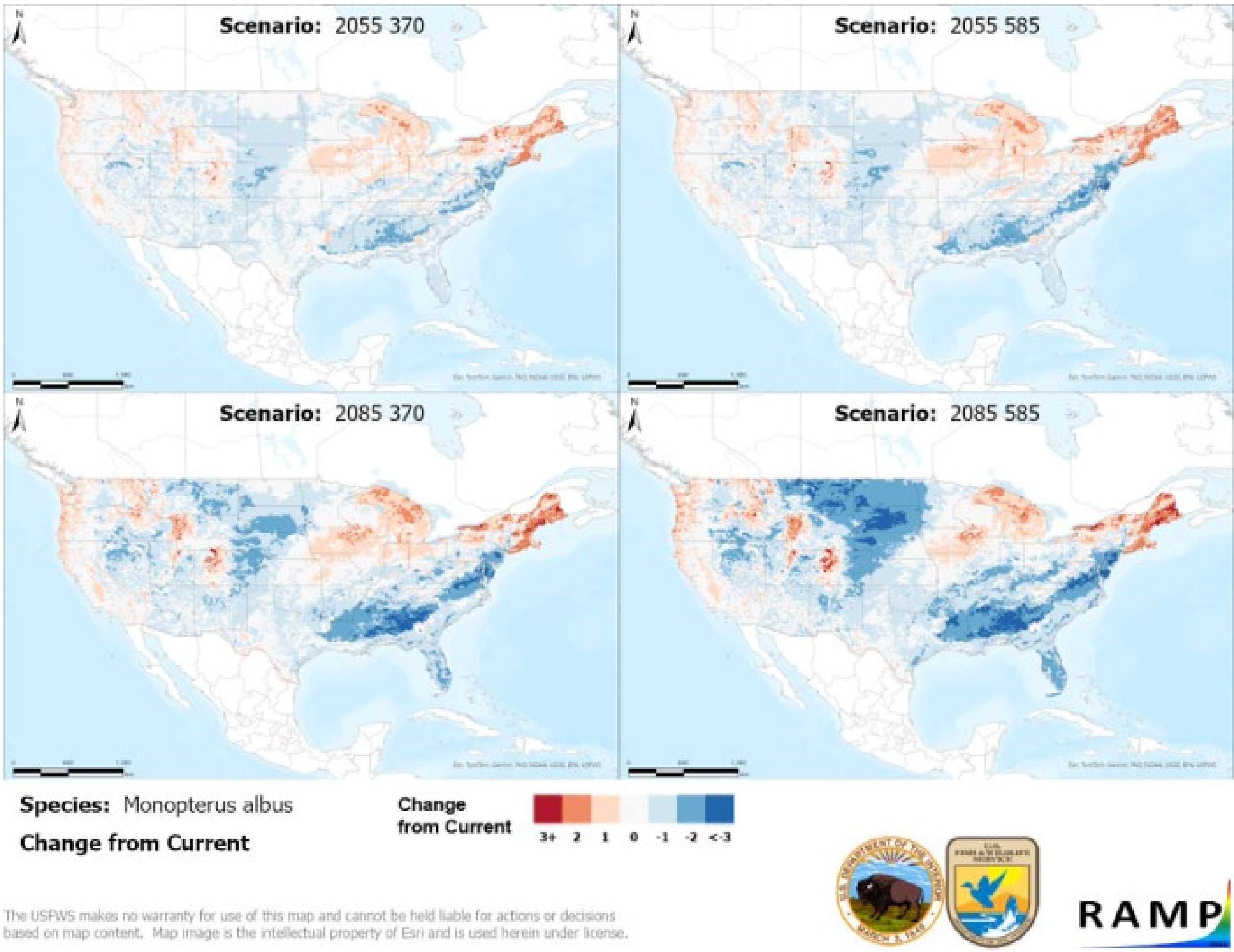

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 4) and the median target point score for future climate scenarios (figure A1) for *Monopterus albus* based on source locations reported by GBIF Secretariat (2023). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. Shades of blue indicate a lower target point score under future scenarios than under current conditions. Shades of red indicate a higher target point score under future scenarios than under current conditions. Darker shades indicate greater change.

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