U.S. Fish & Wildlife Service

Marbled Crayfish (*Procambarus virginalis*)

Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, May 2023
Revised, June 2023
Web Version, 9/22/2023

Organism Type: Crustacean
Overall Risk Assessment Category: Uncertain

Photo: Lyko F. Licensed under Creative Commons (CC-BY 3.0). Available: https://commons.wikimedia.org/wiki/File:Procambarus_virginalis_%2810.11646-zootaxa.4363.4.6%29_Figure_2.png (May 2023).

1 Native Range and Status in the United States

Native Range

From Faulkes (2010):

"[…] there is no known native founder population of Marmorkrebs [*P. virginalis*]."

From Pârvulescu et al. (2017):

"Their origin is unknown, as the first record of their presence comes from the German aquarium trade (Lukhaup 2001)."

From GISD (2023):

"Because its closest phylogenetic relationship is *P. fallax*, it is considered a North American species. It may have originated in the native range of its mother species or in captivity (Vogt, 2015)."

Status in the United States

No records of *P. virginalis* in the wild in the United States were found. *P. virginalis* is in trade in the United States.

From Faulkes (2010):

"The earliest report of Marmorkrebs being available in the North American pet trade was in 2004, just one year after the first scientific paper in English on Marmorkrebs (Scholtz et al. 2003). Acquisitions have increased sharply from 2007 onwards […]."

"While many Marmorkrebs are sold through online sources, face-to-face personal contacts account for almost as many acquisitions."

From Faulkes (2015):

"By every measure, Marmorkrebs are the most common crayfish species in the North American pet trade. They are the most commonly offered at auction. They are the most commonly bought, as measured by number of individuals sold and number of unique buyers. They are tied with *C*[*ambarellus*] *patzcuarensis* as the cheapest crayfish on the market."

P. virginalis is listed as a prohibited species in Arkansas (specifically for commercial aquaculture or private stocking; AGFC 2022), Georgia (Georgia DNR 2023), Kansas (KDWP 2022), Maryland (Code of Maryland Regulations 2022), Michigan (State of Michigan 2023), Missouri (MDC 2022), North Carolina (North Carolina DEQ 2022), and Oklahoma (Oklahoma Department of Wildlife Conservation 2023).

P. virginalis is listed as an injurious aquatic invasive species in Ohio (ODNR 2022).

P. virginalis (as *P. fallax f. virginalis*) is listed as an aquatic invasive vertebrate species in Idaho (IDDA 2022).

P. virginalis (as *P. fallax f. virginalis*) is regulated as a Class V wildlife species in Tennessee (TWRA 2022).

P. virginalis (as *Procambarus sp.*, marbled crayfish) is regulated for import, possession, and sale in Virginia (Virginia DWR 2022).

The following States have specific regulations restricting or prohibiting import, transport, possession, or sale of nonnative crayfish (without exception for *P. virginalis*): Arizona (Arizona Game and Fish Commission 2022), California (CDFW 2021), Colorado (CPW 2022), Minnesota (Minnesota DNR 2022), Nevada (Nevada Board of Wildlife Commissioners 2022), New Hampshire (NHFG 2022), New Mexico (NMDGF 2010), Oregon (ODFW 2022), Pennsylvania (PFBC 2022), Rhode Island (Rhode Island DEM 2022), Utah (Utah DWR 2020), Washington (WDFW 2022), and Wisconsin (Wisconsin DNR 2022).

P. virginalis is not included on the list of approved aquatic species for the following States, which allow import, possession, or sale only for those species listed: Hawaii (HDOA 2019), Illinois (Illinois DNR 2015).

Means of Introductions within the United States

No records of *Procambarus virginalis* in the wild in the United States were found.

Remarks

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

From GISD (2023):

"The taxonomy of the species was uncertain for many years, and it was temporarily called "Marmorkrebs" or *P. fallax* forma *virginalis* (Martin et al., 2010[a]). Recently, it was formally described as an independent species under the name of *Procambarus virginalis* in Lyko, 2017."

From Vogt et al. (2018):

"Comparison of morphological traits of marbled crayfish and *Procambarus fallax* revealed no obvious differences between the species. […] Thus, we did not succeed in finding a morphological character that unambiguously identifies marbled crayfish. […] The distinction of these two species is then only possible with the presence or absence of males, different maximum sizes and particularly the microsatellite marker PclG-02."

"Marbled crayfish found in European rivers and lakes were sometimes identified by their eponymous marbled coloration alone (Chucholl & Pfeiffer, 2010; Chucholl et al., 2012; Lipták et al., 2016; Novitsky & Son, 2016); however, this marbled colour pattern is not limited to the

marbled crayfish. Indeed, *Procambarus fallax* displays the same marbled coloration, and numerous *Procambarus* species are speckled (Lukhaup, 2003)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2023):

Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Protostomia
Superphylum Ecdysozoa
Phylum Arthropoda
Subphylum Crustacea
Class Malacostraca
Subclass Eumalacostraca
Superorder Eucarida
Order Decapoda
Suborder Pleocyemata
Infraorder Astacidea
Superfamily Astacoidea
Family Cambaridae
Genus *Procambarus*
Species *Procambarus virginalis* Lyko, 2017

According to DecaNet (2023), *Procambarus virginalis* is the current valid name for this species.

Both the valid scientific name, *Procambarus virginalis*, and the synonym, *Procambarus fallax* f. *virginalis*, were used to search for information for this report.

Size, Weight, and Age Range

From Vogt et al. (2018):

"The maximum body size reliably recorded is about 11 cm corresponding to an estimated body weight of approximately 35 g (Vogt et al., [2019])."

From Andriantsoa et al. (2019):

"Measurements established carapace lengths that were often between 10 and 35 mm and total lengths between 30 and 80 mm […] Animal weights usually ranged from 1 to 10 g […]"

From GISD (2023):

"Its lifespan is around four years in a broad range of conditions."

Environment

From GISD (2023):

"Has been found in lentic and lotic freshwater systems (Lyko, 2017)."

From Kaldre et al. (2015):

"With respect to temperature tolerance range, the high temperature limit is more variable than the low temperature limit (Freitas et al. 2010). Marble [sic] crayfish are best cultured at temperatures of 18–25°C, but could withstand temperatures below 8°C and above 30°C for many weeks, although mortality increases under such conditions and reproduction stops (Vogt et al. 2004)."

"Experiments with outdoor tanks in Estonia indicated that marble [sic] crayfish survive temperatures below 6°C for six months and tolerate temperatures below 2°C at least one week."

From Veselý et al. (2017):

"Evaluation of survival, growth and reproduction suggests that marbled crayfish have a lower salinity tolerance than other crayfish species, which may limit their invasive potential in brackish environments. However, its ability to survive for more than 80 days at 18 ppt [parts per thousand] opens up the possibility of gradual dispersion and adaptation to brackish conditions."

From Andriantsoa et al. (2019):

"[…] we detected marbled crayfish at a wide range of altitudes (3–1491 m […])."

"Additional examples for the ability of marbled crayfish to colonize different habitats were provided by the Anjingilo rice fields […] that are irrigated by thermal water and the Ranomaimbo lake located in the city center of Antsirabe […]. The water of Anjinglio is characterized by a particularly high temperature of 37 °C and elevated Barium concentrations, which are characteristic of thermal water […] The water of the Ranomaimbo lake was characterized by particularly high conductivity levels and a high concentration of dissolved solids […] such as Natrium (157 mg/l) and Nitrate (20 mg/l). These values reflect the high levels of pollution that are often associated with urban settlements. Taken together, our findings suggest that marbled crayfish can tolerate substantial variation in ecological parameters."

Climate

From Dobrović et al. (2021):

"[…] marbled crayfish has a wide thermal niche and viable and reproducing populations have been reported from areas/countries with temperate continental climates (i.e. Germany; Chucholl and Pfeiffer 2010; Slovakia; Lipták et al. 2016, 2017; Czech Republic; Patoka et al. 2016) to those with tropical climate (i.e. Madagascar; Jones et al. 2009)."

Chucholl (2011) reports a latitude range for *Procambarus virginalis* (as *P. fallax f. virginalis*) from 52°N to 19°S.

Distribution Outside the United States

Native

From Faulkes (2010):

"[…] there is no known native founder population of Marmorkrebs [*P. virginalis*]."

From Pârvulescu et al. (2017):

"Their origin is unknown, as the first record of their presence comes from the German aquarium trade (Lukhaup 2001)."

From GISD (2023):

"Because its closest phylogenetic relationship is *P. fallax*, it is considered a North American species. It may have originated in the native range of its mother species or in captivity (Vogt, 2015)."

Introduced

North America

From USGS (2023):

"Found [single individual] deceased on path in park [City View Park, Burlington, Ontario, Canada]. Using photos from https://www.inaturalist.org/observations/98794697 the specimen was identified by experts as *Procambarus virginalis*. Follow-up sampling has not found any further individuals or evidence thereof as of 2023-02-27."

Europe

From Kouba et al. (2014):

"The first European specimen of marbled crayfish found in the wild was caught in Germany in 2003 (Marten et al. 2004). A few specimens were found crawling on the land after the cleaning of a canal in the Netherlands in 2004 (Soes and van Eekelen, 2006) and a single specimen of marbled crayfish was reported in a well-established population of the red swamp crayfish in a slow flowing canal in Tuscany, central Italy in 2008 (Marzano et al., 2009). Further records of isolated specimens were meanwhile reported from Germany. The situation dramatically changed in 2010, when established populations were found not only in Germany but also in Slovakia (Janský [and] Mutkovič, 2010; see Chucholl et al., 2012 for review), and additional findings in Germany followed. Since the overview by Chucholl et al. (2012), at least three further records are reported from Germany, some of which may represent established populations (C. Chucholl, pers. comm.). Self-sustaining population was also suggested to occur close to Venice, Italy (Z. Duriš, pers. comm.)."

“Recently, another alarming report came from Sweden where 13 specimens of marbled crayfish were found in December 2012 in the River Märstaån in the central part of country (Bohman et al., 2013). Later attempts to confirm the presence of this species failed, so it is not known whether it can establish reproducing population under Scandinavian climatic conditions. Further potential occurrence of marbled crayfish was also suggested close to Skara, southern Sweden (Bohman et al., 2013). However, although the photographs of the respective animals are of low quality and lack essential details, we believe they actually do not represent this taxon. Further attempts to confirm its occurrence were also unsuccessful (L. Edsman, pers. comm.).”

From Scheers et al. (2021):

“In Europe, established populations are known from Croatia (Cvitanić 2017), Czech Republic (Patoka et al. 2016), Estonia (Ercoli et al. 2019), France (Collas [2019]), Germany (Martin et al. 2010b), Hungary (Lökkös et al. 2016), Italy (Vojkovská et al. 2014), Malta (Deidun et al. 2018), Romania (Pârvulescu et al. 2017), Slovakia (Janský and Mutkovič 2010) and Ukraine (Novitsky and Son 2016). Furthermore, there are records from The Netherlands and Sweden, but in these countries the species did not establish viable populations (Koese and Soes 2011; Soes 2016; Bohman et al. 2013).”

“In 2020, four populations of the marbled crayfish *Procambarus virginalis* […] were discovered in northern Belgium. These records represent the first established populations of this invasive parthenogenetic species in the Benelux [countries of Belgium, the Netherlands, and Luxembourg].”

From Sanna et al. (2021):

“In 2019, some individuals morphologically attributable to the marbled crayfish were found in freshwater habitats of southern Sardinia (Italy). Just one year later, individuals that can be identified as marbled crayfish have been found in many other areas of Sardinia (pers. obs.). […] This paper reports the first record of *Procambarus virginalis* in Sardinia, supported by molecular identification.”

From Ercoli et al. (2019):

“Here we report the first record of marbled crayfish in Estonia. In total, 104 individuals were found in the artificially warm outflow channel of the cooling system of Balti Power Plant, entering to the water reservoir of the River Narva.”

From Pichler and Timaeus (2020):

“The marbled crayfish, *Procambarus virginalis* Lyko 2017 (Decapoda: Astacidae), a highly invasive species, is reported in Vienna [Austria] for the first time. Several individuals have been documented around the artificial ponds Wienerbergteich and Kastanienalleeteich.”

No further information was found to confirm whether *P. virginalis* is established in Austria.

From Maciaszek et al. (2022):

"The invasive *P. virginalis* was first reported in Szczecin (north-west Poland) in 2009. Afterward, other observations followed, mostly of single individuals (Śmietana et al. 2018). The first breeding population was observed in 2019 in the semi-natural pond of Morskie Oko park in Warsaw (Mazurska et al. 2019), where thousands of crayfish have already been caught under Łowca Obcych/Alien Hunter initiative (Maciaszek 2022)."

"We hereby provide the first documented data on the occurrence of viable *P. virginalis* population in a nature-protected area in Poland […] The new localization in Ostrów Lubelski represents the most north-eastward distribution area of the species in European waters with a natural water temperature regime."

"Tourists notified [*sic*] another breeding population of *P. virginalis* on August 22, 2020, in Białka Lake (51.5337, 23.0157), ca. 8 km west from Kleszczów Lake and ca. 7 km from the borders of Polesie National Park."

Africa

From Gutekunst et al. (2018):

"We estimate that between 2007 and 2017, the size of the marbled crayfish distribution area [in Madagascar] increased about 100-fold from 10^3 km^2 to more than 10^5 km^2 […] and that the current population on Madagascar comprises millions of animals."

Asia

From Faulkes et al. (2012):

"One marbled crayfish, Marmorkrebs, *Procambarus fallax* f. *virginalis* (Hagen, 1870), was discovered in a natural ecosystem [river near Sapporo] in Japan in 2006."

From Usio et al. (2017):

"On 9 November 2016, an unknown Cambaridae crayfish was collected from the outflow stream of Matsubara Izumi along the Shigenobu River in western Japan. On the basis of COI and 12S rRNA analyses, we identified the crayfish as the Marmorkrebs (*Procambarus fallax* f. *virginalis*), which serves as the first record for this species from western Japan."

According to NIES (2023), *P. virginalis* (as *P. fallax* f. *virginalis*) is not established in Japan.

From Faulkes (2019):

"I heard from astacologist Chris Lukhaup today that marbled crayfish are now in the rivers and ponds on [sic] Israel. Yes, plural. This represents another significant expansion of Marmorkrebs across the globe, as it is the first report in western Asia. I don't have more details at this time as to location and such, but am sure it will be forthcoming."

No further information was found on the status of *P. virginalis* in Israel.

From Sanna et al. (2021):

"Furthermore, although not yet mentioned in scientific publications, several individuals of marbled crayfish have been discovered in different freshwater areas of […] Taiwan, and Macau, based on recent local reports."

No further information was found on the status of *P. virginalis* in Macau.

From Shih (2021):

"In July 2020, a large number of individuals were found in Daan Forest Park, Taipei City [Taiwan]. Although more than 10,000 individuals have been removed in the related removal work, there are still many individuals that have not been removed, which shows their amazing reproductive ability (Ji Chongyou, Shi Xide 2021)."

Means of Introduction Outside the United States

From Chucholl et al. (2012):

"Marmorkrebs populations in Europe are most likely the result of deliberate releases from aquaria, although secondary introductions may have occurred in one instance."

From Madzivanzira et al. (2020):

"In 2003, *P. virginalis* was introduced to Madagascar in Ambohimangakely, a village 15 km from the capital city, Antananarivo by foreign contractors working on a road building project (Jones et al. 2009). […] The motivation for the introduction into Madagascar freshwater systems remains unknown (Jones et al. 2009)."

From Andriantsoa et al. (2020):

"In Madagascar, […] farmers were observed transporting the species intentionally around the island as early as 2007, suggesting that they were considered a valued food source [Jones et al. 2009]. While the Ministry of Agriculture, Livestock and Fisheries issued legislation to prohibit the transportation of live marbled crayfish in 2009, the animals have recently been observed being widely sold in markets across Madagascar, without sanctions [Andriantsoa et al. 2019]."

From Maciaszek et al. (2022):

"According to local anglers, *P. virginalis* was introduced there [Ostrów Lubelski, Poland] approximately three years earlier as a food source for native predatory fish that had been overfished and competitively displaced by the invasive brown bullhead, *Ameiurus nebulosus* (Lesueur, 1819). The population was then kept by anglers in good condition by immediate releasing caught crayfish to the lake."

Short Description

From Vogt et al. (2018):

"The marbled crayfish is a relatively slender cambarid […] comprised of females only. […] Marbled crayfish are well pigmented and show variable patterns of lighter spots on darker background […]. The carapace is wider than the pleon and the pleon inclusive of the telson is longer than the carapace […]"

"Marbled crayfish have creamy patches on a darker background, which are most prominent on the branchiostegal part of the carapace […] Additionally, there are black and white spots, particularly on the pleon and chelipeds […]"

"Coloration in marbled crayfish is highly variable. In wild specimens from Lake Moosweiher, the background colour was mostly dark brown to olive dorsally (Fig. 3A [in source material]) and reddish brown laterally (Fig. 3B [in source material]). In laboratory raised specimens, the background colour was more variable ranging between brown, ochre (Fig. 8A [in source material]), reddish (Fig. 8C [in source material]) and bluish."

Biology

From Hossain et al. (2018):

"They reproduce via obligatory apomictic parthenogenesis, producing genetically identical offspring, which are clones of the mother (Martin et al. 2007; Martin 2015)."

"Under favourable conditions, marbled crayfish reproduces year-round with intervals of only 8–9 weeks between spawnings (Vogt et al. 2004) […]"

"Marbled crayfish begin to reproduce when younger than 6 months, at total body length of c. 40 mm (Vogt [2008]), which is early in comparison with other crayfish species […]"

"It can survive in dry periods by burrowing (Kouba et al. 2016) […]"

"The maximum [clutch size] values reported in laboratory culture and free-living populations ranged from 416 to 731 eggs (Seitz et al. 2005; Jones et al. 2009; Chucholl and Pfeiffer 2010; Vogt et al. 2015; Lipták et al. 2017)."

From Lipták et al. (2017):

"In total, 27 marbled crayfish (69% of the catch [sampled in the Danube River basin in Slovakia]) carried eggs or juveniles. The quantity of the offspring ranged between 147 and 647 (on average 420) eggs or juveniles per female, with a positive correlation with the size of the mother […]. Altogether, the 27 captured berried females carried 11 348 offspring."

From Guo et al. (2019):

"Our study revealed an ability of marbled crayfish to undergo terminal phases of embryogenesis, including hatching, as well as early post-embryonic development in high air humidity alone. Importantly, our finding that stage 2 juveniles were able to persist for a prolonged duration at this stage under humid conditions, and that they were able to resume normal ontogeny once re-immersed, greatly increases our understanding of this species' resilience in habitats with variable hydrology. […] This unprecedented life history trait in freshwater crayfish is probably crucial for inhabiting ecosystems with high water level fluctuations and severe drought."

From Lipták et al. (2019):

"Algae and detritus were identified as the most important food sources for the marbled crayfish [in a Slovakian population], while zoobenthos and macrophytes were less important. Moreover, the marbled crayfish was found to be an important food source for top fish predators, but marginal for omnivorous fish. Being able to utilize energy from the bottom of the trophic food web, the marbled crayfish may have important roles in the ecosystem, transferring energy to higher trophic levels. It processes allochthonous and autochthonous matter in the ecosystem, thus being a competitor to other organisms with similar food preferences and impacting zoobenthos, algae and macrophytes through predation or direct consumption."

From Linzmaier et al. (2020):

"Marbled crayfish and spiny-cheek crayfish [*Faxonius limosus*] occupied a wide range of trophic positions [in German lakes] corresponding to a very generalist diet. However, marbled crayfish were more relying on arthropod prey than spiny-cheek crayfish which fed more on mollusks."

"While our results are consistent with Lipták et al. (2019) regarding the low importance of macrophytes and generally a wide range of ingested resources, the populations we studied were much more carnivorous. This disparity could arise from differences in crayfish and food density but could also stem from high trophic plasticity."

From Deidun et al. (2018):

"Both species of *Procambarus* spp. [i.e., *P. clarkii* and *P. virginalis*] were observed to prey and feed on the gastropod *Cornu aspersum* (Müller, 1774), tadpoles of the painted frog *Discoglossus pictus* Otth, 1837 and of Bedriaga's frog *Pelophylax bedriagae* Camerano, 1882, adults of the western mosquito fish *Gambusia affinis* (S. F. Baird & Girard, 1853), adults of the scarlet darter nymph *Crocothemis erythrae* (Brulle, 1832), and larvae of the lesser drone fly *Eristalinus taeniops* (Wiedemann, 1818). Most of the feeding by both crayfish species took place early in the morning, with the crayfishes also observed scavenging under reeds and vegetation but in a largely inactive state later during the day. When disturbed, individuals of *Procambarus* sp. were observed to retreat in the mud by beating the abdomen backwards."

"A number of mammals, notably the long-tailed field mouse (*Apodemus sylvaticus*) (Linnaeus, 1758), the brown rat (*Rattus norvegicus*) (Berkenhout, 1769), and the North African hedgehog

(*Erinaceus algirus*) (Lereboullet, 1842), were observed to prey on individuals of *Procambarus* spp. in shallow, restricted water where the crayfishes were easily accessible from land. Bedriaga's frog (*Pelophylax bedriagae*), a non-native species […] was observed feeding on numerous sub-adults of *Procambarus virginalis* […] at Ta' Sarraflu pond, Gozo [Malta]. The common chameleon *Chamaeleo chamaeleon* (Linnaeus, 1758) and the praying mantis *Mantis religiosa* (Linnaeus, 1758) occasionally preyed on *Procambarus* individuals along the margins of these ponds."

From Chucholl et al. (2012):

"The frequent observation of Marmorkrebs migrating over land suggests that this behavior is most likely an inherent dispersal mechanism for this species, rather than an escape mechanism in response to adverse environmental conditions."

Human Uses

From Hossain et al. (2018):

"[…] the marbled crayfish was originally discovered in the German aquarium trade in the mid-1990s (Scholtz et al. 2003) […]"

"The marbled crayfish is frequently sold in pet shops and online (Chucholl 2013; Faulkes 2013; Lipták and Vitázková 2015; Mrugała et al. 2015)."

"Genetic uniformity, ease of culture, and a broad behaviour repertoire fosters the use of marbled crayfish in epigenetics and developmental biology, as well as physiological, ecotoxicological, and ethological research. Marbled crayfish could be further exploited for basic and applied fields of science such as evolutionary biology and clonal tumour evolution."

From Maciaszek et al. (2022):

"Despite being listed as an invasive alien species, *P. virginalis* is still present in aquarium trade within the European Union (EU), which banned the species in 2016."

From Faulkes (2010):

"The earliest report of Marmorkrebs being available in the North American pet trade was in 2004, just one year after the first scientific paper in English on Marmorkrebs (Scholtz et al. 2003). Acquisitions have increased sharply from 2007 onwards […]."

"While many Marmorkrebs are sold through online sources, face-to-face personal contacts account for almost as many acquisitions."

From Faulkes (2015):

"By every measure, Marmorkrebs are the most common crayfish species in the North American pet trade. They are the most commonly offered at auction. They are the most commonly bought,

as measured by number of individuals sold and number of unique buyers. They are tied with *C*[*ambarellus*] *patzcuarensis* as the cheapest crayfish on the market."

From Andriantsoa et al. (2019):

"Marbled crayfish currently represent an important component of the animal protein supply on local markets in all areas [of Madagascar] that were analyzed in this study and are being sold both as live animals […] and as boiled and processed tail meat […] Prices [are] comparable to the price of rice […] Popular marbled crayfish foods include deep-fried beignets and rice with marbled crayfish in tomato sauce […]. The increasing acceptance and popularity of marbled crayfish foods in Madagascar is likely to further increase their commercial demand and intentional propagation."

From Chucholl et al. (2012):

"In recent years, Marmorkrebs have also become popular as live food for predatory aquarium fish and ornamental turtles owing to their undemanding nature and high reproductive potential."

From Lipták et al. (2023):

"Based on the authors' personal communication with a seller located in Titel [Serbia], we know that the marbled crayfish is sold to local anglers as bait for the European catfish *Silurus glanis* Linnaeus, 1758."

Diseases

***Procambarus virginalis* has been documented as a carrier of *Aphanomyces astaci*. This pathogen can cause crayfish plague, a disease listed by the World Organisation for Animal Health (2023).**

From Keller et al. (2014):

"[…] marbled crayfish in captivity as well as in nature were infected with the crayfish plague agent."

"Although infection status in laboratory kept specimens reached high levels, marbled crayfish showed no obviously plague-related mortality."

From Hossein et al. (2018):

"Besides the crayfish plague, detection of rickettsial and coccidian-like organisms in the ovary and further organs of marbled crayfish make fears also real for native European species by transmission of pathogens once escaped into the wild (Vogt et al. 2004)."

Threat to Humans

From Andriantsoa et al. (2020):

"[…] some [survey] respondents [in Madagascar] have also experienced and witnessed allergic reactions, and stomach pain due to consumption of marbled crayfish […]"

3 Impacts of Introductions

The following quotations detail **potential, anecdotal,** or **highly generalized** information on impacts of introduction from *Procambarus virginalis*. No information was found documenting observed impacts of *P. virginalis* in natural settings.

From Jones et al. (2009):

"We lack direct information on the effects of *Procambarus* [*virginalis*] invasion but anecdotal observations of the effect of *Procambarus* on fish populations (so far only in areas where only introduced fish are present) suggest that they may have a significant impact. […] We have spoken to many fishermen who say that *Procambarus* has destroyed fishing in their local area. Inland fisheries, mostly based on introduced species, are very important to the economy of many parts of Madagascar and provide an important protein source."

"Arguably we lack the necessary information to conclude that *Procambarus* will harm biodiversity and livelihoods in Madagascar and so know little about the benefits of control or eradication."

From Vojkovska et al. (2014):

"[*P. virginalis*] can be a threat to vulnerable endemic crayfish species (Jones et al., 2009), including through the potential transmission of new pathogens from another non-indigenous crayfish species. Currently, however, cases of crayfish plague due to transmission from the marbled crayfish have yet to be found (Jones et al., 2009; Chucholl et al., 2012)."

From Andriantsoa et al. (2019):

"We also noticed that the distribution area of marbled crayfish showed a strong overlap with the freshwater snail *Biomphalaria pfeifferi*, which acts as the main intermediate host of the parasitic flatworm *Schistosoma mansoni* in Madagascar [Charbonnel et al. 2002; Morgan et al. 2005]. However, we could not find *B. pfeiferi* at the locations that we analyzed for marbled crayfish, suggesting possible predation. To confirm this possibility, we performed a laboratory experiment by placing snails of different sizes in laboratory boxes with a single marbled crayfish […] After the first night, all (N=28) snails had been eaten by the crayfish, and only leftover shells […] were found in the boxes. This suggests that marbled crayfish can act as effective predators of *B. pfeifferi*."

From Andriantsoa et al. (2020):

"The reasons [given in response to open-ended survey questions] for widely reported negative impacts of marbled crayfish on rice fields was due to burrowing activities, which dry up the rice fields and require the farmers to regularly repair their banks and irrigation canals. For example: 'the marbled crayfish destroy the mud walls we build around our rice fields' […]. This can also lead to arguments between rice field owners as they would accuse each other to have dried the rice field by digging burrows."

"However, the extent to which rice production is impacted by marbled crayfish in Madagascar remains poorly understood and our survey results, associated qualitative information, provided some contradictory evidence. In Analamanga (where the crayfish have been present over the longest period of time), the largest proportion of respondents reported no impact, while some reported a positive impact, perhaps because of the impact of the crayfish on soil aeration. It is possible that reported negative impacts of crayfish stem from extensive media reporting of possible negative impacts on rice, rather than firsthand experience."

From Chucholl and Chucholl (2021):

"The parthenogenetic all-female marbled crayfish featured a stronger per capita effect on zebra mussel prey than the native noble crayfish [in laboratory studies], suggesting a somewhat different impact on local macroinvertebrate communities. However, the magnitude of difference in FR [functional response] was only moderate and noble crayfish was estimated to be slightly more impactful on gammarid prey. Marbled crayfish currently co-occurs with invasive spiny-cheek crayfish in several lentic habitats across Europe (Linzmaier et al., 2020; Veselỳ et al., 2021); in line with field studies reporting marbled crayfish to be more carnivorous than spiny-cheek crayfish (Veselỳ et al., 2021), our results seem to indicate a somewhat stronger top-down pressure of marbled crayfish on macroinvertebrates, including mussels."

From Maciaszek et al. (2022):

"Following the introduction of *P. virginalis* in the Pojezierze Łęczyńskie Landscape Park [Poland], the local community confirmed a remarkable shift in frog croaking activity, with the forest becoming increasingly quiet. […] Unfortunately, no previous amphibian survey has been conducted in the same area. Therefore, we cannot quantify the decline caused by the marbled crayfish."

Within the United States, *Procambarus virginalis* is regulated in Arizona (Arizona Game and Fish Commission 2022), Arkansas (AGFC 2022), California (CDFW 2021), Colorado (CPW 2022), Georgia (Georgia DNR 2023), Hawaii (HDOA 2019), Idaho (IDDA 2022), Illinois (Illinois DNR 2015), Kansas (KDWP 2022), Maryland (Code of Maryland Regulations 2022), Michigan (State of Michigan 2023), Minnesota (Minnesota DNR 2022), Missouri (MDC 2022), Nevada (Nevada Board of Wildlife Commissioners 2022), New Hampshire (NHFG 2022), New Mexico (NMDGF 2010), North Carolina (North Carolina DEQ 2022), Ohio (ODNR 2022), Oklahoma (Oklahoma Department of Wildlife Conservation 2023), Oregon (ODFW 2022), Pennsylvania (PFBC 2022), Rhode Island (Rhode Island DEM 2022), Tennessee (TWRA 2022),

Utah (Utah DWR 2020), Virginia (Virginia DWR 2022), Washington (WDFW 2022), and Wisconsin (Wisconsin DNR 2022). See Section 1:Status in the United States for more details.

4 History of Invasiveness

There is no known indigenous population of *Procambarus virginalis*, although it is assumed to have originated from North America as a form of *P. fallax*. *Procambarus virginalis* was first detected as part of the aquarium trade in Germany, and has since established wild populations in Belgium, Croatia, Czech Republic, Estonia, France, Germany, Hungary, Italy, Madagascar, Malta, Poland, Romania, Slovakia, Ukraine, and possibly Israel. There is much concern about potential impacts of introduction, but there is little documentation of impacts beyond anecdotal information and laboratory studies of potential mechanisms of impact. *Procambarus virginalis* has been a popular and easily accessible aquarium animal in the United States, although possession and trade of *Procambarus virginalis* is now regulated in 21 U.S. States (sometimes as part of a blanket regulation covering all nonnative crayfish) and the European Union. Despite having successfully established nonnative populations, the History of Invasiveness for *Procambarus virginalis* is classified as Data Deficient due to the lack of clear, convincing, and reliable documentation of impacts of introduction.

5 Global Distribution

Figure 1. Reported distribution of *Procambarus virginalis* in Europe. Map from GBIF Secretariat (2023). Observations are reported from Austria, Belgium, France, Germany, Hungary, Italy (Sardinia), the Netherlands, Slovakia, and Ukraine. *P. virginalis* is not known to be established in Austria or the Netherlands, so observations in those countries were not used to select source points for the climate matching analysis. Establishment status could not be confirmed for western Ukraine, so observations there were not used to select source points for the climate matching analysis. For Belgium, only established populations according to Scheers et al. (2021) were used to select source points for the climate matching analysis.

Patoka et al. (2016) provide locations of established populations in the Czech Republic. Deidun et al. (2018) provide locations of established populations in the Maltese Archipelago. Dobrović et al. (2021) provide the location of an established population in Croatia. Shih (2021) provides the location of an established population in Taiwan. Maciaszek et al. (2022) provide locations of established populations in Poland.

Established populations of *P. virginalis* have been reported in thermal spring-fed ponds in Romania (Pârvulescu et al. 2017) and in a power plant outflow in Estonia (Ercoli et al. 2019). Because these populations exist in waters that are warmer than typical for each location's climate, they were not represented in the climate matching analysis.

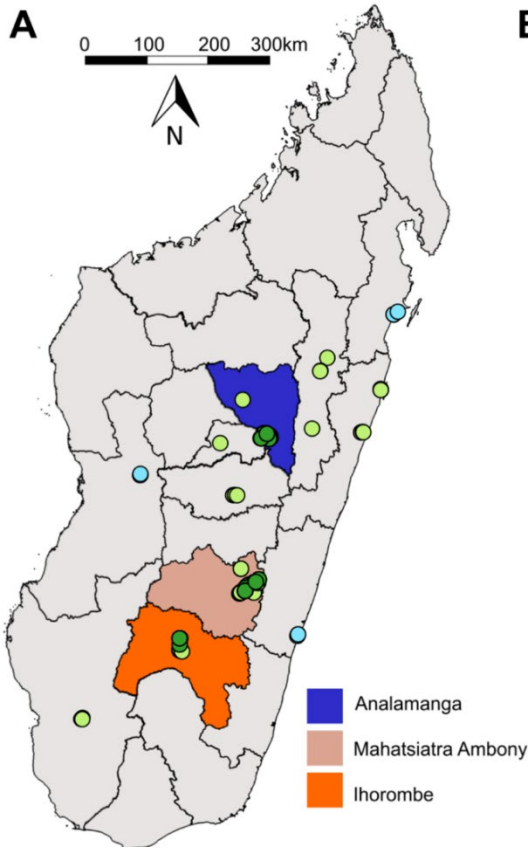

Figure 2. Map of known *Procambarus virginalis* observations in Madagascar. Green dots represent observations of *P. virginalis*, with lighter green dots representing established populations. Blue dots represent negative sampling events. Map from Andriantsoa et al. (2020), licensed under Creative Commons (CC BY).

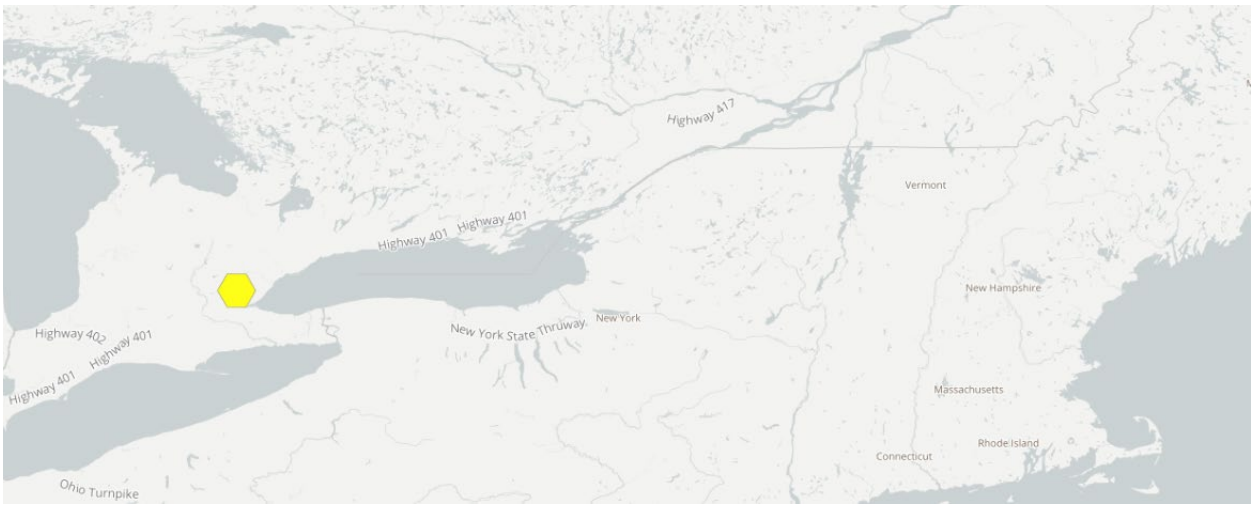

Figure 4. Reported distribution of *Procambarus virginalis* in North America. Map from GBIF Secretariat (2023). Observation reported from Canada. This observation was not used to select source points for the climate match as it does not represent a known established population.

6 Distribution Within the United States

No records of *Procambarus virginalis* in the wild in the United States were found.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Procambarus virginalis* to the contiguous United States was generally medium to high. Areas of high match extended from the Great Lakes region through the southern Great Plains to the southern Rocky Mountains, and also along the Appalachian Mountains. Other high matches were scattered throughout the Rocky Mountains and Intermountain West, and along the coasts of southern California and New England. Areas of low match were found along the northern Pacific Coast, in the Sierra Nevada and Cascade Mountains, and in inland areas from eastern Texas to southwestern Georgia. Everywhere else had a medium match. The overall Climate 6 score (Sanders et al. 2021; 16 climate variables; Euclidean distance) for the contiguous United States was 0.663, indicating a High Overall Climate Match (scores greater than 0.103, inclusive, are classified as High; table 1). The majority of the States had high individual Climate 6 scores. Alabama and Louisiana had medium individual Climate 6 scores. Mississippi had a low individual Climate 6 score.

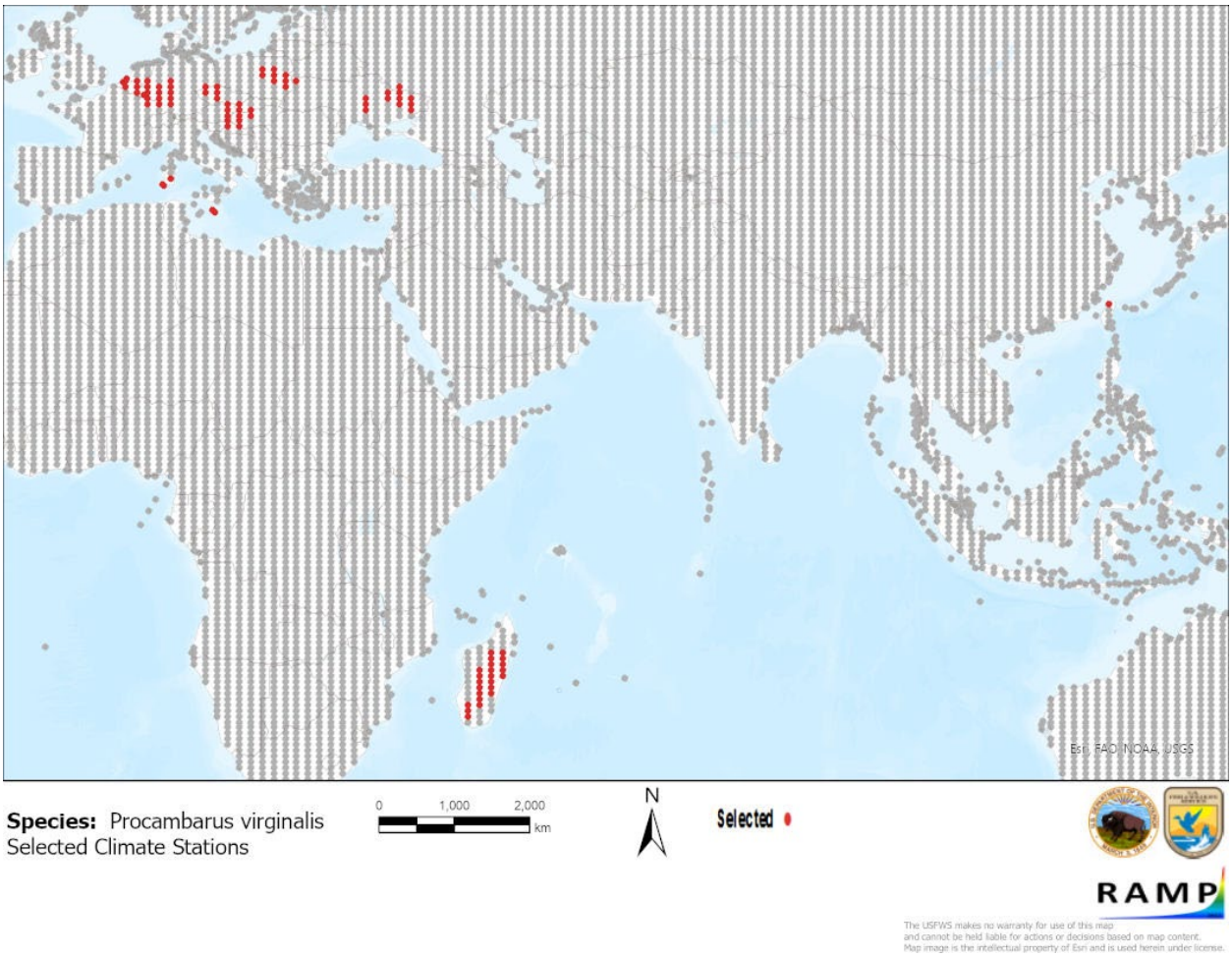

Figure 5. RAMP (Sanders et al. 2021) source map showing weather stations in Europe, Africa, and Asia selected as source locations (red; France, Belgium, Netherlands, Germany, Czech Republic, Austria, Hungary, Slovakia, Croatia, Slovenia, Poland, Ukraine, Italy (Sardinia), Malta, Madagascar, and Taiwan) and non-source locations (gray) for *Procambarus virginalis* climate matching. Source locations from GBIF Secretariat (2023), Patoka et al. (2016), Deidun et al. (2018), Andriantsoa et al. (2020), Dobrovic et al. (2021), Scheers et al. (2021), Shih (2021), and Maciaszek et al. (2022). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

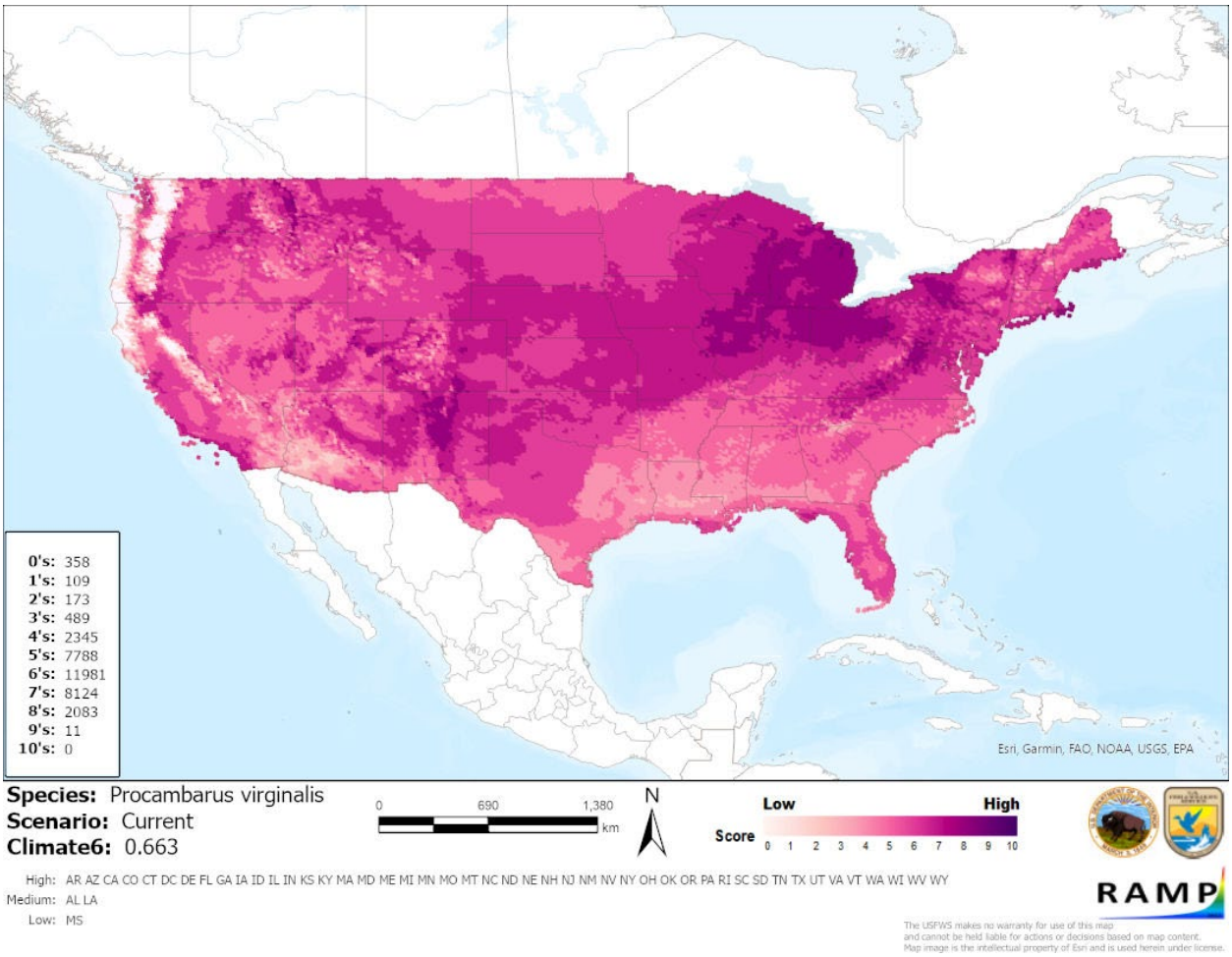

Figure 6. Map of RAMP (Sanders et al. 2021) climate matches for *Procambarus virginalis* in the contiguous United States based on source locations reported by GBIF Secretariat (2023), Patoka et al. (2016), Deidun et al. (2018), Andriantsoa et al. (2020), Dobrovic et al. (2021), Scheers et al. (2021), Shih (2021), and Maciaszek et al. (2022). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

Table 1. Climate 6 scores and associated Overall Climate Match category. The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). Climate match categories predict likelihood of establishment based on analysis of data on 255 species established in 10 countries (Bomford 2008; USFWS 2023).

Climate 6	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 *Procambarus virginalis* is classified as Low. There is clear and reliable documentation of the distribution of *Procambarus virginalis* showing nonnative establishment. However, the information available on impacts of these introductions is currently comprised of only anecdotal accounts from wild populations and laboratory studies. To increase assessment certainty, more rigorous study of wild populations is needed.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Procambarus virginalis, marbled crayfish, was initially discovered in the aquarium trade in Germany in the 1990s but was thought to be a form of the North American *P. fallax.* In 2017, it was described as a full species for which no native range is known. In the 21st century, nonnative populations have become established in several European countries, Madagascar, Taiwan, and possibly Israel. *P. virginalis* reproduces via parthenogenesis, meaning a single individual can found a new population. Although popular in aquaria, several U.S. States are implementing bans on the possession and trade of *P. virginalis*. There are anecdotal reports of impacts of *P. virginalis* on fisheries, rice agriculture, and native amphibian and snail populations, but clear, convincing, and reliable documentation of these impacts is not yet available. For this reason, the History of Invasiveness for *P. virginalis* is classified as Data Deficient and the Certainty of Assessment is Low. The Overall Climate Match to the contiguous United States is High. Areas of high match were found primarily around the Great Lakes, the Appalachian Mountains, and the southern Rocky Mountains. The Overall Risk Assessment Category for *P. virginalis* in the contiguous United States is Uncertain.

Assessment Elements

- **History of Invasiveness (Sec. 4): Data Deficient**
- **Overall Climate Match Category (sec. 7): High**
- **Certainty of Assessment (sec. 8): Low**
- **Remarks, Important additional information: Reproduces by apomictic parthenogenesis so the release of one individual is sufficient to start a new population. Carrier of *Aphanomyces astaci* (crayfish plague disease agent); crayfish plague is a listed disease for the World Organisation for Animal Health.**
- **Overall Risk Assessment Category: Uncertain**

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