Marmorkrebs (*Procambarus fallax* f. *virginalis*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, April 2014
Revised, June 2015

Photo: "Procambarus sp. (aka)" by André Karwath aka Aka - Own work. Licensed under CC BY-SA 2.5 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Procambarus_sp._(aka).jpg#/media/File:Procambarus_sp._(aka).jpg.

1 Native Range, and Status in the United States

Native Range

From CABI (2015):

"To this day, Marmorkrebs is only known from aquaria and its introduced range - an indigenous population has never been reported. However, it is reasonable to assume that the Marmorkrebs originates from the indigenous range of *P. fallax*, which comprises southern Georgia and Florida (USA) (Hobbs, 1989)."

Status in the United States

From CABI (2015):

"To this day, Marmorkrebs is only known from aquaria and its introduced range - an indigenous population has never been reported. However, it is reasonable to assume that the Marmorkrebs originates from the indigenous range of *P. fallax*, which comprises southern Georgia and Florida (USA) (Hobbs, 1989)."

Means of Introductions in the United States

This species has not been reported as introduced outside of its native range in the United States.

Remarks

From CABI (2015):

"The proliferation of Marmorkrebs as aquarium pet increases the propagule pressure and thereby the probability and risk of establishment in the wild. For instance, there is concern that its arrival and spread in the North American pet trade will inevitably also result in releases from captivity there (Faulkes, 2010). Marmorkrebs are available through online pet shops and may be readily shipped across borders (Chucholl, 2010; Peay et al., 2010). Additionally, personal contacts between crayfish enthusiasts may lead to cross-border acquisitions (Faulkes, 2010)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From CABI (2015):

"Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda
Subphylum: Crustacea
Class: Malacostraca
Subclass: Eumalacostraca
Order: Decapoda
Suborder: Reptantia
Superfamily: Astacoidea
Family: Cambaridae
Genus: Procambarus
Species: Procambarus fallax f. virginalis"

Taxonomic Status: From CABI (2015):

"The Marmorkrebs is a parthenogenetic lineage of the `slough crayfish´ [*Procambarus fallax* (Hagen, 1870); Martin et al., 2010a]. However, scientists have puzzled for almost a decade about its phylogenetic position and status. … Most recently, Martin et al. (2010a) showed by genetic and morphological comparisons that the Marmorkrebs is the parthenogenetic form of *Procambarus fallax*, and proposed the tentative scientific name *Procambarus fallax* f. *virginalis*.

Although `forma´ is not approved by the International Code of Zoological Nomenclature (ICZN, 1999), this name is the first scientific designation of the Marmorkrebs and can be used for the time being. … Additional data on the origin and ecology of the Marmorkrebs may warrant a further evaluation of its taxonomic status."

Size, Weight, and Age Range

From CABI (2015):

"The total length can be up to 13 cm, but is more often less than 10 cm. There exist only females."

Environment

From CABI (2015):

"Introduced Marmorkrebs have been found in both lentic and lotic freshwater habitats (e.g. Marten et al., 2004; Martin et al., 2010b). In Madagascar, Marmorkrebs were reported from a great variety of habitats, including rice paddies, rivers, lakes and swamps (Heimer, 2010), as well as brick pits, drainage ditches and fish ponds (Jones et al., 2009). Established populations in Germany are known from lentic habitats only (Chucholl and Pfeiffer, 2010; Privenau, 2010)."

"Since an indigenous Marmorkrebs population has never been reported, nothing is known about its natural prime habitat. However, it is reasonable to consider the habitat requirements of its closest relative, *Procambarus fallax*: *P. fallax* occurs in streams and rivers but seems to prefer lentic or slow flowing habitats and is typically found in marshes, wet prairies and sloughs with lightweight organic soils (Hendrix and Loftus, 2000; Martin et al., 2010a). This preference is also reflected by the common name of *P. fallax* of `slough crayfish´. *P. fallax* also inhabits temporary wetlands, which feature brief dry-downs during which crayfish retreat into refugia or simple burrows (Martin et al., 2010a). It is considered as a tertiary burrowing species, i.e. it lives in open water during most of its life and burrows only under extreme conditions (Dorn and [Volin], 2009)."

Climate/Range

From CABI (2015):

"Marmorkrebs seem to be tolerant of a wide range of environmental conditions, including low oxygenation and temporary exposure to temperatures < 8°C and > 30°C (Seitz et al., 2005; Souty-Grosset et al., 2006; Feria and Faulkes, 2011; C Chucholl, University of Ulm, Germany, personal communication, 2011)."

Distribution Outside the United States

Native

This species is not native outside the United States.

Introduced

From CABI (2015):

"The first free-living Marmorkrebs was captured from a gravel pit lake near Karlsruhe in southwestern Germany in late 2003 (Marten et al., 2004). In 2005, anecdotal evidence was presented for a population in a sedimentation pond near the city of Braunschweig (Lower Saxony, Germany); however, this has never been verified. Subsequently, single specimens were captured from small brooks near the city of Neu-Ulm (Bavaria) in 2008 (C Chucholl, University of Ulm, Germany, personal communication, 2011) and in Saxony in 2009 (Martin et al., 2010b). The first informal evidence for an established Marmorkrebs population in Germany was published by newspapers in mid-2010 (Privenau, 2010): local media repeatedly reported on Marmorkrebs coming out of an overpopulated small pond in a village near Halle (Saale, Saxony-Anhalt). Shortly after, another research paper evidenced that Marmorkrebs had formed a stable, reproducing population in a small lake near the city of Freiburg (Baden-Württemberg) (Chucholl and Pfeiffer, 2010). The first Marmorkrebs from this population was captured in 2009, but reported observations date back even further. In North-Rhine Westphalia (western Germany), single Marmorkrebs have been found in the Rivers Ruhr and Rhine (LANUV NRW, 2011) and there exist additional records from southwestern and central Germany which are yet unpublished. Chucholl and Pfeiffer (2010) suggested that the published Marmorkrebs records from Germany represent merely the `tip of the iceberg´."

"Free-living Marmorkrebs were also found in the Netherlands (Dordrecht) in 2004 (Soes and van Eekelen, 2006; Souty-Grosset et al., 2006), approximately 30 Marmorkrebs were introduced into a small waterbody in 2003 (Souty-Grosset et al., 2006) and were still present there in 2008 (according to http://www.marmorkrebs.org)."

"In Italy, a single Marmorkrebs was found living in syntopy with a large *Procambarus clarkii* population in 2008 (Nonnis Marzano et al., 2009)."

"Up to date, the Marmorkrebs is most widespread and abundant in Madagascar, where it was probably introduced in 2003 in Ambohimangakely (Jones et al., 2009) and is now present in eight of the country's 22 regions (Heimer, 2010). It is primarily distributed in the central high plains around the capital Antananarivo and is well established in the Ikopa and the Ampasimbe River systems (Jones et al., 2009; Kawai et al., 2009; Heimer, 2010). Large numbers of Marmorkrebs were sold in Moramanga (eastern Madagascar) in 2008 and it might be established in the area by now (Jones et al., 2009)."

"In Japan, one Marmorkrebs was captured from a river in Sapporo City (Hokkaido) in 2006 (Kawai and Takahata, 2010)."

Means of Introduction Outside the United States

From CABI (2015):

"The major pathway for Marmorkrebs introductions is the deliberate release of aquarium specimens (Soes and van Eekelen, 2006; Souty-Grosset et al., 2006; Chucholl and Pfeiffer, 2010)."

"In Madagascar, Marmorkrebs are harvested for human consumption and were sold in markets as cheap source of protein. They are reared in rice paddies and may be given as present to relatives in other regions. Further introductions along the major transport routes are therefore likely (Jones et al., 2009; Kawai et al., 2009; Heimer, 2010)."

Short description

From CABI (2015):

"The Marmorkrebs is a medium sized crayfish with a distinct, appealing marbled colour pattern and small chelae. The total length can be up to 13 cm, but is more often less than 10 cm. There exist only females."

Biology

From CABI (2015):

"**Genetics**
The Marmorkrebs propagates apomictically and produces genetically uniform clones (Martin et al., 2007). Developmental variation, however, leads to numerous phenotypes, even when reared under identical conditions (Vogt et al., 2008)."

"**Reproductive Biology**
The Marmorkrebs is unique in the manner that it is the only known decapod crustacean that reproduces by apomictic parthenogenesis: there exist only females which lay unfertilized eggs that develop into genetically uniform offspring (Scholtz et al., 2003; Martin et al., 2007; Vogt et al., 2008). No males have been found in laboratory or introduced, wild populations (Seitz et al., 2005; Jones et al., 2009)."

"The available data suggest that the Marmorkrebs is a fast growing species, which exhibits r-selected life history traits like early maturation, an extended breeding period and high fecundity. Parthenogenesis permits a high reproductive potential and since the females do not need to mate in order to reproduce, one single specimen is sufficient to create a new population."

"Reproduction and growth of the Marmorkrebs have been studied in the laboratory by Seitz et al. (2005). They found that growth rate was largely temperature dependant and highest at 30°C, while highest survival occurred at 20°C. Marmorkrebs exposed to low water temperatures (8-10°C) mostly survived and some individuals moulted at 10°C."

"Females reared at a temperature of 20-25°C started reproduction at an age of 141-255 days (carapace length = 14-22 mm). Fecundity ranged between 45 and 416 pleopodal eggs and increased with the size of the mother. Brooding took between 22 and 42 days and interclutch periods varied between 50 and 85 days."

"The fecundity of free-living Marmorkrebs in Madagascar was slightly higher and ranged between approximately 50 and 525 pleopodal eggs (Jones et al., 2009). Three ovigerous Marmorkrebs captured in southwestern Germany carried seven, 160 and 724 pleopodal eggs (Chucholl and Pfeiffer, 2010)."

"Only limited information is available on the timing of reproduction in free-living Marmorkrebs populations: In Madagascar, ovigerous females have been observed in March, June, July-September and December (Jones et al., 2009). In southwestern Germany, ovigerous females were found from early June to mid-October, at water temperatures between 26 and 15°C (Chucholl and Pfeiffer, 2010; M Pfeiffer and C Chucholl, University of Ulm, Germany, personal communication, 2011). Seitz et al. (2005) reported that Marmorkrebs in the laboratory ceased to reproduce at temperatures of 15°C or below."

"**Nutrition**
Like most crayfish species, the Marmorkrebs is most likely a polytrophic omnivore. It probably feeds on detritus, algae, plants and invertebrates and may also impact on higher trophic levels (e.g. fish). Vegetable substances dominated the stomach content of ten free-living Marmorkrebs sampled in Madagascar (Kawai et al., 2009)."

Human uses

From CABI (2015):

"**Economic Value**
The Marmorkrebs is a popular pet species in Europe and North America (Chucholl, 2010; Faulkes, 2010). In Germany, Marmorkrebs are sold at approximately 5 € per specimen (C Chucholl, University of Ulm, Germany, personal communication, 2011)."

"In Madagascar, Marmorkrebs are sold in markets for human consumption (Jones et al., 2009, Kawai et al., 2009; Heimer, 2010). However, Heimer (2010) and Jones et al. (2009) concurrently indicate that Marmorkrebs are of low economic value."

"**Social Benefit**
The Marmorkrebs was suggested as laboratory model organism for development, epigenetics and toxicology. Its high number of genetically identical offspring and its undemanding nature are, among other peculiarities, ideal prerequisites for this role (Vogt, 2008; 2010). Recent publications document its increasing use as model organism (e.g. Jirikowski et al., 2010; Rubach et al., 2011)."

Diseases

From Mrugała et al. (2015):

"Viability of *A. astaci* was confirmed by its isolation to axenic cultures from three host taxa, including the parthenogenetic invader Marmorkrebs (*Procambarus fallax* f. *virginalis*)."

From CABI (2015):

"Rickettsiosis and coccidiosis have both been found in Marmorkrebs and *Psorospermium* sp. is known to infect *P. fallax* in its indigenous range (Souty-Grosset et al., 2006)."

Crayfish plague (infection with *A. astaci*) is an OIE-reportable disease.

Threat to humans

From CABI (2015):

"Anecdotal observations from Madagascar suggest a significant impact on fish populations. Local fishermen reported that Marmorkrebs have destroyed fishing in their area (Jones et al., 2009; Heimer, 2010). Inland fisheries in Madagascar rely mostly on introduced fish (e.g. small carp and tilapia) and are an important source of protein and income (Jones et al., 2009; Heimer, 2010). Although the Marmorkrebs may represent a substitute for fish, preliminary data of Jones et al. (2009) suggest that it is of lower economic value and in less demand."

"There is also substantial concern that the invasion of Marmorkrebs will negatively impact rice culture in Madagascar (Jones et al., 2009; Kawai et al., 2009; Heimer, 2010). Introduced, non-indigenous crayfish are mostly considered a pest in rice paddies worldwide, because they damage young rice plants as well as irrigation systems and dams (e.g. Anastacio et al., 1995; Souty-Grosset et al., 2006). Preliminary stomach content data stress the ability of Marmorkrebs to feed on plant matter (Kawai et al., 2009) and Heimer (2010) indicated that Marmorkrebs may indeed damage young rice plants. Given the strong dependence of Madagascar's economy on rice culture, a reduction in rice productivity would involve serious economic damage (Jones et al., 2009)."

3 Impacts of Introductions

From CABI (2014):

"There has been merely anecdotal evidence for its economic and ecological impact – although preliminary data, along with the well-documented impacts of its invasive congener *P. clarkii*, justify eradication and control measures (cf. Jones et al., 2009; Kawai et al., 2009), further studies are necessary to assess its actual impact."

"**Impact on Habitats**
Marmorkrebs act probably as polytrophic omnivores and were found at very high densities in Madagascar (Jones et al., 2009). Given that, they might have a profound impact on ecosystem functioning and integrity, although specific information is currently lacking."

"**Impact on Biodiversity**
Marmorkrebs probably impact fish populations in Madagascar; however, explicit evidence is lacking (Jones et al., 2009; Heimer, 2010)."

"Marmorkrebs pose a threat to indigenous crayfish species in Madagascar and Europe, due to competition for food and space and crayfish plague transmission (Jones et al., 2009; Kawai et al., 2009; Chucholl and Pfeiffer, 2010)."

"Jimenez and Faulkes (2011) studied direct aggressive interactions between Marmorkrebs and *Procambarus clarkii* and concluded that Marmorkrebs have the potential to compete with other crayfish species. Furthermore, Marmorkrebs differ ecologically from indigenous crayfish in

Europe and Madagascar in having a fast growth rate, a very high fecundity and an extended breeding period (Seitz et al., 2005; Jones et al., 2009; Chucholl and Pfeiffer, 2010). These life history traits might give an additional competitive advantage to Marmorkrebs."

"The risk of devastating consequences for indigenous crayfish would dramatically increase if Marmorkrebs are infected with crayfish plague: Any contact of Marmorkrebs to susceptible crayfish (i.e. all crayfish native to Europe, Madagascar, Asia, Australia, and South America) would almost certainly result in mass mortalities among the susceptible species (Souty-Grosset et al., 2006; Jones et al., 2009)."

4 Global Distribution

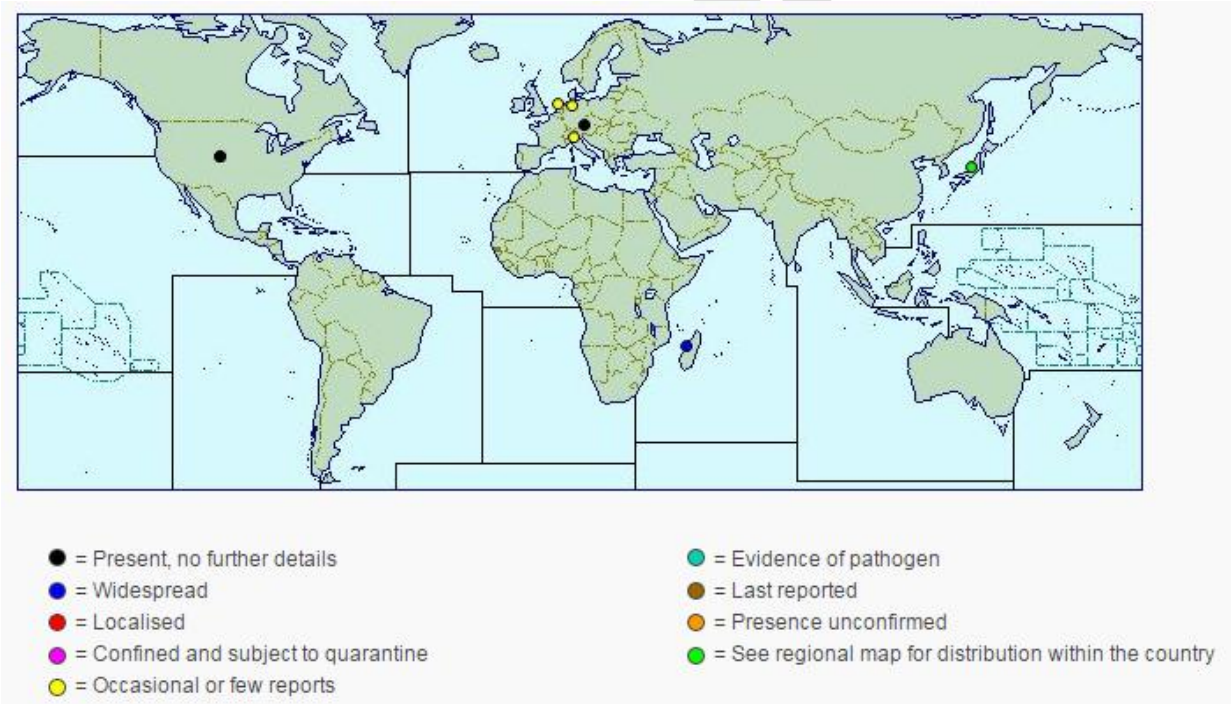

Figure 1. Map of known global distribution of *Procambarus fallax f. virginalis* (CABI 2015).

5 Distribution within the United States

From CABI (2015):

"To this day, Marmorkrebs is only known from aquaria and its introduced range - an indigenous population has never been reported. However, it is reasonable to assume that the Marmorkrebs originates from the indigenous range of *P. fallax*, which comprises southern Georgia and Florida (USA) (Hobbs, 1989)."

6 CLIMATCH

Summary of Climate Matching Analysis

The climate match (Australian Bureau of Rural Sciences 2008; 16 climate variables; Euclidean Distance) for only the introduced populations of *P. fallax* f. *virginalis* (Fig. 3) is moderate in portions of the Great Lakes and Mid-Atlantic regions, and low elsewhere. Adding in the presumed native range of *P. fallax* f. *virginalis*, i.e. the native range of *P. fallax*, the climate match is additionally high in Florida, in the Southeast along the Atlantic Coast, and along portions of the Gulf Coast (Fig. 5). Climate 6 match indicated that the continental U.S. has a medium climate match. The range for a medium climate match is 0.005 to 0.103; climate match of *Procambarus fallax f. virginalis* is 0.031 without the presumed native range and 0.076 including the presumed native range.

Crayfishes have been observed to establish populations in climates different from that found within their native range (M. Hoff, U.S. Fish and Wildlife Service, personal communication). The climate match shown here may be an underestimate of climate suitability for the establishment of *P. fallax* f. *virginalis*.

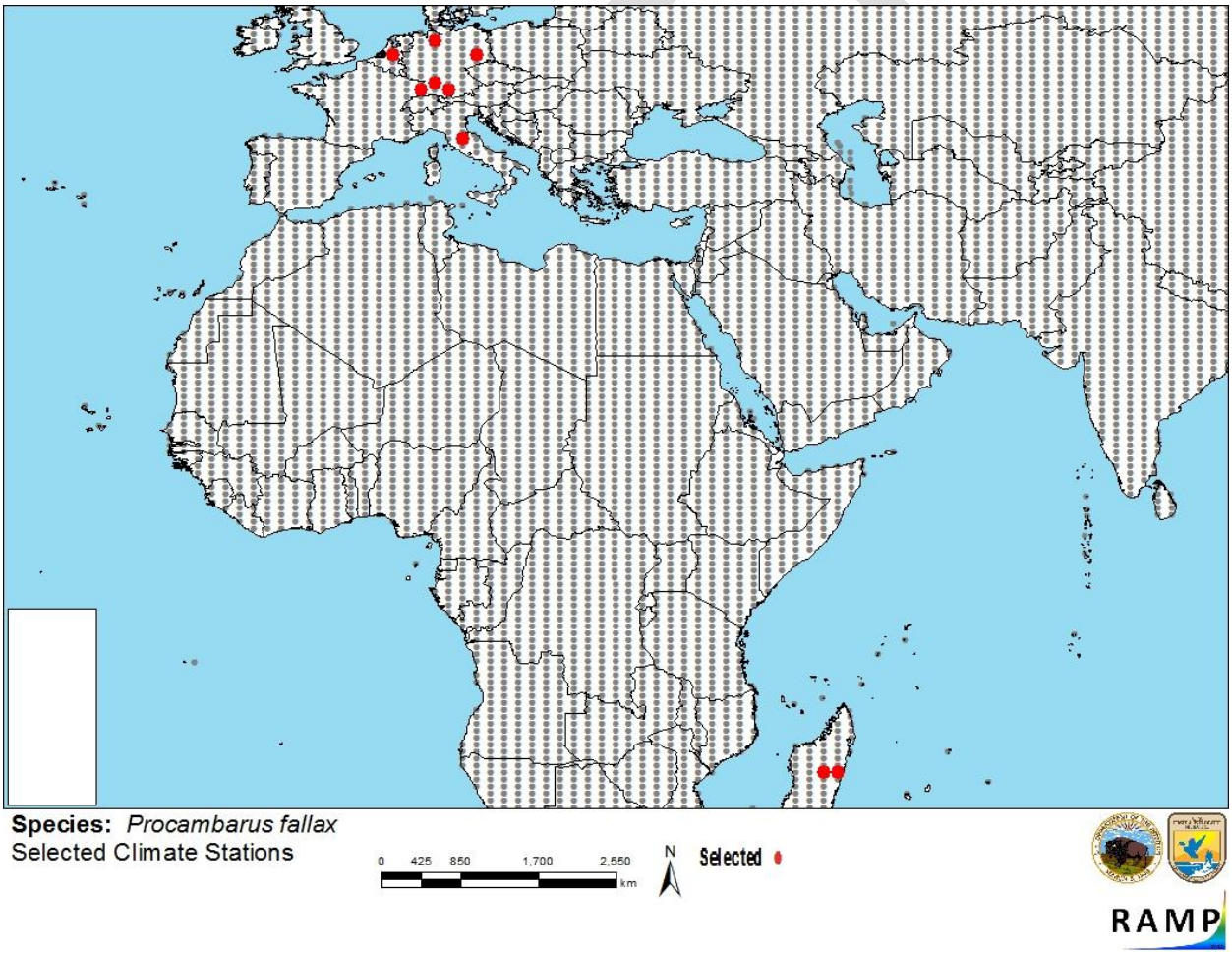

Figure 2. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Procambarus fallax f. virginalis* climate matching. Source locations from Feria and Faulkes (2011). These source locations include only the known introduced range of the subspecies.

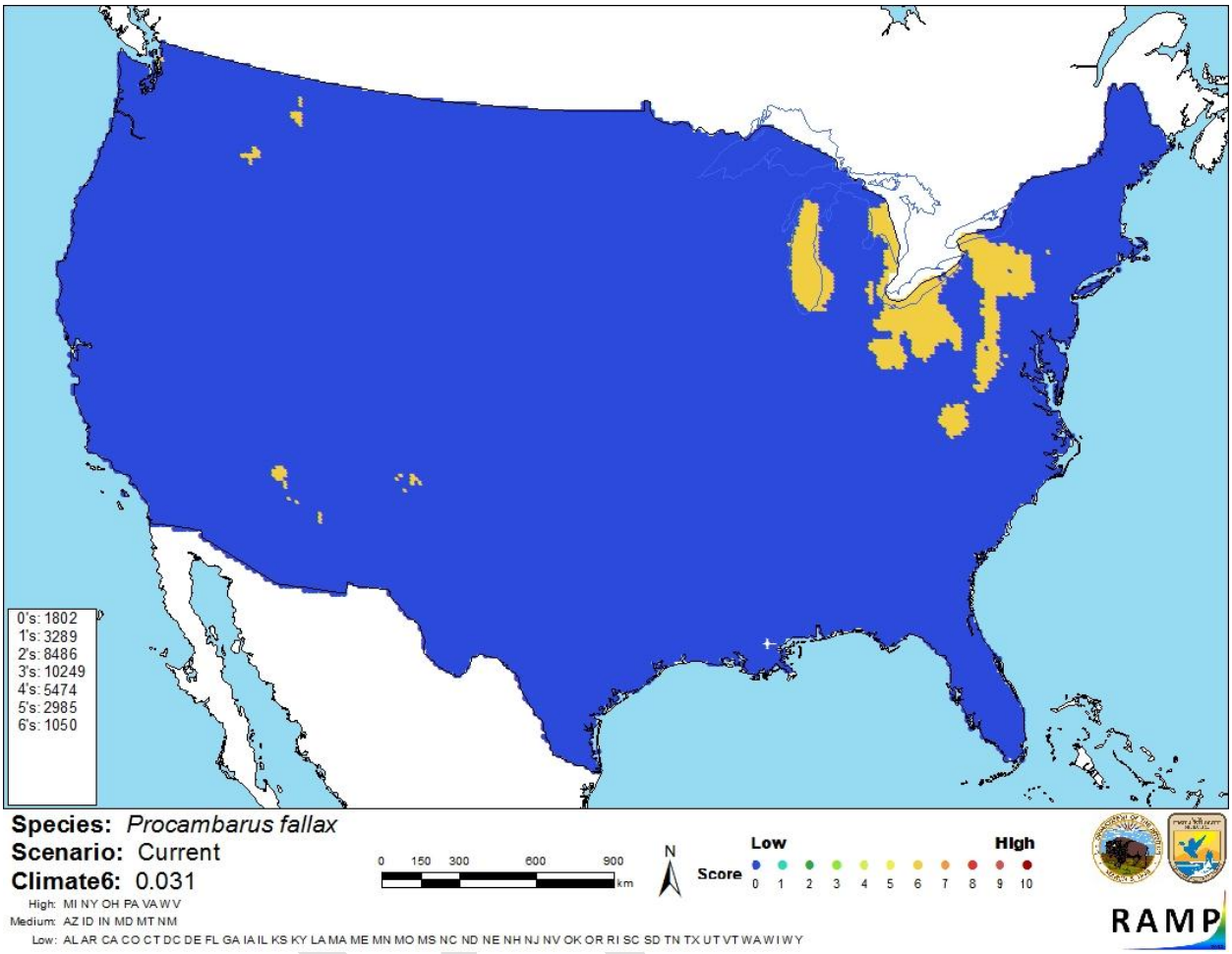

Figure 3. Map of RAMP (Sanders et al. 2014) climate matches for *Procambarus fallax f. virginalis* in the continental United States based on source locations reported by Feria and Faulkes (2011). 0= Lowest match, 10=Highest match. Climate match scores are tabulated on the left.

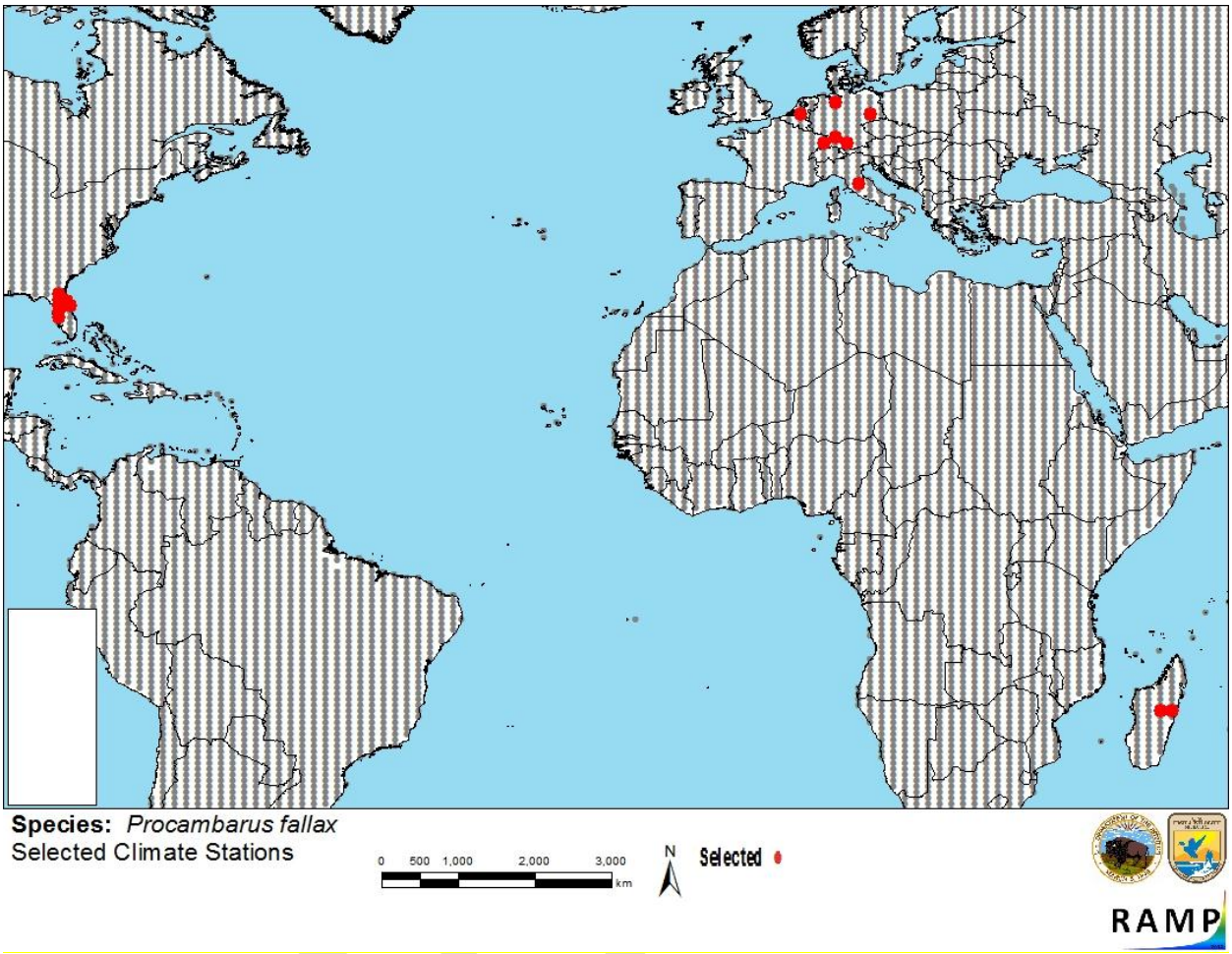

Figure 4. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Procambarus fallax f. virginalis* climate matching. Source locations from Feria and Faulkes (2011) and GBIF (2015). These source locations include the known introduced range of the subspecies as well as its presumed native range.

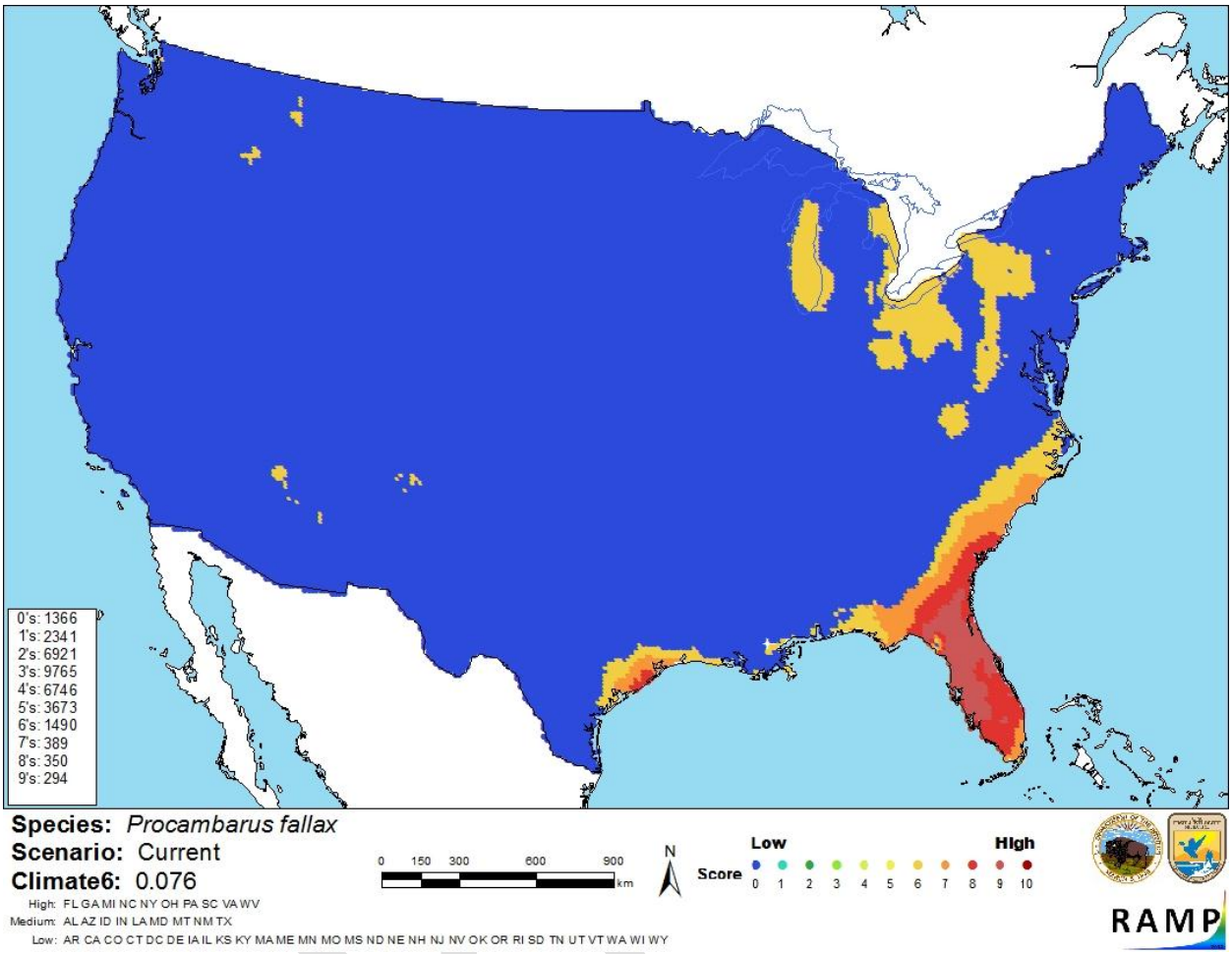

Figure 5. Map of RAMP (Sanders et al. 2014) climate matches for *Procambarus fallax f. virginalis* in the continental United States based on source locations reported by Feria and Faulkes (2011) and GBIF (2015). 0= Lowest match, 10=Highest match. Climate match scores are tabulated on the left.

7 Certainty of Assessment

The biology of *P. fallax* f. *virginalis* has been studied extensively in captivity. However, information on its ecology and impacts on native ecosystems is not well understood. Further direct study of its impacts is necessary. Certainty of this assessment is low.

8 Risk Assessment

Summary of Risk to the Continental United States

P. fallax f. *virginalis* is a parthenogenetic lineage of *Procambarus fallax*, native to the southeastern US. This species has become established in Madagascar and Europe, primarily due to the release of aquarium pets. There is much concern over the high reproductive capacity of the species, the potential for established populations to originate from introduction of a single individual, and the close relationship of the species to *P. clarkii*, for which negative impacts of invasion are well-documented. However, negative ecological impacts of *P. fallax* f. *virginalis*

have yet to be documented. Anecdotal evidence suggests impacts to native crayfish and fish populations, as well as to rice culture. High densities of *P. fallax* f. *virginalis*, achievable through its parthenogenic form of reproduction, could have important effects on ecosystem processes. The species is a carrier of crayfish plague, and so poses a risk to native crayfish on all continents except North America. Climate match of this species to the contiguous US is medium, but this is likely an underestimate as populations of *P. fallax* f. *virginalis* are not fully documented. Overall risk posed by this species is uncertain.

Assessment Elements

- **History of Invasiveness (Sec. 3):** Uncertain
- **Climate Match (Sec.6):** Medium
- **Certainty of Assessment (Sec. 7):** Low
- **Remarks/Important additional information:** Reproduces by parthenogenesis
- **Overall Risk Assessment Category: Uncertain**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

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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.

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