U.S. Fish & Wildlife Service

Signal Crayfish (*Pacifastacus leniusculus*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, December 2023
Revised, January 2024
Web Version, 12/8/2025

Organism Type: Crustacean
Overall Risk Assessment Category: High

Photo: Roger Tabor (USFWS). Public Domain. Available: https://commons.wikimedia.org/wiki/File:Signal_Crayfish_Roger_Tabor_(USFWS)_(6092822807).jpg (December 2023).

1 Native Range and Status in the United States

Native Range

From Houghton and Allen (2014):

"*P. leniusculus* is distributed from British Columbia in Canada at the northern part of its range, south to central California and east to Utah and Montana in the USA."

From Procopio (2021):

"Pacifastacus leniusculus is a wide-ranging species native to the Northwestern United States (Larson and Olden 2011). Much of the Signal Crayfish's presumed native range is found within the Columbia River Basin. From the Columbia River's lower estuary, the native range spans northwest up the mainstem to tributaries that reach into Washington, Oregon, Idaho, and British Columbia. The native range extends south from the Columbia River along Oregon's coast where the Klamath River and its drainages form its southern boundary (Miller 1960; Larson et al. 2012)."

Status in the United States

From Procopio (2021):

"Pacifastacus leniusculus is a wide-ranging species native to the Northwestern United States (Larson and Olden 2011). Much of the Signal Crayfish's presumed native range is found within the Columbia River Basin. From the Columbia River's lower estuary, the native range spans northwest up the mainstem to tributaries that reach into Washington, Oregon, Idaho, […]. The native range extends south from the Columbia River along Oregon's coast where the Klamath River and its drainages form its southern boundary (Miller 1960; Larson et al. 2012)."

"Human mediated introductions have allowed Signal Crayfish (*P. l. leniusculus, P. l. klamathensis,* and *P. l. trowbridgii*) to expand their distributions into a variety of habitats ranging from the warm coastal waterways of the Sacramento River Delta to the sub-alpine waters of Lake Tahoe and Donner in California ([Lowery and Holdich] 1988; Larson et al. 2012; Larson and Williams 2015). The Signal Crayfish (*Pacfastacus l. leniusculus*) has been introduced to and is established in regions of Oregon, Washington, California, Nevada, [and] Utah, […]. The Columbia River Signal Crayfish (*Pacifastacus l. trowbridgii*) is also known to be established in regions outside of its native range in Oregon, Washington, California and Nevada (Taylor et al. 2007). Based on the invasion history, it is likely that the distributions of *P. leniusculus* subspecies have been augmented within their own proposed native ranges through additional stockings (Larson and Olden 2011). For example, Signal Crayfish in Crater Lake, OR., were historically restricted from entering the waterbody, but later stocked there in 1915 to provide food for game fish previously introduced to the lake (Lowery and Holdich 1988; Girdner [et al.] 2018)."

USGS (2025) reports nonnative introductions of *Pacifastacus leniusculus* in Montana that resulted in an established population, in Idaho with an unknown population status, and in Minnesota that failed.

Dunker (2018) states that this species is established in Buskin Lake on Kodiak Island of Alaska.

Signal crayfish are available seasonally to purchase for consumption (e.g., Washington Crawfish 2021).

Regulations

Pacifastacus leniusculus is regulated in Alaska (ADF&G 2023). It is regulated at the family level (Astacidae) in Arizona (Arizona Game and Fish Commission 2022), Georgia (State of Georgia 2023), New Mexico (NMDGF 2023), Nevada (Nevada Board of Wildlife Commissioners 2022), Utah (Utah DWR 2023), and Wisconsin (Wisconsin DNR 2022). All species of crayfish are regulated in Pennsylvania (PFBC 2022) and Minnesota (Minnesota DNR 2022), and species not indigenous to New Hampshire (NHFG 2022) and Rhode Island (Rhode Island DEM 2022) are regulated in those respective States. 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 Procopio (2021):

"Potential introduction pathways for *P. leniusculus* include stocking for harvest, the release of crayfish used as live bait, and stocking as an additional food source for fish (Lowery and Holdich 1988; Lodge et al. 2000). […] In both [California and Nevada], *P. leniusculus* was intentionally stocked to enhance the forage available to fish (both native and nonnative), and to provide a harvest fishery for residents (La Rivers 1962; Abrahamsson and Goldman 1970; Lowery and Holdich 1988, Lodge et al. 2000)."

Remarks

This ERSS was previously published in June 2015. Revisions were completed to incorporate new information and conform to updated standards.

From Procopio (2021):

"*Pacifastacus leniusculus* (Dana, 1852), which is part of the subgenus *Pacifastacus*, is divided into three subspecies; *leniusculus*, *klamathensis* (Stimpson, 1857), and *trowbridgii* (Stimpson, 1857). Initially described as separate species, the similar, yet highly variable morphology shared by these subspecies has challenged taxonomists for decades (Larson et al. 2012). Miller (1960) was the first to describe these as subspecies of *P. leniusculus*. Genetic studies have since identified *P. l. leniusculus* and *P. l. trowbridgii* as being the most similar of the three subspecies, while *P. l. klamathensis* is the most distinct (Agerberg and Jansson 1995)."

"The subspecies of Signal Crayfish are believed to have once been geographically isolated populations (Hobbs [and Jass] 1988). Mixing due to the prevalence of early introductions, a lack of historical records, and hybridization between subspecies has made describing their native range and taxonomic status problematic (Hobbs [and Jass] 1988; Lowery and Holdich 1988; Larson and Williams 2015). This has led the subspecies of Signal Crayfish to be commonly regarded as a single species (Hobbs [and Jass] 1988). Genetic tests have begun to shed light on this, but the extent of the native distributions of Signal Crayfish subspecies continues to be a contested subject (Larson and Williams 2015)."

From NIES (2023):

"Import, transport and keeping are legally restricted in Japan."

Pacifastacus leniusculus has been intentionally stocked outside its native range to achieve fishery management objectives. Government fish and wildlife management agencies are responsible for balancing multiple fish and wildlife management objectives. The potential for a species to become invasive is now one important consideration when balancing multiple management objectives and advancing sound, science-based management of fish and wildlife and their habitat in the public interest.

Mention of commercial products in this Ecological Risk Screening Summary does not entail endorsement by the U.S. Federal Government.

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 Astacidae
Genus *Pacifastacus*
Subgenus *Pacifastacus*
Species *Pacifastacus leniusculus* (Dana, 1852)

According to DecaNet eds. (2023), *Pacifastacus leniusculus* (Dana, 1852) is the current valid name for this species.

Size, Weight, and Age Range

From Procopio (2021):

"The average Signal Crayfish attains a carapace length (CL) of 50-70 mm (Capurro et al. 2007). […] *Pacifastacus leniusculus* is both a fast growing and long-lived species. It's known as one of the fastest growing species of temperate zone crayfish ([Lowery and Holdich] 1988), and in general, the highest growth rates are associated with populations which have recently invaded an unexploited habitat (Hogger 1986). These rapid growth rates subside as populations establish and densities surge, presumably because of increased competition for food and space (Hogger 1986). […] Hogger (1984) found that individuals from a population of *P. leniusculus* in southern England had the potential to grow up to 62 mm CL in as few as three years when grown in ideal conditions. Overall, the Signal Crayfish may survive up to 9 years or more when living in the wild (Goldman and Rundquist 1977)."

From Houghton and Allen (2014):

"Male crayfish can reach a length of 16 cm, while females can only achieve a maximum size of 12 cm. Age at maturity varies from 1 to 3 years, and a life expectancy of up to 20 years is possible."

From GISD (2023):

"Based on the use of the lipofuschin technique it has been estimated that some individuals can live 16 years, and other estimates state that it may be as long as 20 years. Some individuals may grow to a large size, i.e. 95mm CL, but this may not represent a great age, but that of a fast-growing newly introduced population that encounters little competition."

Environment

From Houghton and Allen (2014):

"*P. leniusculus* can be found in a variety of habitats, from small streams to large rivers and natural lakes. It is also known to occur in brackish waters along the Pacific Coast in salinities as high as 20 ppt (Riegel, 1959). Its ability to tolerate water temperatures up to 33°C has allowed it to prosper in many environments."

From Procopio (2021):

"*Pacifastacus leniusculus* also occupies the saline and often turbid waters of major river deltas (Shimizu and Goldman 1983). Wheatly & McMahon (1983) revealed via a laboratory study that Signal Crayfish can occupy waterways with salinity as high as ~26 ppt (75% seawater), for several days."

"The Signal Crayfish occupies a range of habitats throughout its native and non-native distribution (Goldman and Rundquist 1977; [Lowery and Holdich] 1988). Though *P. leniusculus* prefers low gradient streams typical of agricultural low-lands in western Oregon (Avault 1973), they inhabit both coastal and upland streams, lakes, and rivers (Lowery and Holdich 1988).

Signal crayfish can be found in habitats ranging from clear, shallow coastal streams (Lowery and Holdich 1988), to major rivers with high turbidity (Ibbotson and Furse 1995), as well as eutrophic and oligotrophic lakes and reservoirs ([Lowery and Holdich] 1988)."

Climate

From Houghton and Allen (2014):

"Temperate/Mesothermal climate"

From Procopio (2021):

"It's known as one of the fastest growing species of temperate zone crayfish ([Lowery and Holdich] 1988)"

Distribution Outside the United States

Native

From Houghton and Allen (2014):

"*P. leniusculus* is distributed from British Columbia in Canada at the northern part of its range, […]."

A portion of the species' native range is within the United States, see section 1 for a full description.

Introduced

From NIES (2023):

"[Introduced to] Hokkaido, Fukushima, Shiga, Nagano, Tochigi and Chiba Prefs [Japan]."

From Houghton and Allen (2014):

"*Pacifastacus leniusculus*, […] most widespread non-native crayfish in Europe. It has been found in 28 territories in Europe since the 1960s […]"

"In the 1960s, *P. leniusculus* was introduced into Europe and now occurs in many countries from the UK and France in the west, to Russia in the east. A population near Inverness, Scotland constitutes the limit of the species range in the northwest; the northern extent is Norway, Sweden and Finland, while the southern extent is the Iberian Peninsula. There are also satellite populations in Greece and Cyprus."

Means of Introduction Outside the United States

From Procopio (2021):

"Beginning in the 1960's, *Pacifastacus leniusculus* were imported to Sweden and introduced throughout Europe in an attempt to establish a plague resistant species that would supplement stocks decimated by the crayfish plague."

From NIES (2023):

"Deliberate introduction (for food). At first from Portland to Lake Mashu, Hokkaido, and after from Lake Mashu to other region of Japan."

Short Description

From GISD (2023):

"The cephalothorax is smooth with two pairs of post-orbital ridges, the anterior pair with an apical spine; and no spines on shoulders of the carapace behind cervical groove; the areola between branchiocardiac grooves is obvious. The rostrum sides are smooth and more or less parallel until the apex; the acumen is very pointed with prominent shoulders; and a simple median carina down whole length. Its claws are robust and smooth on both surfaces, the underside is red in colour; with a single tubercle on the inner side of the fixed finger; and a white-turquoise patch on top of the junction of fixed and moveable fingers; adult males are massive either lengthways or in width."

From Procopio (2021):

"The dorsal surface of Signal Crayfish is typically brownish-tan in coloration. Although most individuals of *Pacifastacus leniusculus* conform to this, coloration may be highly variable based on locality and can range from bright red to blue in some cases (Larson and Olden 2011). A bright red coloration on the underside of claws, and a white or turquoise colored patch present at the base of each claw joint is distinctive to the Signal Crayfish (Riegel 1959; Larson and Olden 2011). Additionally, the surface of the carapace and claws are smooth, lacking the pronounced bumps that are typical of other nonnative crayfish (*Orconectes rusticus* and *O. virilis*) introduced to the Pacific Northwest (Larson and Olden 2011). Signal Crayfish can be distinguished from the White Claw Crayfish (*Austropotamobius pallipes*) in Europe by the absence of spines along the cervical groove (margin between the head and body) (Pöckl et al. 2006)."

Biology

From Procopio (2021):

"*Pacifastacus leniusculus* typically seek shelter in rocky crevices or woody debris within streambeds and littoral zones ([Lowery and Holdich] 1988). The signal crayfish is considered a non-burrowing crayfish (Shimizu and Goldman 1983), although they are known to construct shallow borrows. Burrowing activity is most common in crayfish smaller than 50 mm and the least common in larger males (Guan 2010). The population density of Signal Crayfish is correlated with refugee [sic] availability (Flint 1975), and waterbodies with rocky littoral zones support far greater densities than places with clay banks (Shimizu and Goldman 1983)."

"Additionally, Miller (1965) noted that Signal Crayfish have been observed copulating, molting, and laying eggs in brackish water."

"The breeding cycle of the Signal Crayfish follows that of most temperate zone crayfish. Copulation occurs during the autumn months (September or October), and females carry the eggs throughout the winter ([Lowery and Holdich] 1988). Eggs then typically hatch in March and April as the water warms (Shimizu and Goldman 1983). The young from populations residing in cooler waters may hatch later in the year (June and July), since growth is temperature dependent. Once hatched, *P. leniusculus* grow rapidly and most individuals mature during their second summer. The time to maturity may also be delayed by cooler water temperatures, such as that of Lake Tahoe. Here, males may mature during their third summer, while females may not mature until fourth ([Lowery and Holdich] 1988). Abrahamsson and Goldman (1970) estimated that male and female *P. leniusculus* in the Sacramento River, CA., mature when they reach the size of 29-37 mm CL and 25-35 mm CL, respectively. Crayfish growth is also density dependent, which often results in small, newly established populations of *P. leniusculus* experiencing a short period of rapid growth (Hogger 1986)."

From GISD (2023):

"Egg incubation time ranges from 166 to 280 days. In natural populations hatching occurs from late March to the end of July depending on latitude and temperature. Egg numbers usually range from 200 to 400, although some individuals of 66mm CL have been reported as having over 500 eggs. […] Estimates of survivorship to age 2 vary from 10-52%, being dependent on both abiotic and biotic factors. Competition and cannibalism can greatly affect survival in dense populations. Stebbing et al. (2003) demonstrated for the first time the presence of a sex pheromone, released during the breeding season by mature females, that stimulates courtship and mating behaviour in male *P. leniusculus*."

Human Uses

From GISD (2023):

"Commercially harvested in the western USA, mainly in Washington and Oregon States, although a larger harvest is obtained from the introduced population in the Sacramento River (Lewis, 2002). It was originally hoped that stocking *P. leniusculus* into European waters would revive catches of crayfish to their pre-plague levels, particularly in Sweden and Finland (Skurdal et al. 1999), this has not proved to be the case. In Sweden the catch in 1996 was 265 tonnes (compared to 52 for *A. astacus*) and that cultured amounted to 42 tonnes (compared to 12 for *A. astacus*). The catch of *P. leniusculus* in Finland in 2001 was 22 tonnes (compared to 57.5 for *A. astacus*). However, the Finnish catch of *P. leniusculus* is increasing and is estimated to double every 1-2 years. In 2004 it exceeded 50% of the catch (Erkamo et al. 2004). *P. leniusculus* fetches approximately half the price as *A. astacus* in Finland and Sweden. The introduced species has done better in southern Sweden than in the north and in Finland, and this may be a consequence of the cool climatic conditions in the latter two regions (Henttonen & Huner, 1999).

In Europe as a whole in 1994 a total of 355 tonnes of *P. leniusculus* originated from capture fisheries and 51 tonnes from culture. This represents only 9% of European capture fisheries and 32.5% of culture fisheries (Ackefors, 1998, 1999)."

From Procopio (2021):

"Their potential for rapid growth has made them the focus of both aquaculture productions and commercial fisheries in several countries (Westman 1973; Furst 1977; McGriff 1983; Goddard and Hogger 1986; Lowery and Holdich 1988)"

"*Pacifastacus leniusculus* is now so abundant in California it supports a robust commercial fishery in the Sacramento River Delta (McGriff 1983)."

Diseases

***Pacifastacus leniusculus* has been documented a carrier of *Aphanomyces astaci* (crayfish plague), a disease listed by the World Organisation for Animal Health (2023).**

Poelen et al. (2014) state that the following are either parasites or pathogens of *Pacifastacus leniusculus*: *Aphanomyces astaci, Aphanomyces frigidophilus*, *Aphanomyces laevis, Aphanomyces repetans, Thelohania contejeani*, *Triannulata*, and *Xironogition instabilius*.

From Houghton and Allen (2014):

"The spread of *P. leniusculus* throughout Europe has enabled *Aphanomyces astaci*, the crayfish plague, to spread as well, decimating native crayfish populations (Holdich et al., 2009)."

Threat to Humans

No information was found on threats to humans from *Pacifastacus leniusculus*.

3 Impacts of Introductions

From Scordo (2023):

"The extent of crayfish distribution along the shoreline of Crater Lake doubled over a 13-year period, leaving less than 20% of the shoreline free from crayfish. At high crayfish density sites, benthic macroinvertebrate biomass was 99% lower, and taxa richness was 50% lower than at low crayfish areas. High crayfish sites show tenfold greater periphyton biovolume, sixfold higher periphyton biomass (chlorophyll a), twofold higher metabolic productivity, and the presence of large filamentous algae (*Cladophora* sp.). The invasion of crayfish had negative consequences for a lake protected under the management of the USA National Park Service, with direct impacts on many levels of ecological organization."

From Procopio (2021):

"The presumed extinction of the Sooty Crayfish (*P. nigrescens*) is attributed to the introduction of the Signal Crayfish, as well as the impacts associated with the urbanization of the Sacramento

River (Bouchard 1977; Larson and Williams 2015). Currently, the Shasta Crayfish (*P. fortis*), is threatened by the introduction of *P. leniusculus* and the Virile Crayfish (*Orconectes virilis*), which has led both directly and indirectly to its recent range restriction (Lowery and Holdich 1988; Light et al. 1995). Signal Crayfish are also known to prey upon the eggs of game fish, such as the Atlantic Salmon (*Salmo salar*), which can contribute to declines in fish populations (Findlay et al. 2015). *Pacifastacus leniusculus* may have led to the collapse of a federally listed three-spined stickleback (*Gasterosteus aculeatus*) after it was introduced to Enos Lake in British Columbia (Behm et al. 2010)."

"The Mazama Newt (*Taricha granulosa mazamae*), which is endemic to Crater Lake, Oregon, is greatly threatened by the presence of the nonnative Signal Crayfish (Girdner [et al.] 2018). Although newts remained in uninvaded regions of the lake, they were nearly absent from areas occupied by the crayfish. Mesocosm experiments revealed that *P. leniusculus* prey directly on newts, displace newts from cover, and have the potential to alter their overall behavior. Areas inhabited by the introduced crayfish also experienced dramatic decreases in benthic macroinvertebrate diversity (Girdner [et al.] 2018). Crawford et al. (2006) found that the total number of invertebrates was significantly lower in sites where Signal Crayfish were present. Moorhouse et al. (2014) observed an inverse relationship between *P. leniusculus* and macroinvertebrate abundance and taxon richness."

"The spread of American crayfish species in Europe during the 19th, 20th, and 21st century is closely associated with the spread of the crayfish plague (Holdich et al. 2009). Signal Crayfish serve as carriers of the crayfish plague, which is caused by a fungus-like organism (*Aphanomyces astaci*) (Cerenius et al. 1988). While *P. leniusculus* are highly resistant to the illness, Asiatic, Australian, and European crayfish are very susceptible to the plague's ill effects (Unestam 1969). Although it was not introduced until the mid-1900's, the Signal Crayfish is thought to be vector for spreading the plague (Lowery and Holdich 1988), and introductions of *P. leniusculus* to new regions in Europe are believed to contribute to the infection of new drainages (Cerenius et al. 1988)."

"Though uncommon, Signal Crayfish have been documented burrowing in river banks (Guan 2010). In the Great River Ouse, England, burrows were constructed at high densities (5.6 burrows per meter length), which increased the erosion of the river banks (Guan 2010)."

From Houghton and Allen (2014):

"*P. leniusculus* presence in the River Clyde, Scotland, was associated with a 40% reduction in benthic invertebrate density compared to *P. leniusculus* absence, with an associated reduction in species diversity (Crawford et al., 2006). This impact on macroinvertebrate communities was alleviated by intensive removal of signal crayfish using traps (Moorhouse et al., 2014). In two similar rivers in Yorkshire (UK), high *P. leniusculus* densities correlated with low salmonid fish densities (brown trout, *Salmo trutta*), whilst high native white-clawed crayfish, *Austropotamobius pallipes,* densities correlated with high fish densities, suggesting a population level impact of *P. leniusculus* on fish communities (Peay et al., 2009). Melero et al. (2014) have also demonstrated an increased density and resilience to control of invasive non-native mammalian carnivore populations such as the American mink, *Neovison vison*, in ecosystems with established invasive non-native crayfish populations, due the availability of a superabundant prey item."

From GISD (2023):

"*Pacifastacus leniusculus* displays opportunistic polytrophic feeding habits, although more animal than plant material may be consumed if available. It can have a considerable impact on populations of macro-invertebrates, benthic fish, and aquatic plants (Guan & Wiles 1997; Nyström, 1999; Lewis, 2002), it also has been used to clear weed from ponds on fish farms. Griffiths et al. (2004) found that the presence of *P. leniusculus* significantly reduced the number of Atlantic salmon using shelters in artificial test arenas."

"*P. leniusculus* was introduced into Japan from Portland, Oregon five times during 1926 to 1930, where it has reduced the range of the indigenous *Cambaroides japonicus* on the island of Hokkaido (Hiruta, 1996; Kawai & Hiruta, 1999). It has also been found in some lakes on Honshu (Hiruta, S., 2005, pers. Comm.). In Europe, it has extirpated populations of the indigenous crayfish species, particularly the white-clawed crayfish (see *Austropotamobius pallipes* in IUCN Red List of Threatened Species in England (Holdich, 1999; Hiley, 2003). However, in Finland it coexisted with the noble crayfish, (see *Astacus astacus* in IUCN Red List of Threatened Species), in a lake for 30 years, before reproductive interference led to the demise of the latter species (Westman et al. 2002). Its main impact has been as a vector of the crayfish plague fungus, *Aphanomyces astaci*, which has caused large-scale mortalities amongst indigenous European crayfish populations, particularly in England (Alderman, 1996)."

Pacifastacus leniusculus is regulated by name, family, or as a crayfish generally in 11 States, see section 1.

4 History of Invasiveness

The History of Invasiveness for *Pacifastacus leniusculus* is classified as High. There are reported introductions resulting in establishment outside of this species native range in the United States as well as in Europe and Japan. These nonnative populations have resulted in negative impacts including population reduction or extirpation of native crayfish species, reductions in biomass of other macroinvertebrates, increases in periphyton biomass, predation on fish eggs, and reductions in some fish and amphibian populations. In Europe, *P. leniusculus* is a carrier of the highly impactful crayfish plague.

5 Global Distribution

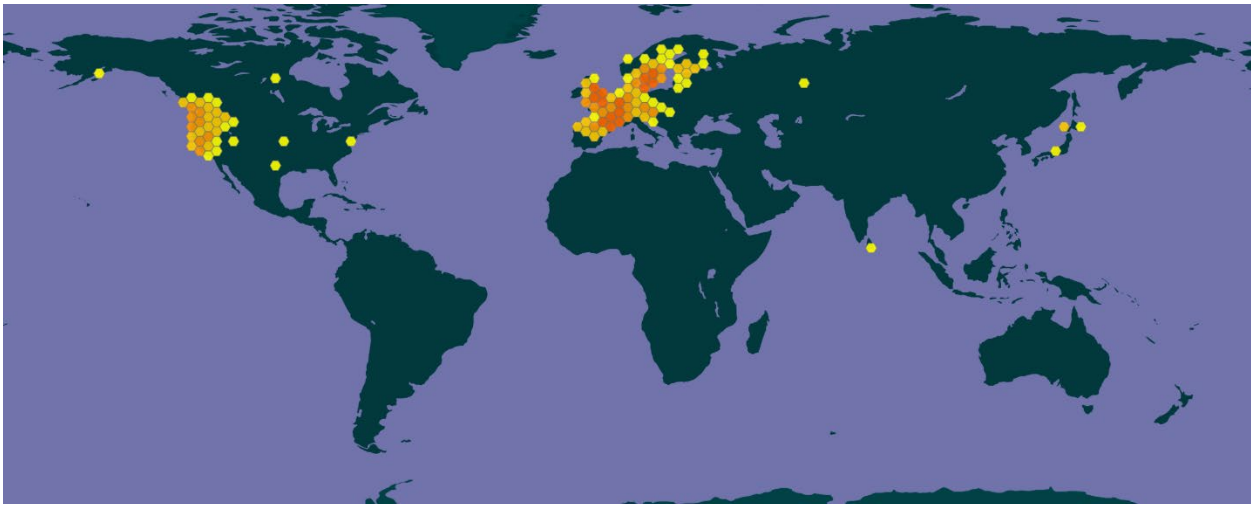

Figure 1. Reported global distribution of *Pacifastacus leniusculus*. Map from GBIF Secretariat (2023). Points in the Eastern half of the United States, Alaska, northern Canada, Sri Lanka, and western Russia do not represent established populations and were not used in the climate matching analysis.

6 Distribution Within the United States

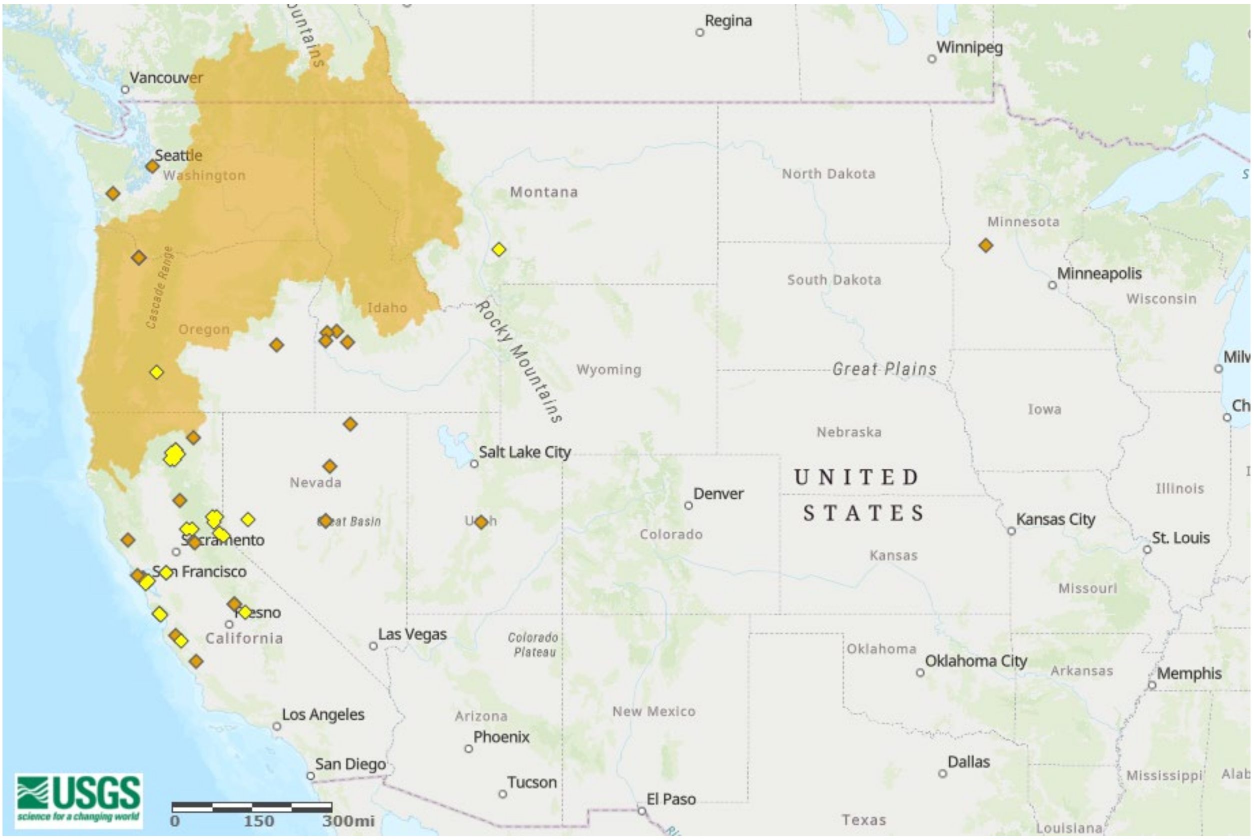

Figure 2. Reported distribution of *Pacifastacus leniusculus* in the contiguous United States. Map from USGS (2025). Observations are reported from the Western United States and Minnesota. Orange shading indicates the native range of the species. Yellow diamonds indicate observations representing established nonnative populations. Orange diamonds indicate introduction records with unknown or failed establishment status or state non-specific geographic information. Only records within the native range and those representing established nonnative populations were used in the climate matching analysis.

Figure 3. Reported distribution of *Pacifastacus leniusculus* in Alaska. Map from GBIF-US (2024). Observation is located on Kodiak Island and does represent an established nonnative population.

7 Climate Matching

Summary of Climate Matching Analysis

The climate matching analysis for *Pacifastacus leniusculus* to the contiguous United States found mostly medium to high matches. Areas of medium match were found in the Southeast, the Great Plains, and eastern New England. Areas of low match were found in southern Florida and along the Gulf Coast. All other areas were found to have high match, including the species' native range. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) for the contiguous United States was 0.929, indicating that Yes, there is establishment concern for this species outside its native range. 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).

Projected climate matches in the contiguous United States under future climate scenarios are available for *Pacifastacus leniusculus* (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.

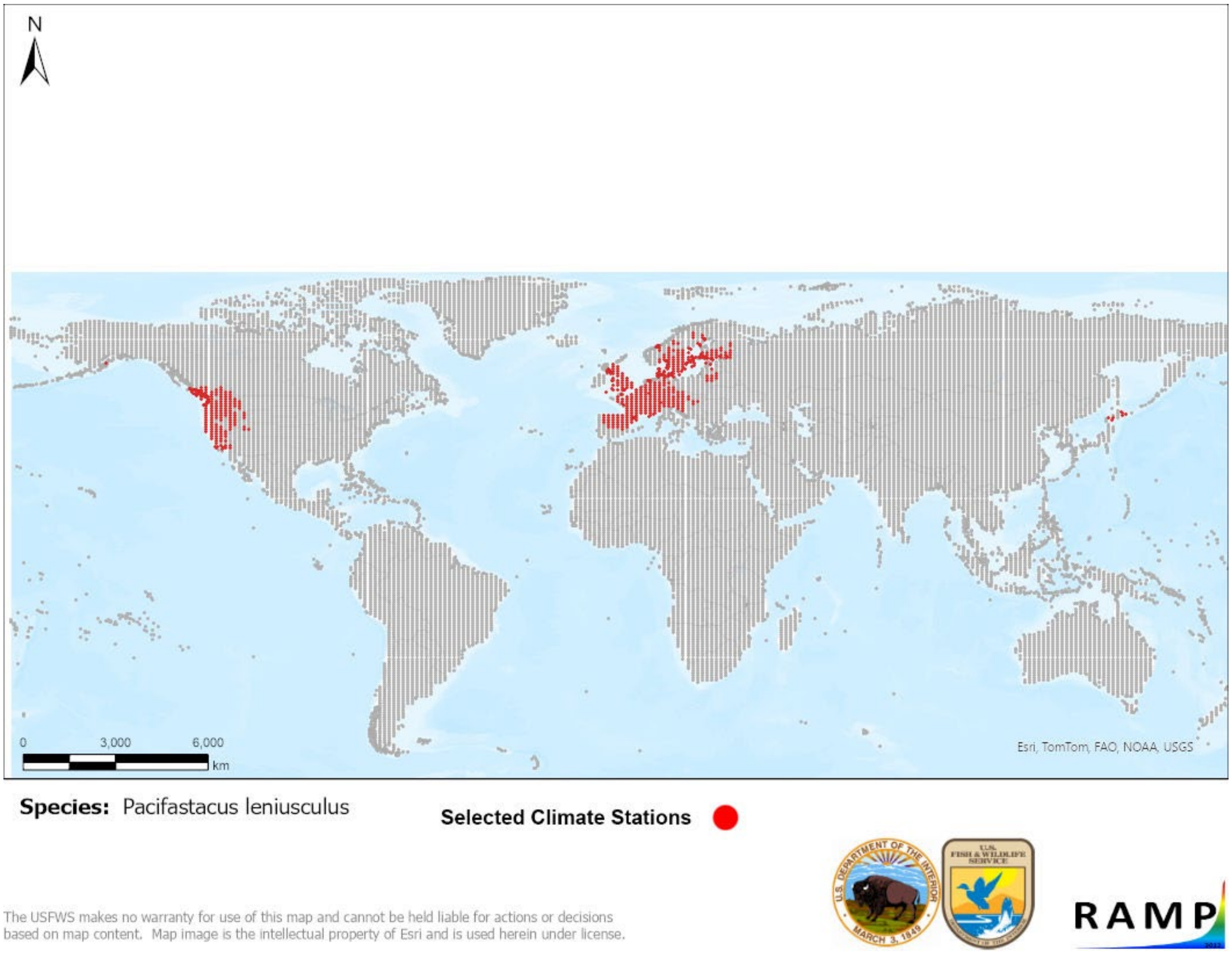

Figure 4. RAMP (Sanders et al. 2023) source map showing weather stations in the world selected as source locations (red; United States, Europe, Canada, and Japan) and non-source locations (gray) for *Pacifastacus leniusculus* climate matching. Source locations from GBIF Secretariat (2023). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

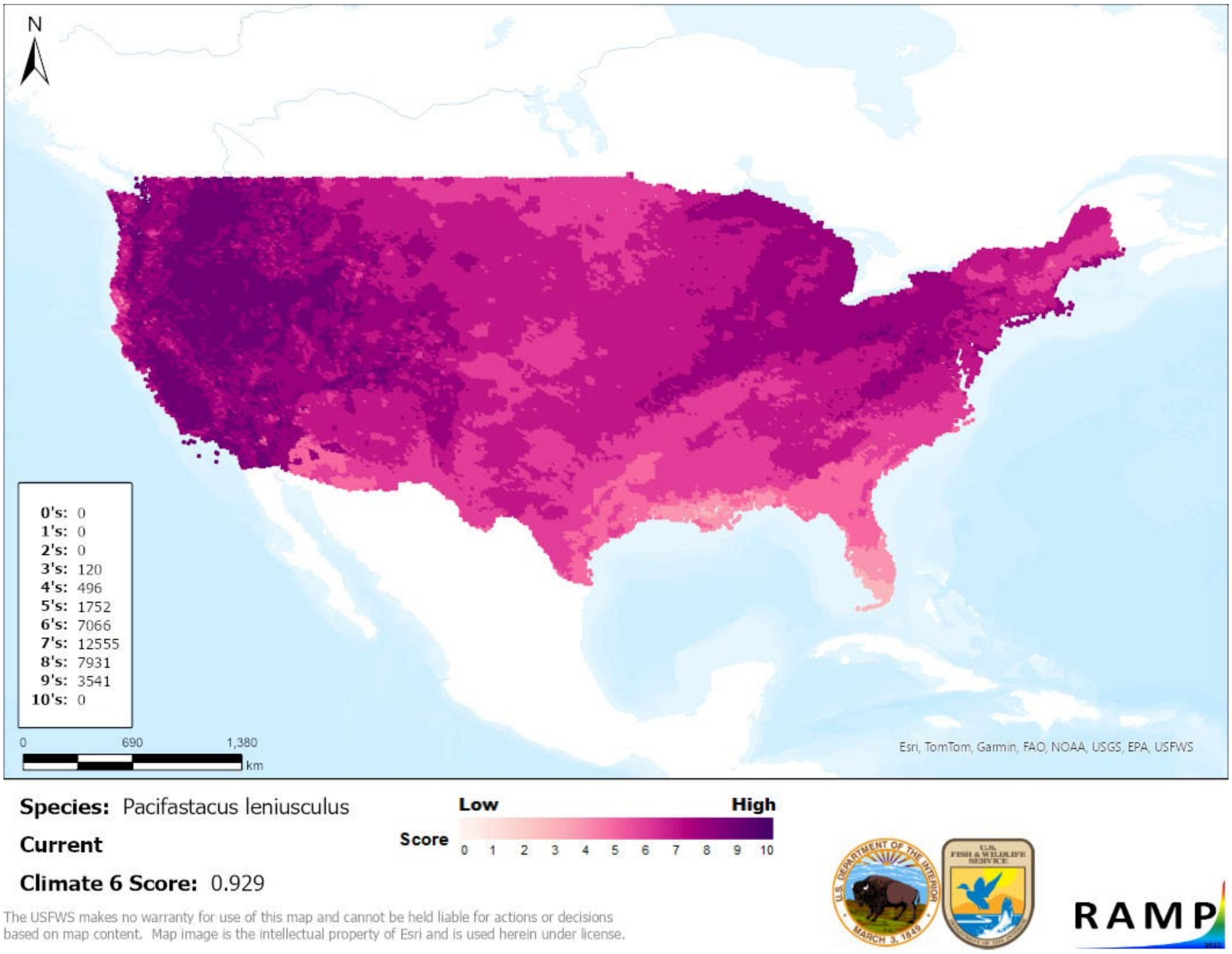

Figure 5. Map of RAMP (Sanders et al. 2023) climate matches for *Pacifastacus leniusculus* in the contiguous United States based on source locations reported by GBIF Secretariat (2023). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

There is quality information available about the biology and ecology of *Pacifastacus leniusculus*. The distribution, both native and introduced, is well documented. There is substantial peer reviewed information about impacts from these introductions in nonnative areas. Due to the amount and quality of available information, the Certainty of Assessment for *Pacifastacus leniusculus* is classified as High.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Pacifastacus leniusculus, signal crayfish, is a crustacean that is native to the Columbia River basin in the Northwestern United States and southwestern Canada. This species has high fecundity and a long lifespan. *P. leniusculus* is a carrier of *Aphanomyces astaci*, the crayfish plague, a listed disease according to the World Organisation for Animal Health. It has been introduced and established nonnative populations outside its native range in the United States, Europe, and Japan. Impacts of these introductions include reductions in the biomass of macroinvertebrates and decreases in the abundance of native crayfish, fish, and amphibians. Eleven States may regulate this species to some extent. The History of Invasiveness for *Pacifastacus leniusculus* is classified as High. The climate matching analysis for the contiguous United States indicates establishment concern outside its native range. Areas of high match were found in the west, including the species' native range. Most of the remainder of the contiguous United States had medium climate matches except for areas of southern Florida and the Gulf Coast. The Certainty of Assessment for this ERSS is classified as High due to the amount and quality of information available. The Overall Risk Assessment Category for *Pacifastacus leniusculus* 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): High**
- **Remarks, Important additional information: *Pacifastacus leniusculus* is susceptible to *Aphanomyces astaci*, the crayfish plague, a disease listed by the World Organisation for Animal Health.**
- **Overall Risk Assessment Category: High**

10 Literature Cited

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

[ADF&G] Alaska Department of Fish and Game. 2023. General provisions. Collection, transportation, possession, propagation, or release of aquatic organisms; aquatic farming. 5 Alaska Administrative Code 41.070-41.075.

Arizona Game and Fish Commission. 2022. Restricted live wildlife. Arizona Administrative Code R12-4-406.

DecaNet eds. 2023. *Pacifastacus leniusculus* (Dana, 1852). World Register of Marine Species. Available: https://www.marinespecies.org/aphia.php?p=taxdetails&id=885106#links (December 2023).

Dunker K. 2018. Buskin or the Bayou... What's up with all the Crayfish?. Alaska Fish and Wildlife News. Available: https://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=884 (January 2024)

GBIF Secretariat. 2023. GBIF backbone taxonomy: *Pacifastacus leniusculus* (Dana, 1852). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/2226990 (December 2023).

GBIF-US. 2024. Species occurrences: *Pacifastacus leniusculus*. Available: https://doi.org/10.15468/dl.8gqtek (January 2024).

[GISD] Global Invasive Species Database. 2023. Species profile: *Pacifastacus leniusculus*. Gland, Switzerland: Invasive Species Specialist Group. Available: http://www.iucngisd.org/gisd/speciesname/Pacifastacus+leniusculus (December 2023).

Houghton R, Allen US. 2014. *Pacifastacus leniusculus (*American signal crayfish). In CABI Compendium. Wallingford, United Kingdom: CAB International. Available: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.70581 (December 2023).

[ITIS] Integrated Taxonomic Information System. 2023. *Pacifastacus leniusculus* (Dana, 1852). Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=97326#null (December 2023).

Minnesota [DNR] Department of Natural Resources. 2022. Minnesota invasive species laws. Saint Paul: Minnesota Department of Natural Resources. Available: https://www.dnr.state.mn.us/invasives/laws.html (October 2022).

Nevada Board of Wildlife Commissioners. 2022. Hunting, fishing and trapping; miscellaneous protective measures. Nevada Administrative Code 503.

[NHFG] New Hampshire Fish and Game Department. 2022. The importation, possession and use of all wildlife. New Hampshire Code of Administrative Rules Fis 800.

[NIES] National Institute for Environmental Studies. 2023. *Pacifastacus leniusculus*. Invasive species of Japan. Tsukuba, Japan: National Research and Development Agency, National Institute for Environmental Studies. Available: https://www.nies.go.jp/biodiversity/invasive/DB/detail/70050e.html (December 2023).

[NMDGF] New Mexico Department of Game and Fish. 2023. Director's species importation list. Santa Fe: New Mexico Department of Game and Fish. Available: https://www.wildlife.state.nm.us/download/enforcement/importation/information/Importation-Info-Directors-Species-Importation-List-1-3-2023.pdf (October 2023).

[PFBC] Pennsylvania Fish and Boat Commission. 2022. Aquatic invasive species. Harrisburg: Pennsylvania Fish and Boat Commission. Available: https://www.fishandboat.com/Resource/AquaticInvasiveSpecies/Pages/default.aspx (October 2022).

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

Procopio J. 2021. *Pacifastacus leniusculus* (Dana, 1852). Nonindigenous Aquatic Species Database. Gainesville, Florida: U.S. Geological Survey. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=200 (December 2023).

Rhode Island [DEM] Department of Environmental Management. 2022. Rules and regulations governing importation and possession of wild animals. 250 Rhode Island Code of Regulations 40-05-3.

Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.

Scordo F, Girdner SF, San Pedro A, Seitz C, Chandra S. 2023. Deterioration of the Littoral-Benthic Ecosystem Following Recent Expansion of Signal Crayfish (*Pacifastacus leniusculus)* in the World's Clearest Large Lake. Ecosystems 26: 1489-1503.

State of Georgia. 2023. Wild animals. Rules and Regulations of the State of Georgia subject 391-4-8.

[USFWS] U.S. Fish and Wildlife Service. 2024. Standard operating procedure: how to prepare an "Ecological Risk Screening Summary." Version 3. Available: https://www.fws.gov/media/standard-operating-procedures-how-prepare-ecological-risk-screening-summary-2024 (December 2025).

[Utah DWR] Utah Division of Wildlife Resources. 2023. Collection, importation, possession (CIP). Administrative rule R657-3.

Washington Crawfish Company. 2021. Order Inquiry. Available: https://www.washingtoncrawfish.com/order-inquiry/ (December 2023).

[Wisconsin DNR] Wisconsin Department of Natural Resources. 2022. Invasive species identification, classification and control. Wisconsin Administrative Code NR 40.

World Organisation for Animal Health. 2023. Animal diseases. Paris: World Organisation for Animal Health. Available: https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-diseases/ (December 2023).

11 Literature Cited in Quoted Material

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

Abrahamsson SAA, Goldman CR. 1970. Distribution, density and production of the crayfish *Pacifastacus leniusculus* Dana in Lake Tahoe, California - Nevada. Oikos 21:83–91.

Ackefors. 1998. [Source material did not give full citation for this reference.]

Ackefors H. 1999. The positive effects of established crayfish introductions in Europe. Pages 49–62 in Gherardi F, Holdich DM, editors. Crustacean issues 11: Crayfish in Europe as alien species (How to make the best of a bad situation?). Rotterdam, Netherlands: A.A. Balkema.

Agerberg A, Jansson H. 1995. Allozymic comparisons between three subspecies of the freshwater crayfish *Pacifastacus leniusculus* (Dana), and between populations introduced to Sweden. Hereditas 122:33–39.

Alderman DJ. 1996. Geographical spread of bacterial and fungal diseases of Crustaceans. Reviews of the Science and Technology Office for International Epizootiology 15:603–632.

Avault JW Jr. 1973. Crayfish farming in the United States. Freshwater Crayfish 1:240–250.

Behm JE, Ives AR, Boughman JW. 2010. Breakdown in postmating isolation and the collapse of a species pair through hybridization. The American Naturalist 175:11–26.

Bouchard RW. 1977. Distribution, systematic status and ecological notes on five poorly known species of crayfish in western North America (Decapoda: Astacidae and Cambaridae). Freshwater Crayfish 3:409–423.

Cerenius L, Soderhall K, Persson M, Ajaxon R. 1988. The crayfish plague fungus *Aphanomyces astaci* - diagnosis, isolation and pathobiology. Freshwater Crayfish 7:131–144.

Crawford L, Yeomans WE, Adams CE. 2006. The impact of introduced signal crayfish *Pacifastacus leniusculus* on stream invertebrate communities. Aquatic Conservation 16:611–626.

Capurro M, Galli L, Mori M, Salvidio S, Arillo A. 2007. The signal crayfish, *Pacifastacus leniusculus* (Dana, 1852) [Crustacea: Decapoda: Astacidae], in the Brugneto Lake (Liguria, NW Italy). The beginning of the invasion of the river Po watershed. Aquatic Invasions 2:17–24.

Erkamo E, Järvenpää T, Mannonen A, Tulonen J. 2004. Ravut - Kräftor, in Kalavarat 2004. SVT Maa-, metsä- ja kalatalous 60:67–71.

Findlay J, Findlay F, Riley W, Lucas M. 2015. Signal crayfish (*Pacifastacus leniusculus*) predation upon Atlantic salmon (*Salmo salar*) eggs. Aquatic Conservation: Marine and Freshwater Ecosystems 25:250–258.

Flint RW. 1975. Growth in a population of crayfish *Pacifastacus leniusculus* from a subalpine lacustrine environment. Journal of the Fisheries Research Board of Canada 32(12):2443–2440.

Furst M. 1977. Introduction of *Pacifastacus leniusculus* (Dana) into Sweden: methods, results, and management. Freshwater Crayfish 3:229–248.

Girdner SF, Ray AM, Buktenica MW, Hering DK, Mack JA, Umek JW. 2018. Replacement of a unique population of newts (*Taricha granulosa mazamae*) by introduced signal crayfish (*Pacifastacus leniusculus*) in Crater Lake, Oregon. Biological Invasions 20:721–740.

Goddard JS, Hogger JB. 1986. The current status and distribution of freshwater crayfish in Britain. Field Studies 6(3):383–396.

Goldman CR, Rundquist JC. 1977. A comparative ecological study of the California crayfish, *Pacifastacus leniusculus* (Dana), from two subalpine lakes (Lake Tahoe and Lake Donner). Freshwater Crayfish 3:51–80.

Griffiths SW, Collen P, Armstrong JD. 2004. Competition for shelter among over-wintering signal crayfish and juvenile Atlantic salmon. Journal of Fish Biology 65:436–447.

Guan. 2010. [Source material did not give full citation for this reference.]

Guan RZ, Wiles PR. 1997. Ecological impact of introduced crayfish on benthic fishes in a British lowland river. Conservation Biology 11(3):641–647.

Henttonen P, Huner JV. 1999. The introduction of alien species of crayfish in Europe: a historical introduction. Pages 13–22 in Gherardi F, Holdich DM, editors. Crayfish in Europe as alien species. How to make the best of a bad situation. Rotterdam, Netherlands: A. A. Balkema.

Hiley PD. 2003. The slow quiet invasion of signal crayfish (*Pacifastacus leniusculus*) in England prospects for the white-clawed crayfish (*Austropotamobius pallipes*). Pages 127–138 in Holdich DM, Sibley PJ, editors. Management & conservation of crayfish. Proceedings of a conference held in Nottingham on 7th November, 2002. Bristol, England: Environmental Agency.

Hiruta S. 1996. The presence of signal crayfish in Hokkaido, Japan. Crayfish News 19:1.

Hobbs HH III, Jass JP. 1988. The crayfishes and shrimps of Wisconsin (Cambaridae, Palaemonidae). Milwaukee, Wisconsin: Milwaukee Public Museum.

Hogger JB. 1984. A study of aspects of the biology and distribution of freshwater crayfish in the Thames catchment. Ph.D. dissertation. London: London Metropolitan University.

Hogger JB. 1986. Aspects of the introduction of “signal crayfish”, *Pacifastacus leniusculus* (Dana), into the southern United Kingdom. 1. Growth and survival. Aquaculture 58(1-2):27–44.

Holdich DM. 1999. The negative effects of established crayfish populations. Pages 31–48 in Gherardi F, Holdich DM, editors. Crustacean issues 11: Crayfish in Europe as alien species (How to make the best of a bad situation?). Rotterdam, Netherlands: A.A. Balkema.

Holdich DM, Reynolds JD, Souty-Grosset C, Sibley PJ. 2009. A review of the ever increasing threat to European crayfish from non-indigenous crayfish species. Knowledge and Management of Aquatic Ecosystems 11:394–395.

Ibbotson AT, Furse MT. 1995. Literature review of the ecology of the signal crayfish *Pacifastacus leniusculus* and its impacts upon the white clawed crayfish *Austropotamobius pallipes*. A report to the Environment Agency, Thames Region by the Institute of Freshwater Ecology.

Kawai T, Hiruta M. 1999. Distribution of crayfish (*Pacifastacus leniusculus* and *Cambaroides japonicus*) in Lake Shikaribetsu and Shihoro, Hokkaido, Japan. Crayfish NEWS 21(3):11.

La Rivers I. 1962. Fishes and fisheries of Nevada. Carson City: Nevada State Print Office.

Larson ER, Olden JD. 2011. The state of crayfish in the Pacific Northwest. Fisheries 36(2):60–73.

Larson ER, Abbott CL, Usio N, Azuma N, Wood KA, Herborg L, Olden JD. 2012. The signal crayfish is not a single species: cryptic diversity and invasions in the Pacific Northwest range of *Pacifastacus leniusculus*. Freshwater Biology 57:1823–1838.

Larson ER, Williams BW. 2015. Historical biogeography of *Pacifastacus* crayfishes and their branchiobdellian and entocytherid ectosymbionts in western North America. Pages 404–447 in Kawai T, Faulkes Z, Scholtz G, editors. Freshwater crayfish: a global overview. Boca Raton, Florida: CRC Press.

Lewis SD. 2002. *Pacifastacus*. Pages 511–540 in Holdich DM, editor. Biology of freshwater crayfish. Oxford: Blackwell Science.

Light T, Erman DC, Myrick C, Clarke J. 1995. Decline of the Shasta crayfish (*Pacifastacus fortis* Faxon) of northeastern California. Conservation Biology 9:1567–1577.

Lodge DM, Taylor CA, Holdich DM, Skurdal J. 2000. Reducing impacts on exotic crayfish introductions: new policies needed. Fisheries 25(8):21–23.

Lowery RS, Holdich DM. 1988. *Pacifastacus leniusculus* in North America and Europe, with details of the distribution of introduced and native crayfish species in Europe. Pages 283–308 in Holdich DM, Lowery RS, editors. Freshwater crayfish: biology, management and exploitation. Portland, Oregon: Timber Press.

McGriff D. 1983. The commercial fishery for *Pacifastacus leniusculus* in the Sacramento River-San Joaquin delta. Freshwater Crayfish 1:403–417.

Melero Y, Palazón S, Lambin X. 2014. Invasive crayfish reduce food limitation of alien American mink and increase their resilience to control. Oecologia 174(2):427–434.

Miller GC. 1960. The taxonomy and certain biological aspects of the crayfish of Oregon and Washington. Master's thesis. Corvallis: Oregon State University.

Miller GC. 1965. Western North American crawfishes (*Pacifastacus*) in brackish water environments. Fish Commission of Oregon Research Briefs 11:42–50.

Moorhouse TP, Poole AE, Evans LC, Bradley DC, Macdonald DW. 2014. Intensive removal of signal crayfish (*Pacifastacus leniusculus*) from rivers increases numbers and taxon richness of macroinvertebrate species. Ecology and Evolution 4(4):494–504.

Nyström P. 1999. Ecological impact of introduced and native crayfish on freshwater communities: European perspectives. Pages 63–85 in Gherardi F, Holdich DM, editors. Crustacean issues 11: Crayfish in Europe as alien species (How to make the best of a bad situation?). Rotterdam, Netherlands: A.A. Balkema.

Peay S, Guthrie N, Spees J, Nilsson E, Bradley P. 2009. The impact of signal crayfish (*Pacifastacus leniusculus*) on the recruitment of salmonid fish in a headwater stream in Yorkshire, England. Knowledge and Management of Aquatic Ecosystems 394/395:12.

Pöckl M, Holdich DM, Pennerstorfer J. 2006. Identifying native and alien crayfish species in Europe. Craynet.

Riegel JA. 1959. The systematics and distribution of crayfishes in California. California Fish and Game 45:29–50.

Shimizu SJ, Goldman CR. 1983. *Pacifastacus leniusculus* (Dana) production in the Sacramento River. Freshwater Crayfish 5:210–228.

Skurdal J, Taugbl T, Burba A, Edsman L, Sderbck B, Styrishave B, Tuusti J, Westman K. 1999. Crayfish introductions in the Nordic and Baltic countries. Pages 193–219 in Gherardi F, Holdich DM, editors. Crayfish in Europe as alien species. How to make the best of a bad situation. Rotterdam, Netherlands: A. A. Balkema.

Stebbing PD, Bentley MG, Watson GJ. 2003. Mating behaviour and evidence for a female released courtship pheromone in the signal crayfish *Pacifastacus leniusculus*. Journal of Chemical Ecology 29:463–473.

Taylor CA, Schuster GA, Cooper JE, DiStefano RJ, Eversole AG, Hamr P, Hobbs HH III, Robinson HW, Skelton CE, Thoma RF. 2007. A reassessment of the conservation status of crayfishes of the United States and Canada after 10+ years of increased awareness. Fisheries 32(8):372–389.

Unestam T. 1969. Resistance to the crayfish plague in some American, Japanese and European crayfishes. Report of the Institute of Freshwater Research, Drottningholm 49:202–209.

Westman K. 1973. Cultivation of the American crayfish *Pacifastacus leniusculus*. Freshwater Crayfish 1:211–220.

Westman K, Savolainen R, Julkunen M. 2002. Replacement of the native crayfish *Astacus astacus* by the introduced species *Pacifastacus leniusculus* in a small, enclosed Finnish lake: a 30-year study. Ecography 25:53–73.

Wheatly MG, McMahon BR.1983. Respiration and ionoregulation in the euryhaline crayfish *Pacifastacus leniusculus* on exposure to high salinity: an overview. Freshwater Crayfish 5:43–55.

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 *Pacifastacus leniusculus* was projected to occur in California, the Colorado Plateau, Great Basin, Great Lakes, and Western Mountains regions of the contiguous United States. Areas of low climate match were projected to occur in the Southern Florida region and, under time step 2085, along the Gulf and Southern Atlantic Coasts. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.325 (model: UKESM1-0-LL, SSP5, 2085) to a high of 0.849 (model: MPI-ESM1-2-HR, 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 (0.929, figure 5) falls above the range of scores for future projections. The time step and climate scenario with the most change relative to current conditions was SSP5, 2085 (figure A3), the most extreme climate scenario. Under most time step and climate scenarios, areas within the Southwest (particularly southwestern Arizona) saw a large increase in the climate match relative to current conditions. Primarily under time step 2085, areas within the Appalachian Range, California, Colorado Plateau, Great Lakes, Mid-Atlantic, Southeast, and Southern Plains saw a large decrease in the climate match relative to current conditions. Additionally, under one or more time step and climate scenarios, areas within the Great Basin, Gulf Coast, Northeast, Northern Pacific Coast, Northern Plains, Southern Atlantic Coast, Southern Florida, Southwest, and Western Mountains saw a moderate decrease in the climate match relative to current conditions. Additional, very small areas of large or moderate change may be visible on the maps (figure A3).

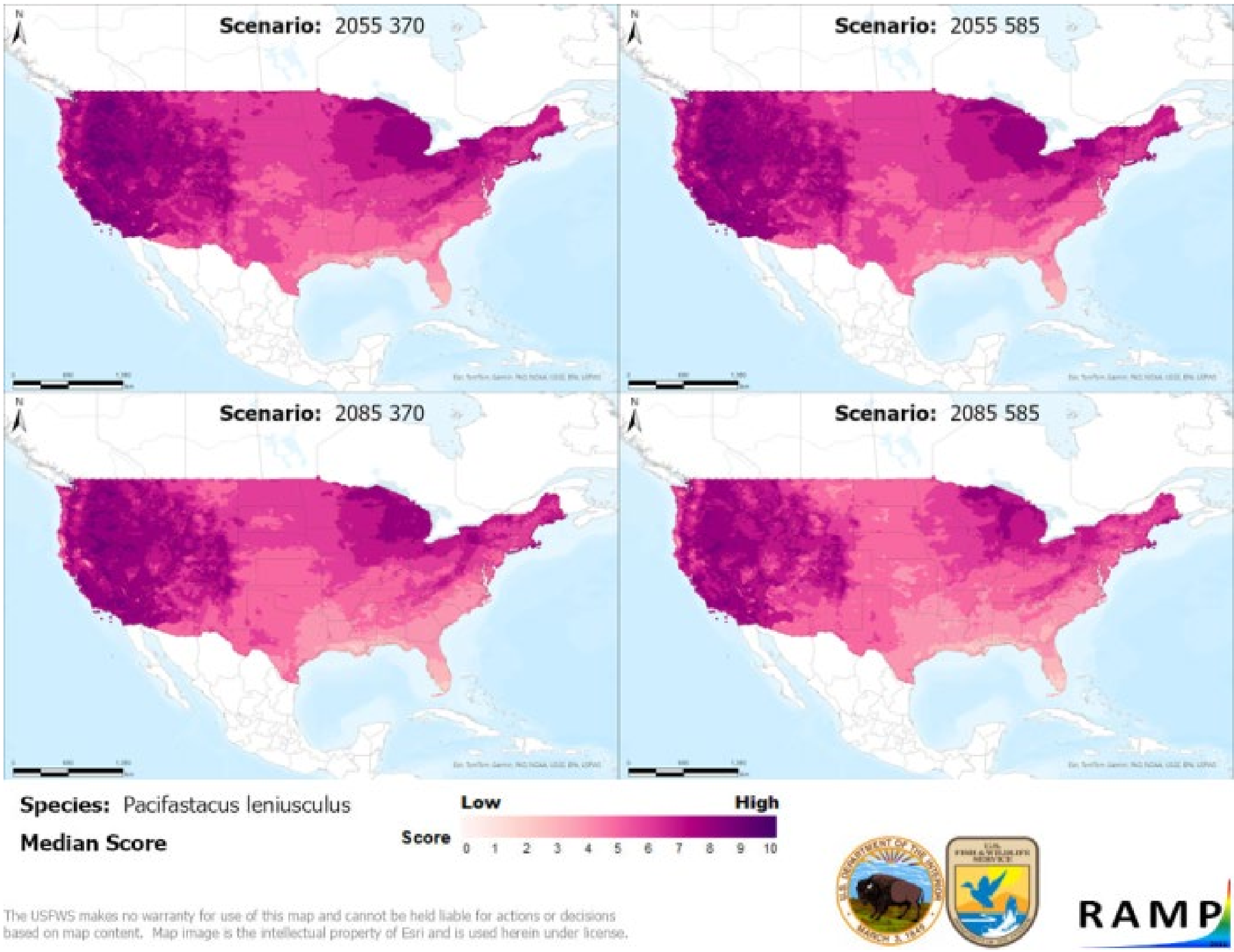

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Pacifastacus leniusculus* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2023). 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.

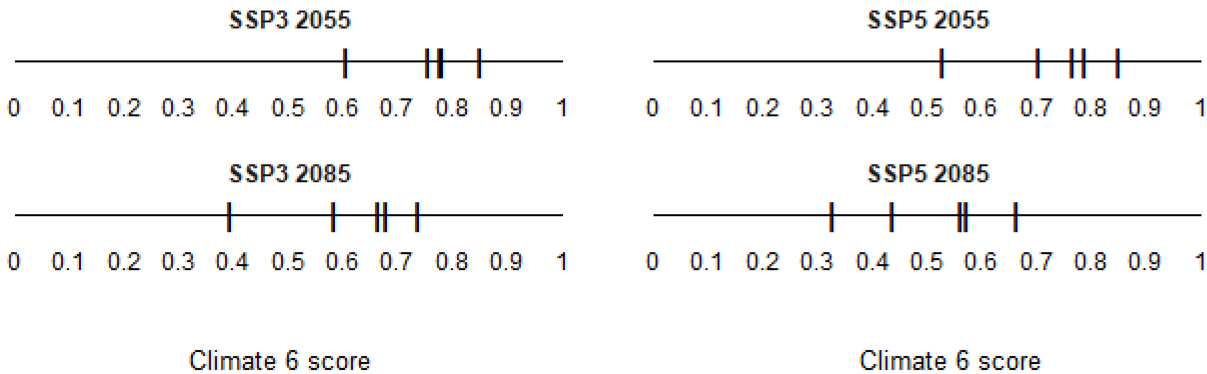

Figure A2. Comparison of projected future Climate 6 scores for *Pacifastacus leniusculus* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 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.

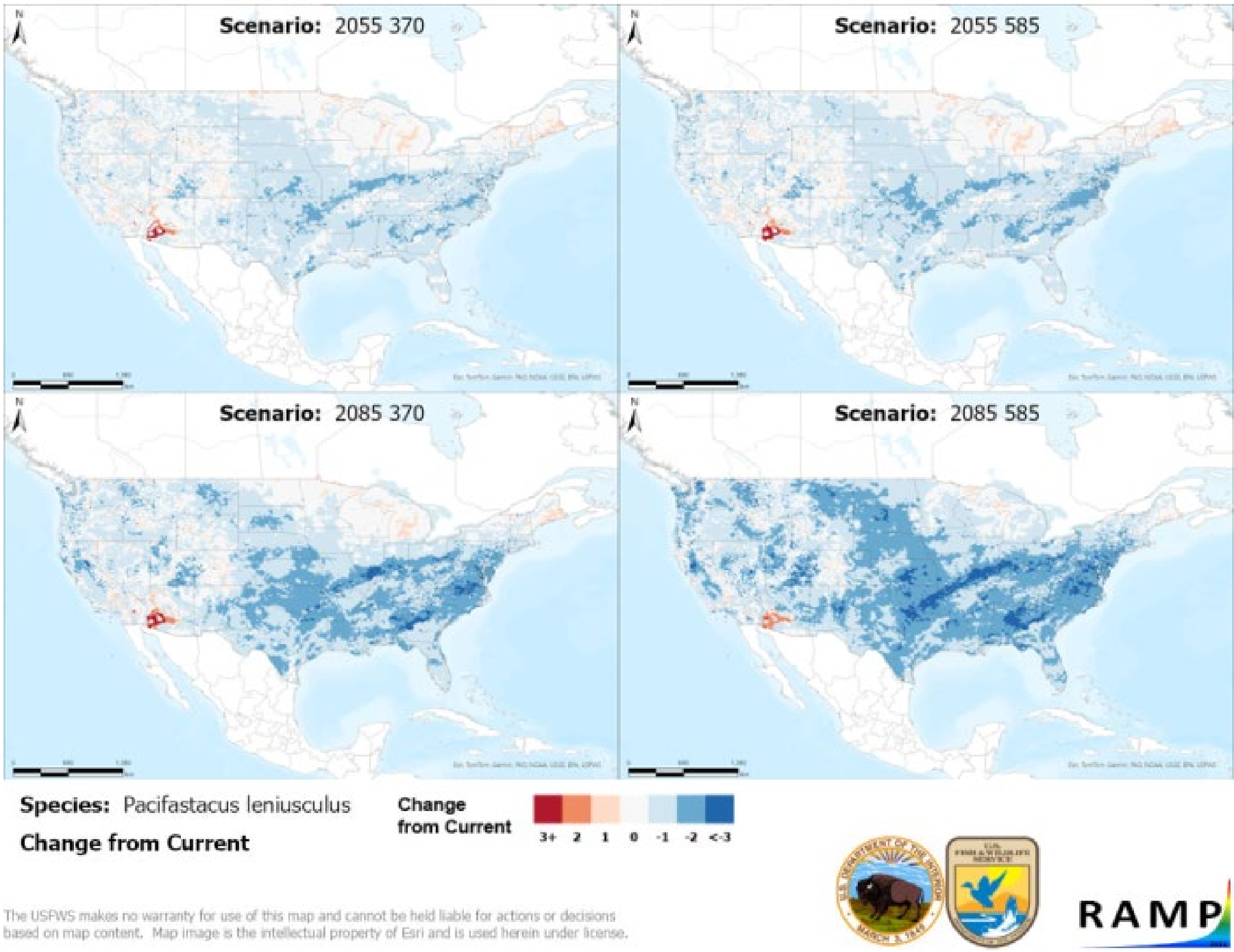

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 5) and the median target point score for future climate scenarios (figure A1) for *Pacifastacus leniusculus* based on source locations reported 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.

Literature Cited

GBIF Secretariat. 2023. GBIF backbone taxonomy: *Pacifastacus leniusculus* (Dana, 1852). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/2226990 (December 2023).

[IPCC] Intergovernmental Panel on Climate Change. 2021. Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder HP, Kessler M. 2018. Data from: Climatologies at high resolution for the earth's land surface areas. EnviDat. Available: https://doi.org/10.16904/envidat.228.v2.1.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder P, Kessler M. 2017. Climatologies at high resolution for the Earth land surface areas. Scientific Data 4:170122.

Sanders S, Castiglione C, Hoff M. 2023. Risk Assessment Mapping Program: RAMP. Version 5.0. U.S. Fish and Wildlife Service.