U.S. Fish & Wildlife Service

Redclaw (*Cherax quadricarinatus*)
Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, 2012
Revised, October 2016 and January 2018
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1 Native Range and Status in the United States

Native Range

From CABI (2016):

"*C. quadricarinatus* is indigenous to the rivers of northwestern Queensland and of the northern and eastern parts of Northern Territory in Australia (Riek, 1969; Curtis and Jones, 1995), and to the catchments of southeastern Papua New Guinea (Holthuis, 1986)."

Status in the United States

From USGS (2016):

"Nonindigenous Occurrences: Loiza River and Carraizo Reservoir in Puerto Rico (Williams et al. 2001)"

"Status: Established in Puerto Rico (Williams et al., 2001)."

From Medley et al. (1994):

"Red claw have been grown successfully in ponds in the southern U.S. on a research scale for the last four years. In addition, many private companies have been aggressively engaged in the development of red claw production in the U.S. and abroad for several years."

From FFWCC (2018):

"Australian red claw crayfish (*Cherax quadricarinatus*)
May be used in commercial systems only under an Aquaculture Certificate of Registration and Restricted Species Authorization issued by DOACS [Florida Department of Agriculture & Consumer Services]"

"Aquatic species that are left over from aquaponics projects may not be released into Florida waters. It's illegal to release any nonnative species in Florida."

From Faulkes (2015):

"The majority of [crayfish] species sold in North America [in the pet trade] are North American species. While species from Australia and New Guinea are occasionally available, none are as widely distributed as some *Cherax* species appear to be in European markets (Chucholl, 2013; Papavlasopoulou et al., 2014; Patoka et al., [2014]; Patoka et al., 2015; Soes and Koese, 2010; Turkmen and Karadal, 2012)."

From Morninstar et al. (2020):

"On August 17, 2019, a specimen of C. quadricarinatus was reported from Lake Balboa, Los Angeles, California, United States (34.18054, −118.49641; Figure 1), where it had been unintentionally caught on hook and line by one of the authors of this study (A.K. Yazaryan) in December 2018."

"Here we report the first known introduction of C. quadricarinatus in the contiguous United States."

"Casual further observations (A.K. Yazaryan pers. obs.) and the media platform investigation performed led to the detection of several other observations of C. quadricarinatus in Lake Balboa. All observations from these platforms ranged from November 2018 to May of 2019 and included both male and female specimens, suggesting that the species overwintered and could potentially become established in the lake, or that the lake has experienced multiple introductions of the species. Formal and thorough sampling is needed to determine the status of the species in the lake and surrounding waterbodies."

Means of Introductions in the United States

From Williams et al. (2001):

"A shipment of 3000 *C. quadricarinatus* was sent to Puerto Rico in 1997, at least partially via a well-known commercial package service, without inspection or knowledge of the local government. These animals were stocked in earthen ponds on a farm in northeastern Puerto Rico. Only after adult *C. quadricarinatus* escaped as a result of Hurricane Georges, 22 September 1998, was the unauthorized introduction discovered. Subsequent investigation suggested that several other farms had received shipments of *C. quadricarinatus* and stocked these animals in various amounts."

From Morninstar et al. (2020):

"Aquarium releases account for many aquatic invasive species introductions in popular lakes in urban areas such as Lake Balboa, which might have been the case here."

"Nevertheless, there is also the possibility that a ceremonial release may have been the introduction pathway for this species (Liu et al. 2012; Nuwer 2014). This is a practice that is common in large cities, although many other potential vectors could have been responsible for the species introduction into this lake (see USGS 2019)."

Remarks

From USGS (2016):

"This species is in the aquaculture industry in countries such as Belize, China, Indonesia, Israel, Morocco, Panama, Spain, and the United States (FAO, 2011-2013)."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From GBIF (2016):

"KINGDOM	Animalia
PHYLUM	Arthropoda
CLASS	Malacostraca
ORDER	Decapoda
FAMILY	Parastacidae
GENUS	*Cherax*
SPECIES	*Cherax quadricarinatus*"

"TAXONOMIC STATUS accepted species"

Size, Weight, and Age Range

From CABI (2016):

"Length: up to 35 cm of total length, seldom longer."

"Life span is 4-5 years based on maximum size recorded of around 650 g. Sexual maturity is reached at 6-12 months with a body weight of approximately 110-120 g. Male specimens are fully grown at two years when they reach the weight of about 400 g. In Queensland, redclaw usually mature at around 6 months of age (45-50 g) […]"

From Ahyong and Yeo (2007):

"The Red-Claw may reach a total length of about 250 mm and weigh up to 600 g."

Environment

From Austin et al. (2010):

"This species can be found in coastal streams and freshwater environments, with a preference for the slower moving upper reaches of rivers as well as lakes and lagoons (Wingfield 2002)."

From CABI (2016):

"Tolerance to salinities as high as 12 ppt for extended periods have […] been established for this species."

"Redclaw is able to survive under conditions of very low dissolved oxygen (1 ppm). If dissolved oxygen in the pond water drops below 1 ppm, redclaw will move to the edge of the pond where oxygen levels are generally higher, and in extreme cases will migrate from the pond over land."

Climate/Range

From CABI (2016):

"The harsh physical extremes of its distribution in tropical Australia have given *C. quadricarinatus* a robust nature with broad tolerances, particularly in the case of Queensland strains. Over 70% of adults' growth occurs in the range 23-31°C. Maximum growth rate of hatchlings occurs when the temperature is about 30°C and growth ceases when the temperature falls to 15°C or rises to 35°C; their thermal tolerance range between 22°C and 32°C (King, 1994). Lethal limits are around 9-10°C and 34-35°C. Reproduction will only occur while water temperature remains above 23°C."

"The survival of *C. quadricarinatus* in earthen ponds under ambient winter temperatures was studied in the temperate zone in the central coastal plain of Israel by Karplus et al. (1998[a]). Notwithstanding that minimum daily temperatures of under 10°C were recorded on 6 days, overall survival was 60% and change in weight was minimal. It can survive short periods of exposure to low temperatures (5°C)."

Distribution Outside of the United States

Native

From CABI (2016):

"*C. quadricarinatus* is indigenous to the rivers of northwestern Queensland and of the northern and eastern parts of Northern Territory in Australia (Riek, 1969; Curtis and Jones, 1995), and to the catchments of southeastern Papua New Guinea (Holthuis, 1986)."

Introduced

From CABI (2016):

"There are reports of established feral populations in Ecuador, Israel, Mexico, Jamaica, Paraguay, Puerto Rico, Singapore, South Africa, Thailand, and Zambia (Romero, 1997, 2002; Williams et al., 2001; de Moor, 2002; Zimmerman, 2003; Ahyong and Yeo, 2007; Bortolini et al., 2007; Garcia Vazquez, 2009)."

From Austin et al. (2010):

"Australia (New South Wales – Introduced […] South Australia - Introduced, Victoria - Introduced, Western Australia – Introduced)"

From Fetzner (2016):

"[…] now translocated widely in eastern Queensland."

From Jaklič and Vrezec (2011):

"The first population of tropical redclaw crayfish, *Cherax quadricarinatus* in the wild in Europe has been found in a thermal oxbow lake in Slovenia (Central Europe). Redclaw specimens had already been found in the wild in some European countries before (Germany, the Netherlands, England), but these occurrences were short-termed and probably representing only released individuals (Holdich et al., 2009)."

Means of Introduction Outside the United States

From Ahyong and Yeo (2007):

"Both within Australia and internationally, *C. quadricarinatus* has been widely translocated for large-scale aquaculture and the aquarium trade (Doupé et al. 2004; Vigliano and Darrigran 2002; Lawrence and Jones 2002)."

From CABI (2016):

"*C. quadricarinatus* was introduced to Israel from the USA in the early 1990s by the Department of Fisheries, Ministry of Agriculture, for aquaculture purposes (FAO-DIAS, 2011). Experimental stocking and growout studies were carried out at the Agricultural Research Organization at Bet Dagan and the Aquacultural Research Station, Ministry of Agriculture, Dor (Karplus et al., 1995, 1998[b]; Sagi et al., 1998). In the latter location, in 1994, individuals were discovered to have overwintered in open earthen ponds. Moreover, it was recorded that "in the absence of fences" individuals wandered into adjacent ponds and drainage canals. […] the species is now raised in Kfar Monash, on the central coastal plain, where intensive farming is able to provide up to 100,000,000 juveniles to distributors and ornamental shop chains in Israel and Europe (http://www.aquology.com). On January 2011, a large specimen was captured in shallow waters (2-3 m depth) at the Sea of Galilee (Lake Tiberias), opposite Tiberias promenade and bathing beach (Snovsky and Galil, 2011)."

"In Mexico, the redclaw crayfish have been introduced a number of times to establish commercial cultures and several ventures have been producing moderate amounts for the local markets in at least the states of Colima, Distrito Federal, Morelos, Jalisco, Tamaulipas, and Yucatan (Bortolini et al., 2007). The first importation of redclaw crayfish into Mexico occurred in 1995 when the Experimental Aquaculture Plant of the Universidad Autónoma Metropolitana, in Mexico City, brought a small stock to initiate a research program to determine its suitability to be cultured in Mexico (Ponce-Palafox et al., 1999). In 1998, organisms were transferred to several research centers in Ensenada, Baja California; La Paz, Baja California Sur; and Mérida, Yucatan, plus to an aquaculture center in the state of Morelos; since then several other research centers and universities around Mexico have started research projects using this species. Feral established populations of *C. quadricarinatus* were reported in the states of Morelos and Tamaulipas in 2005."

"In Singapore, since 2000 sampling and observations in several water catchment reservoirs have revealed the presence of *C. quadricarinatus*. Crayfish were recorded from at least three of Singapore's major reservoirs, namely Kranji, Lower Peirce and Upper Seletar (Ahyong and Yeo, 2007). *C. quadricarinatus* is likely to be a recent introduction, probably becoming feral some time between late 1990s and early 2000s. It is not presently cultured for human consumption, but in the last decade it has become popular in the aquarium trade. As such, feral populations probably derive from accidental or deliberate releases. Multiple independent releases or escapes of *C. quadricarinatus* have probably occurred."

Short Description

From Ahyong and Yeo (2007):

"The body is conspicuously coloured with red and maroon highlights on a bluegreen to green body. In addition, mature male Red-Claws have a bright red pulvinus on the outer surface of the major chelae, hence the common name."

Biology

From CABI (2016):

"*C. quadricarinatus* is a non-burrowing species that is tolerant of a wide variety of habitats, from fast flowing rivers and coastal streams to slower moving upper reaches of rivers, lakes, lagoons, and billabongs (Wingfield, 2002). However, redclaw seem to prefer rocky habitats with plenty of caves for exploring and foraging, as well as for protection during moulting (Souty-Grosset et al., 2006). Billabongs are frequently highly eutrophic with poor water quality, and progressively diminish in size as the water evaporates. Crayfish are thus confined in a few remaining water pools, in which they coexist until the rainy season, showing a gregarious habit which is unusual for crayfish species."

"Mating consists in the male depositing a spermatophore on the underside of the female, from which sperm fertilizes eggs within 24 hours. The eggs are held under the female's abdomen until they are ready to hatch – usually 6 to 8 weeks. The larvae develop within the eggs. Embryonic development, lasting 42 days at 26°C, consists of 10 prehatching and three posthatching stages (García-Guerrero et al., 2003). During embryonic development, eggs change colour from green to brown and orange. Finally the eggs hatch and the 12 mm long juveniles remain attached to the female for 1 to 2 days prior to moving away as completely independent miniature adults. The synchrony and degree of mating activity, the incubation period and the juvenile growth period is primarily influenced by water temperature (Lawrence and Jones, 2002)."

"With respect to other crayfish, such as *Cherax destructor,* female fecundity is relatively low, with 300-1,000 eggs per spawn. The number of both pleopodal eggs and juveniles (but not juvenile weight) was shown to be positively correlated to female size (King, 1993; Barki et al., 1997)."

"An outstanding characteristic of *C. quadricarinatus*, which makes this species an ideal study model of sexual determination and plasticity, is the occurrence within populations, with a frequency of 2-14%, of intersex individuals (Medley and Rouse, 1993; Sagi et al., [1996]). Intersex individuals possess a male opening on one of the fifth pereopod and a female opening on the opposite third pereopod; they also possess an androgenic gland and an active testis on the side of the male opening and an ovary on the opposite side. They have male secondary sexual characteristics and function as males with an ovary in a permanently arrested, pre-vitellogenic state. Removal of the androgenic gland from intersex crayfish was found to induce the shift of the reproductive system from a permanently active male state to a female state."

"*C. quadricarinatus* is omnivorous, but in culture grows well on diets with a high proportion of cheap plant material (Lawrence and Jones, 2002). The optimal food for juveniles is zooplankton. They possess an array of digestive enzymes that enable digestion of a broad range of organic materials of animal and plant origin (Figueiredo et al., 2001). There is evidence of endogenous production of cellulases that enable redclaw to digest cellulose and similar sugars (Xue et al., 1999)."

Human Uses

From Austin et al. (2010):

"All production and supply of this species is from aquaculture. The species' remote distribution and legal prohibition on commercial fishing in Australian freshwater, has restricted fishing of wild populations to a very small volume of recreational catch (C. Jones pers. comm. 2008). Although this wild off-take is very limited, the farmed production of this species is estimated to exceed 100 tonnes in Australia last year (Jones 1990, 1998)."

From CABI (2016):

"The hardiness and conspicuous colouration of this species has also made it popular in the aquarium trade worldwide (Ahyong and Yeo, 2007)."

From Faulkes (2015):

"The majority of [crayfish] species sold in North America [in the pet trade] are North American species. While species from Australia and New Guinea are occasionally available, none are as widely distributed as some *Cherax* species appear to be in European markets (Chucholl, 2013; Papavlasopoulou et al., 2014; Patoka et al., [2014]; Patoka et al., 2015; Soes and Koese, 2010; Turkmen and Karadal, 2012)."

Diseases

From CABI (2016):

"In Australia, the redclaw is known to harbour a variety of disease-causing organisms including protozoans, bacteria, and viruses. A well-studied virus is *Cherax* baculovirus (Edgerton and Owens, 1997), which has been implicated in mortalities and poor production in culture facilities, although there has never been any documented widespread outbreak (Edgerton, 1999)."

"Rickettsia-like organisms have been isolated from *C. quadricarinatus* and are considered to be a significant pathogen of this species, causing mortalities in cultured populations in northern Queensland and Ecuador (Edgerton et al., 1995; Romero et al., 2000). *Psorospermium* sp. and the microsporidian *Thelohania* have also been found in Australian populations (Herbert, 1987; Edgerton et al., 1995). Ciliate epibionts (*Zoothamnium*, *Vorticella* and *Lagenophrys*) and the endoparasite belonging to the *Tetrahymena pyriformis* complex were identified in populations in Queensland (Herbert, 1987; Edgerton et al., 1995)."

"Temnocephalid flatworms (Platyhelminthes: Temnocephalida) have been found on this species, including specimens imported into Europe for growth trials. Four species have been identified (Cannon, 1991): *Temnocephala rouxii*, *Notodactylus handschini*, *Diceratocephala boschmai*, and *Decadidymus gulosus*."

From Ahyong and Yeo (2007):

"Like other crayfish, *C. quadricarinatus* is also a potential disease vector as host to numbers of parasitic or symbiotic microbes and invertebrates. In addition to the fungus *Aphanomyces astaci*, Rickettsia-like parasites and parvo-like virus infections are known from some aquacultured populations (Bowater et al. 2002; Romero and Jimen[e]z 2002)."

Svoboda et al. (2017) summarize the susceptibility of crayfish species to *Aphanomyces astaci* as tested through laboratory experiments. *C. quadricarinatus* is reported as having high susceptibility (Roy (1993) after Stephens et al. (2005)), which they define as "[…] individuals frequently die after exposure to *A. astaci* spores […]."

From Shi et al. (2000):

"The white spot syndrome virus (WSSV) (Lightner 1996) is one of the most dangerous viruses found in farmed penaeid shrimp and other Crustacea, as a result of its pathogenicity and lack of specificity […] Our results show that WSSV is able to develop in *C. quadricarinatus* […] Given the quantity of virions produced in crayfish tissues, *C. quadricarinatus* can be considered as a potential host and carrier of WSSV."

Infection with *Aphanomyces astaci* (crayfish plague) and infection with white spot syndrome virus are OIE-listed infections.

Because crayfish plague can be lethal to *C. quadricarinatus*, the crayfish may not establish if introduced into the United States where *A. astaci* is endemic.

From Panteleit et al.(2019):

"Little is known about either the presence or the influence of *A. astaci* in North America where it originates."

"*Aphanomyces astaci* originates from North America, where it presumably lives as a parasite in the cuticle of freshwater crayfish species of both North American crayfish families, the Astacidae and Cambaridae (Unestam 1972, Martin and Davis 2001)."

Threat to Humans

From CABI (2016):

"No negative social impact is known. The possibility exists that this species might be a vector of parasites and diseases that might affect humans. As shown by Saker and Eaglesham (1999), it can accumulate toxins of cyanobacteria in its tissues and organs."

3 Impacts of Introductions

From Pattillo (2010):

“To assess potential impacts of seasonal redclaw invasions, we examined competition between redclaw and another species [*Procambarus acutissimus*] that is native to the United States and has a similar life history strategy. […] Average weight and carapace length of male *P. acutissimus* decreased significantly with increasing redclaw biomass […] Average weight and carapace size of female *P. acutissimus* did not decline significantly with increasing redclaw biomass […] We found that although redclaws did have a significant, short-term impact on the average size of our model native species, there were also several factors that reduce the potential impact of redclaws on native crayfish populations. […] Juvenile redclaws were immobilized at water temperatures ≤ 14 °C, which would render them susceptible to starvation and predation in the wild. Adult redclaws in the outdoor mesocosms suffered 100% mortality by mid-December when average daily temperatures were still above 14 °C.”

From Zeng et al. (2019):

[in Singapore, Peninsular Malaysia, and Sumatra, Indonesia] “Owing to the asymmetry among the size-success relationship exhibited by both species under specific (attacker/defender) roles, the non-native crayfish [*C. quadricarinatus*] can outcompete native crabs [lowland freshwater crab (*Parathelphusa maculate*) for a limited shelter resource. This, together with the ability of *C. quadricarinatus* to achieve larger sizes than crabs at a faster rate, contributes to the negative correlation observed between the average size of crayfish and crabs found in a stream system where both species are syntopic. These findings suggest a likelihood for displacement of the native crab by *C. quadricarinatus*, highlighting the need for management of this non-native species.”

From Leland et al. (2012):

“Extensive trapping surveys and opportunistic observations of recreational fishers, indicate that large numbers of mature *C. quadricarinatus* can be captured irrespective of season and suggest that the population is well established [in Lake Ainsworth, New South Wales, Australia] (Leland unpublished data). Reproduction is occurring within the population as evidenced by the capture of berried females, which are extremely rare in trap catches, probably because of trap avoidance (Brown & Brewis, 1978). […] The absence of native crayfish in catches is of some concern. It may be that *C. quadricarinatus* has displaced the smaller, native *C. cuspidatus*, which is otherwise ubiquitous in the area. However, it is also possible that native crayfish are present in the lake, and were simply avoiding the traps in the presence of the larger *C. quadricarinatus*. During 2010 and 2011, trapping and sweep-netting surveys of the adjacent *Melaleuca* swamp habitat (~2–3 km north of Lake Ainsworth) confirmed the presence of the native *C. cuspidatus* and *Tenuibranchiurus* sp. in the area (Furse unpublished data). During that time, *C. cuspidatus* were captured with the same bait traps in the *Melaleuca* swamp, which establishes the species was not generally ‘trap shy’ at that time. To date *C. quadricarinatus* have not been captured in any adjacent habitat by the authors or our colleagues.”

From Nunes et al. (2016):

“On the Kafue Flats, artisanal fishermen have reported substantial damage to fish caught in gill nets, as well as to the nets themselves, by scavenging crayfish (Phiri 2009; Tyser 2010). Crayfish caught in nets are generally discarded, as local superstitions seem to inhibit the eating of crayfish/shellfish and there is no local market for them. In both Zambia and South Africa, populations of *C quadricarinatus* have been responsible for the introduction of an undesirable non-native temnocephalan ectoparasite that might be harmful to native decapods (du Preez and Smit 2013; RJD personal obs). Furthermore, although some predatory fish species in the Kafue region have incorporated crayfish into their diets, positive impacts linked to the availability of a new prey species are likely to be limited, as crayfish have relatively low energy content in comparison to fish prey (Elvira et al. 1996). It is also doubtful that fish predation will deplete crayfish populations, because only small-sized crayfish seem to be vulnerable to this (Tyser and Douthwaite 2014).”

From Wong (2007):

“*Cherax quadricarinatus*, the Australian redclaw crayfish, was introduced to Jamaica in the 1990s and is now found in abundance in Black River. Current studies and anecdotal evidence suggest that it is out-competing and predating on native shrimps.”

From Pienkowski et al. (2015):

“We show that the invasive Australian Red Claw crayfish (*Cherax quadricarinatus*) is an important source of income for fishermen within the Black River Lower Morass of Jamaica and supplement incomes during periods when native shrimp (*Macrobrachium* spp.) catches decline. We also show that full-time fishermen and those who have no alternative occupations expend the greatest fishing effort. We use the intra-annual variation of fishermen's harvest effort between seasons (when catch per unit effort changes) as a proxy for dependence. Using this measure, we found that the least wealthy appear to be the most dependent on fishing, and consequently benefit the most from the invasive crayfish.”

“This study did not seek to determine the impact of the invasive crayfish on the native shrimp population, and subsequently the incomes that might be derived from shrimp catches in the absence of the crayfish. Anecdotal evidence suggests that native shrimp catches had been declining since before the introduction of the invasive crayfish in Jamaica. The participating fishermen reported increasing numbers of fishermen and pollution as probable drivers of the decline.”

From Vega-Villasante et al. (2015):

“Fishing and marketing of the crayfish is an important economic activity at both sampling sites [in Jalisco, Mexico] of the present study. At the reservoir, there is an official fishing cooperative that keeps records of crayfish catches. […] During the low season (mid-November through June), fishers collected 4,800 kg per month (190.000-240.000 crayfish per month). During the high fishing season (October and early November; about 45 days), fishers obtained 32,400 kg (about 1,620,000 crayfish). […] The total annual sales of the catch per year was US$280,750 of which 70.7% came from the sale of red claw crayfish and 29.3% originated from the sale of native cauque prawns. […] For the stream location, there are no records available for comparison because these independent fishers do not report catches. Still, it is likely that fishing *C. quadricarinatus* in this stream provides significant economic benefits to the fishers because it has a large regional demand and attractive sale prices."

As mentioned in the Diseases subsection, above, *C. quadricarinatus* is susceptible to two OIE-reportable diseases: crayfish plague and white spot syndrome. There is evidence that these diseases can have an impact on North American crayfish in the wild and in aquaculture.

From Svoboda et al. (2017):

"All North American crayfish species tested so far have shown a lower susceptibility to the crayfish plague pathogen than crayfish species from other regions […] However, even North American crayfish, such as the signal crayfish *Pacifastacus leniusculus* (Dana), can succumb to *A. astaci* infection (Aydin et al. 2014; Edsman et al. 2015). Infected signal crayfish can suffer from extensive mortalities if their immune system is suppressed, which may happen during moulting, when attacked by other parasites, or in unfavourable environmental conditions (Cerenius et al. 2003)."

From Baumgartner et al. (2009):

"In the spring of 2007, 3 crawfish farms experienced heavy mortality in ponds populated by *Procambarus clarkii* and *P. zonangulus*. Histological examination revealed findings consistent with severe viral infection characterized by numerous intranuclear inclusions in ectodermal and mesodermal tissues. Samples tested by in situ hybridization, injection bioassay in *Litopenaeus vannamei*, and PCR (nested and real time) were all positive for WSSV [white spot syndrome virus]. Samples were sent to the National Veterinary Services Laboratory in Ames, Iowa, USA, where WSSV was verified. Subsequently, a multi-parish survey of 184 sites in Louisiana (including farm and wild basin samples) using real-time PCR determined that >60% of sites sampled were positive for WSSV, including wild basin samples."

From Shi et al. (2000):

"The white spot syndrome virus (WSSV) (Lightner 1996) is one of the most dangerous viruses found in farmed penaeid shrimp and other Crustacea, as a result of its pathogenicity and lack of specificity […] Our results show that WSSV is able to develop in *C. quadricarinatus* […] Given the quantity of virions produced in crayfish tissues, *C. quadricarinatus* can be considered as a potential host and carrier of WSSV."

4 Global Distribution

Figure 1. Known global established locations of *C. quadricarinatus* (GBIF 2016).

5 Distribution Within the United States

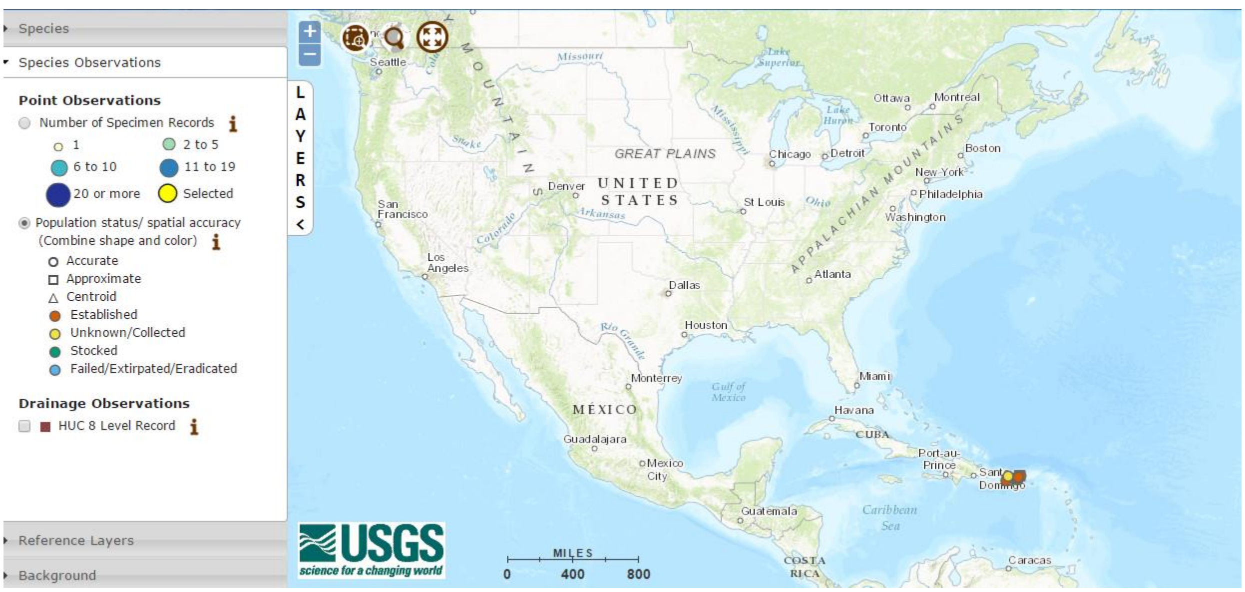

Figure 2. Known established locations of *C. quadricarinatus* in the United States (USGS 2016).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014; 16 climate variables; Euclidean Distance) is high in southern Texas, southern Florida, and the far southwestern United States. Climate match is lowest in the northwestern United States, but climate match is quite low across the northern

United States and in much of the South between Florida and Texas. Climate 6 score indicates that the contiguous United States has a medium climate match. The range of Climate 6 scores for a medium climate match is 0.005 to 0.103; Climate 6 score for *Cherax quadricarinatus* is medium at 0.087. Crayfishes have been observed to establish populations in climates different from that found within their native range (Capinha et al. 2013). The climate match shown here may be an underestimate of climate suitability for the establishment of *C. quadricarinatus*.

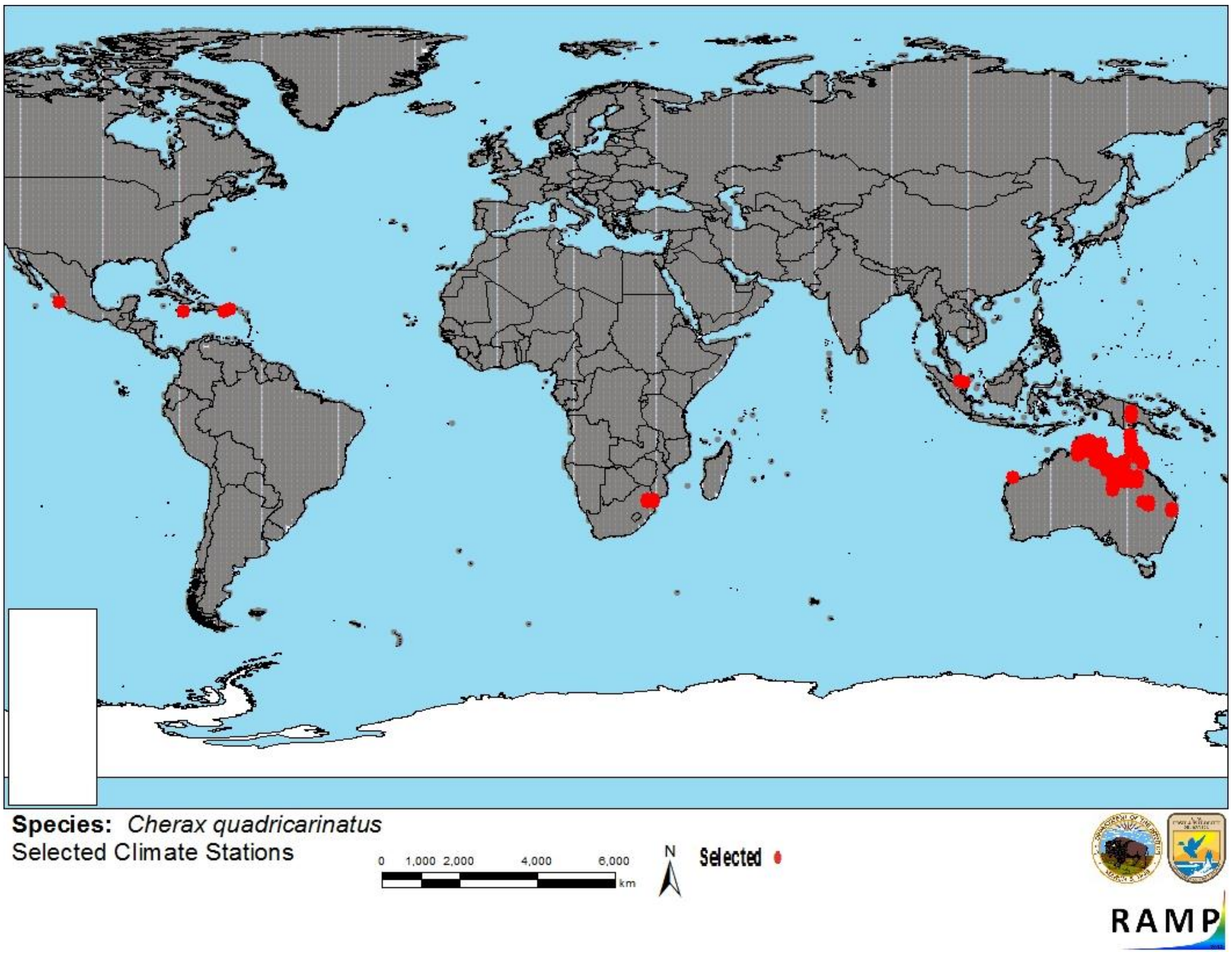

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red: Australia, Singapore, Papua New Guinea, South Africa, Caribbean, Mexico) and non-source locations (gray) for *Cherax quadricarinatus* climate matching. Source locations from Pienkowski et al. (2015), Vega-Villasante et al. (2015), and GBIF (2016).

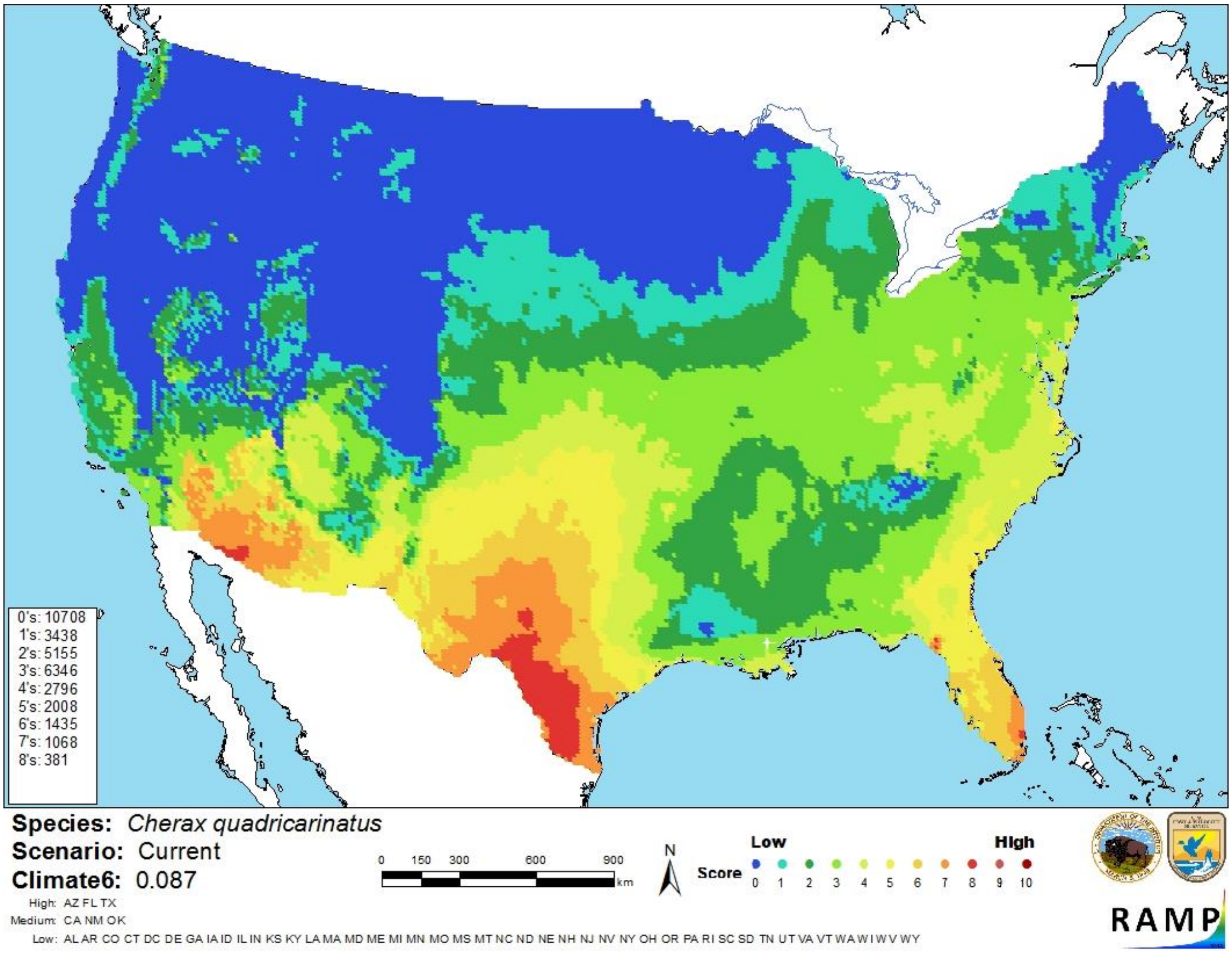

Figure 4. Map of RAMP (Sanders et al. 2014) climate matches for *Cherax quadricarinatus* in the contiguous United States based on source locations reported by Pienkowski et al. (2015), Vega-Villasante et al. (2015), and GBIF (2016). Counts of climate match scores are tabulated on the left. 0=Lowest match, 10=Highest match. Climate match scores are tabulated on the left.

The “High”, “Medium”, and “Low” climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
$0.000 \leq X \leq 0.005$	Low
$0.005 < X < 0.103$	Medium
≥ 0.103	High

7 Certainty of Assessment

C. quadricarinatus has been transported around the world for aquaculture and the aquarium trade and has established populations outside of its native habitat. There is some evidence for adverse ecological impacts of these introductions, but more research is warranted to better understand interactions with native species. Certainty of this assessment is medium.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Cherax quadricarinatus is a crayfish native to northeastern Australia that has become popular in the aquaculture and aquarium industries. It has become established in Asia, Africa, South America, North America, and the Caribbean. Economic impacts of these introductions may benefit some people but harm others, as *C. quadricarinatus* populations have become important to local economies in Jamaica and Mexico when native shrimp decline; however, that decline may be due to the crayfish. The crayfish harm artisanal fishing in the Kafue Flats of Zambia by damaging fish caught in gill nets and damaging the nets themselves. *C. quadricarinatus* is a vector for OIE-reportable pathogens and parasites that cause disease, notably white spot syndrome virus (WSSV) and crayfish plague. WSSV caused heavy mortality in Louisiana crayfish farms during a 2007 outbreak, and although North American species of crayfish are less susceptible to crayfish plague than crayfish native to other continents, there is evidence of disease and mortality in native crayfish under high-stress conditions. *C. quadricarinatus* may not establish if introduced into the United States where crayfish plague is present in the environment; *C. quadricarinatus* is established in Puerto Rico and reported in southern California. Introduced *C. quadricarinatus* populations show an inverse relationship with a native crab population in Singapore and native crayfish populations in New South Wales, Australia, i.e., large introduced crayfish were associated with smaller or absent native species. The climate match indicates a medium match with the contiguous United States, with high matches in Texas and South Florida. Overall risk is high.

Assessment Elements

- **History of Invasiveness (Section 3): High**
- **Climate Match (Section 6): Medium**
- **Certainty of Assessment (Section 7): Medium**
- **Important additional information: Susceptible to white spot syndrome virus and crayfish plague**
- **Overall Risk Assessment Category: High**

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.

Ahyong, S. T., and D. C. J. Yeo. 2007. Feral populations of the Australian Red-Claw crayfish (*Cherax quadricarinatus* von Martens) in water supply catchments of Singapore. Biological Invasions 9:943-946.

Austin, C. M., C. Jones, and M. Wingfield. 2010. *Cherax quadricarinatus*. IUCN Red List of Threatened Species 2010: e.T4621A11041003. Available: http://www.iucnredlist.org/details/4621/0. (October 2016).

Baumgartner, W. A., J. P. Hawke, K. Bowles, P. W. Varner, and K. W. Hasson. 2009. Primary diagnosis and surveillance of white spot syndrome virus in wild and farmed crawfish (*Procambarus clarkii*, *P. zonangulus*) in Louisiana, USA. Diseases of Aquatic Organisms 85:15-22.

CABI. 2016. *Cherax quadricarinatus* (redclaw crayfish) [original text by C. Jones, revised by F. Gherardi]. Invasive Species Compendium. CAB International, Wallingford, UK. Available: http://www.cabi.org/isc/datasheet/89135. (October 2016).

Capinha C, Brotons L, Anastácio P. 2013. Geographical variability in propagule pressure and climatic suitability explain the European distribution of two highly invasive crayfish. Journal of Biogeography 40:548-558.

Faulkes, Z. 2015. Marmorkrebs (*Procambarus fallax* f. *virginalis*) are the most popular crayfish in the North American pet trade. Knowledge and Management of Aquatic Ecosystems 416:20.

Fetzner, J. 2016. *Cherax quadricarinatus* (von Martens, 1868). The crayfish and lobster taxonomy browser, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania. Available: http://iz.carnegiemnh.org/crayfish/NewAstacidea/species.asp?g=Cherax&s=quadricarinatus&ssp=. (October 2016).

FFWCC (Florida Fish and Wildlife Conservation Commission). 2018. Aquaponics licenses & permits. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida. Available: http://myfwc.com/license/aquaculture-certificate/aquaponics/. (January 2018).

GBIF (Global Biodiversity Information Facility). 2016. GBIF backbone taxonomy: *Cherax quadricarinatus* (von Martins, 1868). Global Biodiversity Information Facility, Copenhagen. Available: http://www.gbif.org/species/4648609. (October 2016).

Jaklič, M., and A. Vrezec. 2011. The first tropical alien crayfish species in European waters: the redclaw *Cherax quadricarinatus* (Von Martens, 1868) (Decapoda, Parastacidae). Crustaceana 84(5/6):651-665.

Leland, J. C., J. Coughran, and J. M. Furse. 2012. Further translocation of the Redclaw, *Cherax quadricarinatus* (Decapoda: Parastacidae), to Lake Ainsworth in northeastern New South Wales, Australia.

Medley, P. B., R. G. Nelson, L. U. Hatch, D. B. Rouse, and G. F. Pinto. 1994. Economic feasibility and risk analysis of Australian red claw crayfish *Cherax quadricarinatus* aquaculture in the southeastern United States. Journal of the World Aquaculture Society 25(1):135-146.

Morningstar, C.R., Daniel, W.M., Neilson, M.E., Yazaryan, A.K. 2020. The first occurrence of the Australian redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868) in the contiguous United States. BioInvasions Records 9(1):120-126.

Nunes, A. L., R. J. Douthwaite, B. Tyser, G. J. Measey, and O. L. F. Weyl. 2016. Invasive crayfish threaten Okavango Delta. Frontiers in Ecology and the Environment 14(5):237-238.

Panteleit, J., T. Horvath, J. Jussila, J. Makkonen, W. Perry, R. Schulz, K. Theissinger, and A. Schrimpf. 2019. Invasive rusty crayfish (*Faxonius rusticus*) populations in North America are infected with the crayfish plague disease agent (*Aphanomyces astaci*) Freshwater Science 38(2):425–433.

Pattillo, D. A. 2010. Improving redclaw crayfish (*Cherax quadricarinatus*) aquaculture: assessment of invasive impacts and production of all-male broods. Master's thesis. Auburn University, Auburn, Alabama.

Pienkowski, T., S. Williams, K. McLaren, B. Wilson, and N. Hockley. 2015. Alien invasions and livelihoods: economic benefits of invasive Australian Red Claw crayfish in Jamaica. Ecological Economics 112:68-77.

Sanders, S., C. Castiglione, and M. Hoff. 2014. Risk Assessment Mapping Program: RAMP. U.S. Fish and Wildlife Service.

Shi, Z., C. Huang, J. Zhang, D. Chen, and J. R. Bonami. 2000. White spot syndrome virus (WSSV) experimental infection of the freshwater crayfish, *Cherax quadricarinatus*. Journal of Fish Diseases 23:285-288.

Svoboda, J., A. Mrugała, E. Kozubíková-Balcarová, and A. Petrusek. 2017. Hosts and transmission of the crayfish plague pathogen *Aphanomyces astaci*: a review. Journal of Fish Diseases 40:127-140.

USGS (United States Geological Survey). 2016. *Cherax quadricarinatus*. USGS Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=220. (October 2016).

Vega-Villasante, F., J. J. Ávalos-Aguilar, H. Nolasco-Soria, M. A. Vargas-Ceballos, J. L. Bortolini-Rosales, O. Chong-Carrillo, M. F. Ruiz-Núñez, and J. C. Morales-Hernández. 2015. Wild populations of the invasive Australian red claw crayfish *Cherax quadricarinatus* (Crustacea, Decapoda) near the northern coast of Jalisco, Mexico: a new fishing and profitable resource. Latin American Journal of Aquatic Research 43(4):781-785.

Williams, E. H., Jr., L. Bunkley-Williams, C. G. Lilyestrom, and E. A. R. Ortiz-Corps. 2001. A review of recent introductions of aquatic invertebrates in Puerto Rico and implications for the management of nonindigenous species. Caribbean Journal of Science 37(3-4):246-251.

Wong, W. Y. 2007. Of gods and government: what can *Cherax quadricarinatus* in Black River, Jamaica teach us about invasive species communication and management? [abstract]. 15th International Conference on Aquatic Invasive Species, Nijmegen, The Netherlands. Available: http://www.int-res.com/articles/ab2012/16/b016p287.pdf. (October 2016).

Zeng, Y., Shakir, K.K. and Yeo, D.C.J. 2019. Competition between a native freshwater crab and an invasive crayfish in tropical Southeast Asia. *Biol Invasions* 21(8): 2653-2663. https://link.springer.com/article/10.1007%2Fs10530-019-02009-6.

10 References Quoted But Not Accessed

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.

Aydin, H., H. Kokko, J. Makkonen, R. Kortet, H. Kukkonen, and J. Jussila. 2014. The signal crayfish is vulnerable to both the As and the PsI-isolates of the crayfish plague. Knowledge and Management of Aquatic Ecosystems 413:03.

Barki, A., T. Levi, G. Hulata, and I. Karplus. 1997. Annual cycle of spawning and molting in the red-claw crayfish, *Cherax quadricarinatus*, under laboratory conditions. Aquaculture 157(3/4):239-249.

Bortolini, J. L., F. Alvarez, and G. Rodríguez-Almaraz. 2007. On the presence of the Australian redclaw crayfish, *Cherax quadricarinatus*, in Mexico. Biological Invasions 9(5):615-620.

Bowater, R. O., M. Wingfield, A. Fisk, K. M. L. Conodon, A. Reid, H. Prior, and E. C. Kulpa. 2002. A parvo-like virus cultured in redclaw crayfish *Cherax quadricarinatus* from Queensland, Australia. Diseases of Aquatic Organisms 50:70-86.

Brown, D. J., and J. M. Brewis. 1978. A critical look at trapping as a method of sampling a population of *Austropotamobius pallipes* (Lereboullet) in a mark and recapture study. Freshwater Crayfish 4:159-163.

Cannon, L. R. G. 1991. Temnocephalan symbionts of the freshwater crayfish *Cherax quadricarinatus* from northern Australia. Hydrobiologia 227:341-347.

Cerenius, L., E. Bangyeekhun, P. Keyser, I. Söderhäll, and K. Söderhäll. 2003. Host prophenoloxidase expression in freshwater crayfish is linked to increased resistance to the crayfish plague fungus, *Aphanomyces astaci*. Cellular Microbiology 5:353-357.

Chua, K. W. J., D. J. J. Ng, Y. Zeng, and D. C. J. Yeo. 2015. Habitat characteristics of tropical rainforest freshwater crabs (Decapoda: Brachyura: Potamidae, Gecarcinucidae) in Singapore. Journal of Crustacean Biology 35:533-539.

Chucholl, C. 2013. Invaders for sale: trade and determinants of introduction of ornamental freshwater crayfish. Biological Invasions 15:125-141.

Curtis, M. C., and C. M. Jones. 1995. Overview of redclaw crayfish *Cherax quadricarinatus* farming practices in northern Australia. Freshwater Crayfish 10:447-455.

de Moor, I. 2002. Potential impacts of alien freshwater crayfish in South Africa. African Journal of Aquatic Science 27:125-139.

Doupé, R. G., D. L. Morgan, H. S. Gill, and A. J. Rowland. 2004. Introduction of redclaw crayfish *Cherax quadricarinatus* (von Martens) to Lake Kununurra, Ord River, Western Australia: prospects for a 'yabby' in the Kimberley. Journal of the Royal Society of Western Australia 87:187-191.

du Preez, L., and N. Smit. 2013. Double blow: alien crayfish infected with invasive temnocephalan in South African waters. South African Journal of Science 109:1-4.

Edgerton, B. F. 1999. Diseases of the redclaw crayfish. Aquaculture Magazine 25(6):2.

Edgerton, B., and L. Owens. 1997. Age at first infection of *Cherax quadricarinatus* by *Cherax quadricarinatus* bacilliform virus and *Cherax* Giardiavirus-like virus, and production of putative virus-free crayfish. Aquaculture 152(1/4):1-12.

Edgerton, B., L. Owens, L. Harris, A. Thomas, and M. Wingfield. 1995. Health survey of farmed redclaw crayfish *Cherax quadricarinatus* (Von Martens) in tropical Australia. Freshwater Crayfish 10:322-338.

Edsman, L., P. Nyström, A. Sandström, M. Stenberg, H. Kokko, V. Tiitinen, J. Makkonen, and J. Jussila. 2015. Eroded swimmeret syndrome in female crayfish *Pacifastacus leniusculus* associated with *Aphanomyces astaci* and *Fusarium* spp. infections. Diseases of Aquatic Organisms 112:219-228.

Elvira, B., G. Nicola, and A. Almodovar. 1996. Pike and red swamp crayfish: a new case on predator-prey relationship between aliens in central Spain. Journal of Fish Biology 48:437-446.

FAO. 2011-2013. Cultured aquatic species information programme. *Cherax quadricarinatus* [text by C. Jones]. FAO Fisheries and Aquaculture Department, Rome. Available: http://www.fao.org/fishery/culturedspecies/Cherax_quadricarinatus/en. (September 2013).

FAO-DIAS. 2011. Database on introductions of aquatic species. FAO Fisheries Global Information System. Available: http://www.fao.org/fishery/introsp/search/en.

Figueiredo, M. S. R. B., J. A. Kricker, and A. J. Anderson. 2001. Digestive enzyme activities in the alimentary tract of redclaw crayfish, *Cherax quadricarinatus* (Decapoda: Parastacidae). Journal of Crustacean Biology 21:334-344.

García-Guerrero, M., M. E. Hendrickx, and U. Villarreal. 2003. Description of the embryonic development of *Cherax quadricarinatus* (Von Martens, 1868) (Decapoda, Parastacidae), based on the staging method. Crustaceana 76:269-280.

Garcia Vazquez, S. 2009. Distribution of exotic Australian crayfish *Cherax quadricarinatus* (von Martens, 1868) in Puerto Rico. University of Puerto Rico, Mayagüez, Puerto Rico.

Herbert, B. 1987. Notes on diseases and epibionts of *Cherax quadricarinatus* and *C. tenuimanus* (Decapoda: Parastacidae). Aquaculture 64(3):165-173.

Holdich, D. M., J. D. Reynolds, C. Souty-Grosset, and R. J. Sibley. 2009. A review of the ever increasing threat to European crayfish from non-indigenous crayfish species. Knowledge and Management of Aquatic Ecosystems 394-95:46.

Holthuis, L. B. 1986. The freshwater crayfish of New Guinea. Freshwater Crayfish 6:48-58.

Jones, C. M. 1990. The biology and aquaculture potential of the tropical freshwater crayfish, *Cherax quadricarinatus*. Department of Primary Industries, Queensland, Brisbane, Australia.

Jones, C. M. 1998. Redclaw crayfish. *In* K. W. Hyde, editor. The new rural industries. A handbook for farmers and investors. Rural Industries Research and Development Corporation, Canberra, Australia.

Karplus, I., A. Barki, S. Cohen, and G. Hulata. 1995. Culture of the Australian red-claw crayfish *Cherax quadricarinatus* in Israel: I. Polyculture with fish in earthen ponds. Israel Journal of Aquaculture 47:6-16.

Karplus, I., M. Zoran, A. Milstein, S. Harpaz, Y. Eran, D. Joseph, and A. Sagi. 1998a. Culture of the Australian red-claw crayfish (*Cherax quadricarinatus*) in Israel. III. Survival in earthen ponds under ambient winter temperatures. Aquaculture 166(3/4):259-267.

Karplus, I., M. Zoran, A. Milstein, S. Harpaz, Y. Eran, D. Joseph, and A. Sagi. 1998b. Culture of the Australian redclaw crayfish (*Cherax*) in Israel. Fisheries and Fish breeding in Israel 31:172-182.

King, C. 1993. Potential fecundity of redclaw crayfish, *Cherax quadricarinatus* von Martens, in culture. Aquaculture 114(3-4):237-241.

King, C. R. 1994. Growth and survival of redclaw crayfish hatchlings (*Cherax quadricarinatus* Von Martens) in relation to temperature, with comments on the relative suitability of

Cherax quadricarinatus and *Cherax destructor* for culture in Queensland. Aquaculture (Netherlands) 122(1):75-80.

Lawrence, C., and C. Jones. 2002. *Cherax*. Pages 635-669 *in* D. M. Holdich, editor. Biology of freshwater crayfish. Blackwell Science, London.

Lightner, D. V. 1996. A handbook of pathology and diagnostic procedures for diseases of penaeid shrimp. Special publication of the World Aquaculture Society, Baton Rouge, Louisiana.

Lodge, D. M., A. Deines, F. Gherardi, D. C. J. Yeo, T. Arcella, A. K. Baldridge, M. A. Barnes, W. L. Chadderton, J. L. Feder, C. A. Gantz, G. W. Howard, C. L. Jerde, B. W. Peters, J. A. Peters, L. W. Sargent, C. R. Turner, M. E. Wittmann, and Y. Zeng. 2012. Global introductions of crayfishes: evaluating the impact of species invasions on ecosystem services. Annual Review of Ecology, Evolution, and Systematics 43:449-472.

Martin, J. W., and G. E. Davis. 2001. An updated classification of the recent Crustacea. Science series 39. Natural History Museum of Los Angeles County, Los Angeles, California.

Medley, P., and D. B. Rouse. 1993. Intersex Australian red claw crayfish (*Cherax quadricarinatus*). Journal of Shellfish Research 12:93-94.

Papavlasopoulou, I., C. Perdikaris, L. Vardakas, and I. Paschos. 2014. Enemy at the gates: introduction potential of non-indigenous freshwater crayfish in Greece via the aquarium trade. Central European Journal of Biology 9:11-18.

Patoka, J., L. Kalous, and O. Kopecký. 2014. Risk assessment of the crayfish pet trade based on data from the Czech Republic. Biological Invasions 16:2489-2494.

Patoka, J., L. Kalous, and O. Kopecký. 2015. Imports of ornamental crayfish: the first decade from the Czech Republic's perspective. Knowledge and Management of Aquatic Ecosystems 416:04.

Phiri, S. 2009. Mansangu Fisheries Research Station annual report 2009. Department of Fisheries, Ministry of Agriculture and Cooperatives, Chilanga, Republic of Zambia.

Ponce-Palafox, J. T., J. L. Arredondo-Figueroa, and X. Romero. 1999. Análisis del cultivo comercial de la langosta de agua dulce (*Cherax quadricarinatus*): y su posible impacto en América Latina. [English title not available]. Contactos 31:54-61.

Riek, E. F. 1969. The Australian freshwater crayfish (Crustacea: Decapoda: Parastacidae) with descriptions of new species. Australian Journal of Zoology 17:855-918.

Romero, X. 1997. Production of redclaw crayfish in Ecuador. World Aquaculture 28:5-10.

Romero, X. M. 2002. Ups and downs of red claw crayfish farming in Ecuador. World Aquaculture 33:40-41,70-71.

Romero, X., and R. Jimenez. 2002. Histopathological survey of diseases and pathogens present in redclaw crayfish, *Cherax quadricarinatus* (von Martens), cultured in Ecuador. Journal of Fish Diseases 25:653-667.

Romero, X., J. F. Turnbull, and R. Jiménez. 2000. Ultrastructure and cytopathology of a Rickettsia-like organism causing systemic infection in the redclaw crayfish, *Cherax quadricarinatus* (Crustacea: Decapoda), in Ecuador. Journal of Invertebrate Pathology 76(2):95-104.

Roy, J. S. 1993. Effects of *Aphanomyces astaci* and *Aeromonas hydrophila* on the Australian red claw crayfish *Cherax quadricarinatus*. Masters thesis. Auburn University, Auburn, Alabama.

Sagi, A., I. Khalaila, A. Barki, G. Hulata, and I. Karplus. 1996. Intersex red claw crayfish, *Cherax quadricarinatus* (von Martens): functional males with pre-vitellogenic ovaries. Biological Bulletin 190:16-23.

Sagi, A., A. Milstein, Y. Eran, D. Joseph, I. Khalaila, U. Abdu, S. Harpaz, and I. Karplus. 1998. Culture of the Australian red claw crayfish (*Cherax quadricarinatus*) in Israel. II. Second growout season of overwintered populations. Israel Journal of Aquaculture 49:222-229.

Saker, M. L., and G. K. Eaglesham. 1999. The accumulation of cylindrospermopsin from the cyanobacterium *Cylindrospermopsis raciborskii* in tissues of the Redclaw crayfish *Cherax quadricarinatus*. Toxicon 37(7):1065-1077.

Snovsky, G., and B. S. Galil. 2011. The Australian redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868) (Crustacea: Decapoda: Parastactidae) in the Sea of Galilee, Israel. Aquatic Invasions 6:S29-S31.

Soes, M., and B. Koese. 2010. Invasive freshwater crayfish in the Netherlands: a preliminary risk analysis. Ministry of Agriculture, Nature and Food Quality, Leiden, The Netherlands, 69.

Souty-Grosset, C., D. M. Holdich, P. Y. Noël, J. D. Reynolds, and P. Haffner. 2006. Atlas of crayfish in Europe. Patrimoines naturels 64. Muséum national d'Histoire naturelle, Paris, France.

Stephens, F., N. Buller, D. Alderman, A. Cameron, M. Doroudi, P. Suijdendorp, M. Deveney, and R. Bowate. 2005. Disease strategy: crayfish plague, version 1.0. *In* Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), edition 2. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT, Australia. Available: http://www.agriculture.gov.au/animal/aquatic/aquavetplan/crayfish-plague.

Turkmen, G., and O. Karadal. 2012. The survey of the imported freshwater Decapod species via the ornamental aquarium trade in Turkey. Journal of Animal and Veterinary Advances 11:2824-2827.

Tyser, B. 2010. Predation by native fishes of an invasive crayfish *Cherax quadricarinatus* in the Kafue River, Zambia and its wider ecosystem implications. Master's thesis. University of East Anglia, Norwich, UK.

Tyser, A. B., and R. J. Douthwaite. 2014. Predation on invasive redclaw crayfish *Cherax quadricarinatus* by native fishes in the Kafue River, Zambia. African Journal of Aquatic Science 39:473-477.

Unestam, T. 1972. On the host range and origin of the crayfish plague fungus. Institute of Freshwater Research, Drottningholm, Sweden.

Vigliano, P. H., and G. Darrigran. 2002. Argentina's freshwater systems: aliens in wonderland. Proceedings of the 11th International Conference on Aquatic Invasive Species, Alexandria.

Wingfield, M. 2002. An overview of the Australian freshwater crayfish farming industry. Freshwater Crayfish 13:177-184.

Xue, X. M., A. J. Anderson, N. A. Richardson, A. J. Anderson, G. P. Xue, and P. B. Mather. 1999. Characterisation of cellulase activity in the digestive system of the redclaw crayfish (*Cherax quadricarinatus*). Aquaculture 180(3/4):373-386.

Yeo, D. C. J., P. K. L. Ng, N. Cumberlidge, C. Magalhaes, S. R. Daniels, and M. Campos. 2008. A global assessment of freshwater crab diversity (Crustacea: Decapoda: Brachyura). Hydrobiologia 595:275-286.

Zimmerman, H. G. 2003. South Africa. *In* I. A. W. Mcdonald, J. K. Reaser, C. Bright, L. E. Neville, G. W. Howard, S. J. Murphy, and G. Preston. Invasive alien species in southern Africa: national reports and directory of resources. Global Invasive Species Programme, Cape Town, South Africa.