1-30-2023

Evidence of an established population of Cherax quadricarinatus (von Martens, 1868) in south Texas, USA

Adam Sanjar

Drew R. Davis
The University of Texas Rio Grande Valley, drew.davis@utrgv.edu

Richard J. Kline
The University of Texas Rio Grande Valley, richard.kline@utrgv.edu

Recommended Citation

Sanjar A, Davis DR, Kline RJ (2023) Evidence of an established population of Cherax quadricarinatus (von Martens, 1868) in south Texas, USA. BioInvasions Records 12(1): 284–291, https://doi.org/10.3391/bir.2023.12.1.24

BioInvasions Records (2023) Volume 12, Issue 1: 284–291

Rapid Communication

Evidence of an established population of *Cherax quadricarinatus* (von Martens, 1868) in south Texas, USA

Adam Sanjar[1], Drew R. Davis[1,2] and Richard J. Kline[1,*]

[1]*School of Earth, Environmental, and Marine Sciences, The University of Texas Rio Grande Valley, Brownsville, Texas 78520, USA*
[2]*Biodiversity Collections, Department of Integrative Biology, The University of Texas at Austin, Austin, Texas 78758, USA*

**Corresponding author*
E-mail: *richard.kline@utrgv.edu*

Citation: Sanjar A, Davis DR, Kline RJ (2023) Evidence of an established population of *Cherax quadricarinatus* (von Martens, 1868) in south Texas, USA. *BioInvasions Records* 12(1): 284–291, https://doi.org/10.3391/bir.2023.12.1.24

Received: 21 May 2022
Accepted: 5 November 2022
Published: 30 January 2023

Handling editor: Russ Minton
Thematic editor: Karolina Bącela-Spychalska

Abstract

Cherax quadricarinatus (von Martens, 1868) is a large parastacid crayfish (Decapoda: Parastacidae) native to Australia and Papua New Guinea. Due to various factors, *C. quadricarinatus* is an emerging invasive species in an increasing number of regions across the world. Deleterious ecological effects of *C. quadricarinatus* introduction have been documented in many of these regions, and its spread has been monitored and restricted where possible. Previously, only a small, isolated population of *C. quadricarinatus* in southern California had been reported within the continental United States. Here, we report the collection of three adult *C. quadricarinatus* from Brownsville, Cameron County, Texas, the first record of this species in the state and only the second record for the continental United States. Given the connectivity of aquatic habitats in the area and the duration for which the population has likely been present, there is evidence that *C. quadricarinatus* is poised to invade subtropical watersheds of the southern United States. The ecological effects of *C. quadricarinatus* on aquatic ecosystems in the region are not yet fully understood, but further research is warranted to effectively mitigate negative impacts that may occur and to guide efforts to manage or eradicate these populations.

Key words: aquatic invasive species, Decapoda, non-native species, Parastacidae, species monitoring

Introduction

Cherax quadricarinatus (von Martens, 1868), the Australian redclaw crayfish, is a species of parastacid crayfish native to Australia and Papua New Guinea which has become an emerging freshwater invasive species in tropical and subtropical waterbodies worldwide (Williams et al. 2001; Ahyong and Yeo 2007; Nunes et al. 2017). Invasive populations of *C. quadricarinatus* have been documented in regions of Australia outside of its native range (Pinder et al. 2019), Java (Patoka et al. 2016), Singapore (Ahyong and Yeo 2007), Israel (Snovsky and Galil 2011), Zambia (Nakayama et al. 2010), South Africa (Nunes et al. 2017), Swaziland (Nunes et al. 2017), Costa Rica (Azofeifa-Solano et al. 2017), Jamaica (Pienkowski et al. 2015), Mexico (Bortolini et al. 2007), and the United States (Williams et al. 2001). In the United States, *C. quadricarinatus* has spread throughout

Puerto Rico, and an isolated population has been detected in Lake Balboa, Los Angeles, California (Williams et al. 2001; Morningstar et al. 2020). Accidental escape from aquaculture facilities and aquarium releases have been the primary documented modes of introduction for *C. quadricarinatus* (Bortolini et al. 2007; Belle and Yeo 2010). *Cherax quadricarinatus* is common in the aquaculture industry due to its large size, rapid growth, and tolerance of a wide range of water quality parameters (Jones 1995; Karplus et al. 1998; Bortolini et al. 2007). In aquaculture and lab settings, *C. quadricarinatus* tolerates a wide range of both temperature (10–35 °C survival range for juveniles) and pH (6.5–9), low dissolved oxygen (survival possible in water with dissolved oxygen < 1 mg/L), and high salinity (short-term tolerance of up to 35 PSU) (King 1994; Masser and Rouse 1997; Haubrock et al. 2021). Its hardiness, size, and distinct coloration also makes it a desirable ornamental species for aquarists (Ahyong and Yeo 2007; Belle and Yeo 2010).

Invasive *C. quadricarinatus* in the United States has the potential to disrupt native ecosystems through several types of interactions and has been shown to have a negative impact in other regions where they have been introduced (Morningstar et al. 2020; Haubrock et al. 2021). *Cherax quadricarinatus* has been documented as a vector for intranuclear bacilliform virus, white spot syndrome virus, and other pathogens which could harm native crustaceans (Bowater et al. 2002; Romero and Jiménez 2002; Lee et al. 2021). Additionally, *C. quadricarinatus* has the potential to disrupt food webs across many trophic levels and consequently change species assemblages (Haubrock et al. 2021). Native crustaceans, and potentially some fishes, could be negatively affected due to competition for food and shelter with *C. quadricarinatus* given its large size and high population densities (Masser and Rouse 1997; Williams et al. 2001; Pattillo 2010; Haubrock et al. 2021). Benthic habitat and aquatic vegetation distribution have also been shown to be altered in some regions through the foraging behavior of *C. quadricarinatus* (Marufu et al. 2018; Pinder et al. 2019; Haubrock et al. 2021). As a result of these documented negative impacts and the climate of the southern United States, the U.S. Fish and Wildlife Service categorizes *C. quadricarinatus* as a high-risk potential invasive species (USFWS 2012).

The Lower Rio Grande Valley is the southernmost region of the state of Texas, lies along the border of the United States and Mexico, has a semi-arid subtropical climate, and is characterized by a river delta formed by the Rio Grande near its mouth at the Gulf of Mexico and numerous resacas (Mora et al. 2001). Resacas, a type of oxbow lake, are disconnected remnants of the Rio Grande's previous channels and are an ecologically significant habitat in the region that help to support a unique assemblage of flora and fauna (Jahrsdoerfer and Leslie 1988). Additionally, many resacas are surrounded by urban and suburban development, and many non-native species, including *Pomacea maculata* (Perry, 1810), *Oreochromis aureus*

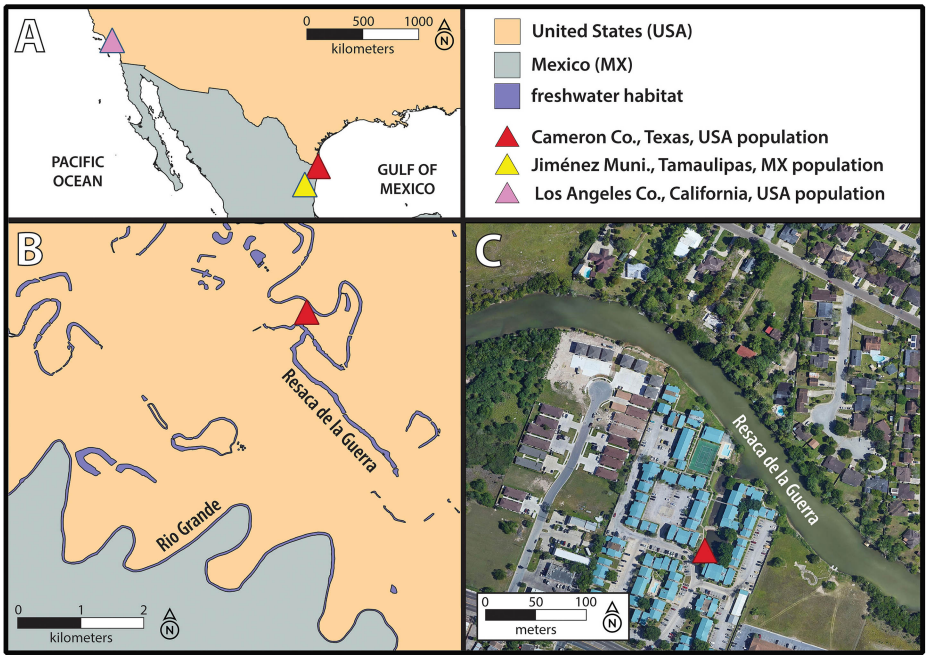

Figure 1. (A) Broad scale map with *Cherax quadricarinatus* populations in the continental United States (Morningstar et al. 2020) and the nearest detection of the population in Tamaulipas marked (Morningstar et al. 2020; iNaturalist 2022). (B) Location from which all three Brownsville, Cameron County, Texas, USA *C. quadricarinatus* specimens were collected with significant natural hydrological features of the area rendered. Hydrology Data Source: USGS. (C) Satellite view of the capture site and surrounding urban areas in Brownsville, Texas.

(Steindachner, 1864), and *Pterygoplichthys anisitsi* (Eigenmann and Kennedy, 1903), have become established in these habitats (Hubbs et al. 2008; Perez et al. 2017; iNaturalist 2022). Due to the human-altered hydrology of the Rio Grande watershed, many resacas currently require water to be pumped from the river to maintain appropriate water levels (Perez et al. 2017). To maintain water levels in resacas and to provide water to large agricultural areas in south Texas, ca. 3200 km of canals and pipelines have been constructed across the region, which could provide a network of connected waterways that may exacerbate the dispersal of invasive aquatic species (Perez et al. 2017).

Materials and methods

Two adult *C. quadricarinatus* were encountered walking on a sidewalk at the Posada de las Palmas apartment complex near an artificial pond (25.919456; −97.458945; WGS 84) adjacent to Resaca de la Guerra, a resaca in Brownsville, Cameron County, Texas, USA, on 8 January 2022 (Figure 1). The individuals were identified as *C. quadricarinatus* using the characteristics outlined in Morningstar et al. (2020), including the four prominent carinae on the cephalon, large blue chelae, red patches on the lateral side of the male's chelae, and large overall body size (> 14 cm rostrum–tail length). To attempt to collect additional *C. quadricarinatus* individuals, five cylindrical minnow traps were deployed in the artificial pond and in a section of Resaca de la Guerra near the location where the initial individuals were found. The traps were deployed intermittently from 17 February–8 March 2022 and

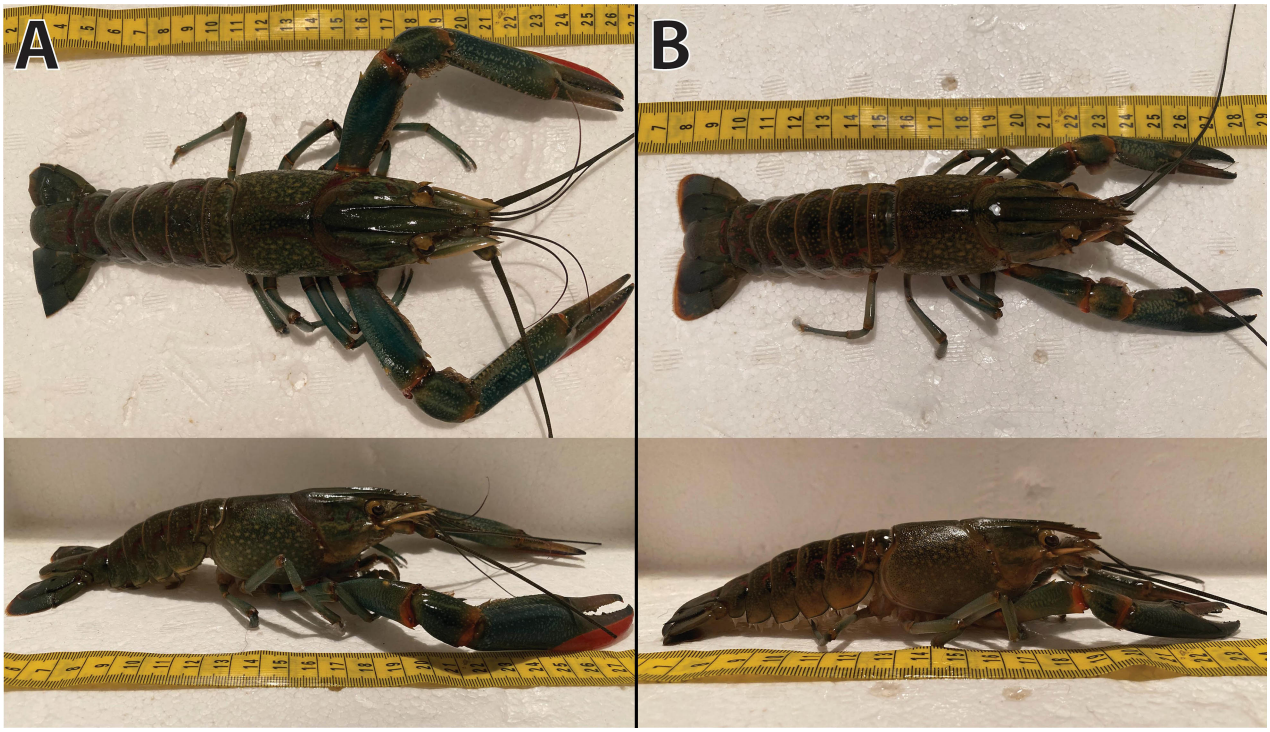

Figure 2. Dorsal and right lateral views of a male (A) and female (B) *Cherax quadricarinatus* specimens collected in Brownsville, Cameron County, Texas, USA on 8 January 2022. Photographs by Adam Sanjar.

checked every 12 h. Both dry dog food and cantaloupe were used for bait as it was a common bait combination recommended for recreational *C. quadricarinatus* trapping from online resources. Social media platforms (e.g., Facebook, Twitter, Instagram, and YouTube) and iNaturalist (www.inaturalist.org) were also reviewed to determine if there were any additional accounts of *C. quadricarinatus* in the area.

Results and discussion

A total of three *C. quadricarinatus* specimens were collected in early 2022, and all individuals were deposited at the University of Texas Insect Collections (UTIC 290040 [n = 2], 290041 [n = 1]). A male (18 cm rostrum–tail length; Figure 2A) and female (15 cm rostrum–tail length; Figure 2B) were the initial pair collected on land on 8 January 2022 (UTIC 290040), and an additional male (UTIC 290041: 15 cm rostrum–tail length) was collected in a minnow trap on 22 February 2022 in the artificial pond that the initial pair likely emerged from. No individuals were collected directly from Resaca de la Guerra, but the artificial pond flows into the resaca, and flooding and high-water levels frequently connect the two. All trapping occurred along the banks and was restricted to areas with water depths of 25–50 cm. Trapping occurred during cooler winter months, and water temperatures stayed low (< 20 °C) while traps were deployed. The combination of shallow water and low water temperatures likely influenced trapping success, especially considering that *C. quadricarinatus* is a tropical species and becomes less active in colder temperatures and is less likely to

enter traps (Karplus et al. 1998; Wu et al. 2018). Additionally, the traps used were constructed for smaller aquatic species, and large *C. quadricarinatus* potentially could have been unable to enter the traps. To better assess the distribution and abundance of *C. quadricarinatus* in the area, it would be prudent for additional surveys to be conducted along Resaca de la Guerra and other nearby resacas with a longer, more thorough trapping effort.

An additional nearby observation of *C. quadricarinatus* was found on iNaturalist (iNaturalist 2022) from 11 September 2013. This observation was of a female with three attached hatchlings from the same artificial pond near where we collected our individuals. The combination of the observation of the reproductive individual in 2013, the three adults collected in 2022, and a reported 3–5-year average lifespan of *C. quadricarinatus* (Sheehy 1992), suggests there is a persistent breeding population in Resaca de la Guerra.

The exact mode of introduction of *C. quadricarinatus* into Resaca de la Guerra remains uncertain. One potential mode for this species' arrival into south Texas is diffusion dispersal of an introduced population of *C. quadricarinatus* in Tamaulipas, Mexico (Bortolini et al. 2007). This population in Tamaulipas was initially observed in 2005, ca. 320 km south of Brownsville, and additional observations in 2018 exist ca. 200 km south of Brownsville (iNaturalist 2022). *Cherax quadricarinatus* can move through connected waterbodies and, to a more limited extent, disperse overland to access unconnected waterbodies. The introduced Tamaulipan populations may have potentially reached the Rio Grande undetected and expanded their range into southern Texas. If *C. quadricarinatus* is present in the Rio Grande watershed, further dispersal into Resaca de la Guerra may have also been mediated by the pumping of water from the Rio Grande into resacas and irrigation canals. Alternatively, *C. quadricarinatus* in Resaca de la Guerra could represent an independent introduction (jump dispersal) and may have been from the release of captive individuals. It has been illegal to posses *C. quadricarinatus* in Texas since 2008, and though evidence of individuals in Brownsville exists from as early as 2013, it is unclear when this population became established. An additional potential dispersal mechanism which may have introduced *C. quadricarinatus* into south Texas from introduced populations or aquaculture sites in Tamaulipas is waterbird-mediated ectozoochory, which occurs when larval crayfish cling to the feathers of waterbirds, survive, and then detach in waterbodies beyond their normal overland dispersal range (Anastácio et al. 2014; Coughlan et al. 2017). Though waterbird-mediated ectozoochory has been observed in *Procambarus clarkii* (Girard, 1852), it has yet to be directly demonstrated for *C. quadricarinatus.*

Several models predict the continued expansion of *C. quadricarinatus* into the United States, and future climate change will only increase the

total area with suitable temperatures (USFWS 2012; Haubrock et al. 2021). *Cherax quadricarinatus* has been shown to survive for short periods in water temperatures below 10 °C, which suggests that temperature alone may not exclude *C. quadricarinatus* from much of the southern United States (Karplus et al. 1998). Based on the presence of individuals in Brownsville, *C. quadricarinatus* may likely be present in the Rio Grande, giving this species direct access to a large network of canals, irrigation networks, reservoirs, and tributaries in both the southern United States and northern Mexico, a region where *C. quadricarinatus* has not been observed previously. Though favorable habitat and climate may suggest future expansion of *C. quadricarinatus*, the presence of *Aphanomyces astaci* (Schikora, 1906), a pathogenic fungus linked to crayfish plague found throughout the United States, can be especially lethal to non-native species, including *C. quadricarinatus* (Unestam 1975; Haubrock et al. 2021).

As with any new invasive species there are many gaps in knowledge that further research is required to fill. A comprehensive survey of the Lower Rio Grande Valley would establish the current extent of the invasion and inform effective management to mitigate negative effects of *C. quadricarinatus.* Environmental DNA (eDNA) surveys have been shown to be an effective way of rapidly surveying large areas for the presence of *C. quadricarinatus* and should be considered as a supplement to trapping (Baudry et al. 2021). Surveys across regions of northeastern Mexico would also help understand if the origin of Texas *C. quadricarinatus* was from introduced populations in Tamaulipas. Though surveys can help understand how widespread *C. quadricarinatus* is across the region, genetic analyses could also be an effective tool to examine similarities between Tamaulipas and Texas populations. Laboratory experiments of waterbird-mediated ectozoochory of *C. quadricarinatus* larvae would also indicate if this species is capable of this and if this needs to be accounted for when modeling its spread. Additionally, determining what pathogens are present in this invasive population could help predict future impacts on native crayfish and how crayfish plague may limit the spread and distribution of *C. quadricarinatus* in the United States.

The invasion of exotic species is considered one of the major threats to biodiversity in freshwater ecosystems worldwide (Dudgeon et al. 2006). Effective local resource management can sometimes mitigate the threat of invasive species, and while control of invasive crayfish is difficult and rare, there have been some successful eradication efforts (Simberloff 2021). The highly invasive nature and known deleterious ecological impacts of *C. quadricarinatus* indicate that a rapid response, including monitoring, containment, and eradication steps, is advisable to prevent further spread in Texas and introduction into other regions of the southern United States.

Acknowledgements

We thank A. Grubh (Texas Parks and Wildlife Department), C. Morningstar (U.S. Geological Survey), W. Daniel (U.S. Geological Survey), and M. McGarrity (Texas Parks and Wildlife Department) for confirming species identification, A. Wild (Biodiversity Collections, The University of Texas at Austin) for accessioning and cataloging these specimens, the staff of the Posada de las Palmas apartment complex for permission to access and sample these sites, and two anonymous reviewers and R. Minton whose comments helped improve the paper.

Authors' contribution

(AS) research conceptualization, sample design and methodology, investigation and data collection, data analysis and interpretation, writing – original draft, and writing – review and editing; (DRD) sample design and methodology and writing – review and editing; (RJK) sample design and methodology and writing – review and editing.

References

Ahyong ST, Yeo DCJ (2007) Feral populations of the Australian red-claw crayfish (*Cherax quadricarinatus* von Martens) in water supply catchments of Singapore. *Biological Invasions* 9: 943–946, https://doi.org/10.1007/s10530-007-9094-0

Anastácio PM, Ferreira MP, Banha F, Capinha C, Rabaça JE (2014) Waterbird-mediated passive dispersal is a viable process for crayfish (*Procambarus clarkii*). *Aquatic Ecology* 48: 1–10, https://doi.org/10.1007/s10452-013-9461-0

Azofeifa-Solano JC, Naranjo-Elizondo B, Rojas-Carranza AH, Cedeño-Fonseca M (2017) Presence of the Australian redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868) (Parastacidae, Astacoidea) in a freshwater system in the Caribbean drainage of Costa Rica. *BioInvasions Records* 6: 351–355, https://doi.org/10.3391/bir.2017.6.4.08

Baudry T, Mauvisseau Q, Goût J-P, Arqué A, Delaunay C, Smith-Ravin J, Sweet M, Grandjean F (2021) Mapping a super-invader in a biodiversity hotspot, an eDNA-based success story. *Ecological Indicators* 126: 107637, https://doi.org/10.1016/j.ecolind.2021.107637

Belle CC, Yeo DCJ (2010) New observations of the exotic Australian red-claw crayfish, *Cherax quadricarinatus* (von Martens, 1868) (Crustacea: Decapoda: Parastactidae) in Singapore. *Nature in Singapore* 3: 99–102

Bortolini JL, Alvarez F, Rodríguez-Almaraz G (2007) On the presence of the Australian redclaw crayfish, *Cherax quadricarinatus*, in Mexico. *Biological Invasions* 9: 615–620, https://doi.org/10.1007/s10530-006-9054-0

Bowater RO, Wingfield M, Fisk A, Condon KM, Reid A, Prior H, Kulpa EC (2002) A parvo-like virus in cultured redclaw crayfish *Cherax quadricarinatus* from Queensland, Australia. *Diseases of Aquatic Organisms* 50: 79–86, https://doi.org/10.3354/dao050079

Coughlan NE, Kelly TC, Davenport J, Jansen MAK (2017) Up, up and away: bird-mediated ectozoochorous dispersal between aquatic environments. *Freshwater Biology* 62: 631–648, https://doi.org/10.1111/fwb.12894

Dudgeon D, Arthington AH, Gessner MO, Kawabata Z-I, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard A-H, Soto D, Stiassny ML, Sullivan CA (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* 81: 163–182, https://doi.org/10.1017/S1464793105006950

Haubrock PJ, Oficialdegui FJ, Zeng Y, Patoka J, Yeo DCJ, Kouba A (2021) The redclaw crayfish: a prominent aquaculture species with invasive potential in tropical and subtropical biodiversity hotspots. *Reviews in Aquaculture* 13: 1488–1530, https://doi.org/10.1111/raq.12531

Hubbs C, Edwards RJ, Garrett GP (2008) An Annotated Checklist of the Freshwater Fishes of Texas, with Keys to Identification of Species, 2nd Edition. *The Texas Academy of Science,* Supplement 43(4): 1–87

Jahrsdoerfer SE, Leslie DM (1988). Tamaulipan brushland of the Lower Rio Grande Valley of south Texas: description, human impacts, and management options. Biological Report 88(36), U.S. Department of Interior, Washington, D.C., , United States, viii + 63 pp

Jones CM (1995) Production of juvenile redclaw crayfish, *Cherax quadricarinatus* (von Martens) (Decapoda, Parastacidae) I. Development of hatchery and nursery procedures. *Aquaculture* 138: 221–238, https://doi.org/10.1016/0044-8486(95)00068-2

Karplus I, Zoran M, Milstein A, Harpaz S, Eran Y, Joseph D, Sagi A (1998) Culture of the Australian red-claw crayfish (*Cherax quadricarinatus*) in Israel: III. Survival in earthen ponds under ambient winter temperatures. *Aquaculture* 166: 259–267, https://doi.org/10.1016/S0044-8486(98)00290-7

King CR (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* 122: 75–80, https://doi.org/10.1016/0044-8486(94)90335-2

Lee C, Kim JH, Choi S-K, Jeon HJ, Lee SH, Kim BK, Kim YK, Lee K-J, Han JE (2021) Detection of infectious white spot syndrome virus in red claw crayfish (*Cherax quadricarinatus*)

and red swamp crayfish (*Procambarus clarkii*) imported into Korea. *Aquaculture* 544: 737117, https://doi.org/10.1016/j.aquaculture.2021.737117
Marufu LT, Dalu T, Crispen P, Barson M, Simango R, Utete B, Nhiwatiwa T (2018) The diet of an invasive crayfish, *Cherax quadricarinatus* (von Martens, 1868), in Lake Kariba, inferred using stomach content and stable isotope analyses. *BioInvasions Records* 7: 121–132, https://doi.org/10.3391/bir.2018.7.2.03
Masser MP, Rouse DB (1997) Australian red claw crayfish. Southern Regional Aquaculture Center, Stoneville, Mississippi, United States, 8 pp
Mora MA, Papoulias D, Nava I, Buckler DR (2001) A comparative assessment of contaminants in fish from four resacas of the Texas, USA–Tamaulipas, Mexico border region. *Environment International* 27: 15–20, https://doi.org/10.1016/S0160-4120(01)00047-2
Morningstar CR, Daniel WM, Neilson ME, Yazaryan AK (2020) The first occurrence of the Australian redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868) in the contiguous United States. *BioInvasions Records* 9: 120–126, https://doi.org/10.3391/bir.2020.9.1.16
Nakayama SMM, Ikenaka Y, Muzandu K, Choongo K, Oroszlany B, Teraoka H, Mizuno N, Ishizuka M (2010) Heavy metal accumulation in lake sediments, fish (*Oreochromis niloticus* and *Serranochromis thumbergi*), and crayfish (*Cherax quadricarinatus*) in Lake Itezhi-tezhi and Lake Kariba, Zambia. *Archives of Environmental Contamination and Toxicology* 59: 291–300, https://doi.org/10.1007/s00244-010-9483-8
Nunes AL, Zengeya TA, Hoffman AC, Measey GJ, Weyl OLF (2017) Distribution and establishment of the alien Australian redclaw crayfish, *Cherax quadricarinatus*, in South Africa and Swaziland. *PeerJ* 5: e3135, https://doi.org/10.7717/peerj.3135
Patoka J, Wardiatno Y, Kuříková P, Petrtýl M, Kalous L (2016) *Cherax quadricarinatus* (von Martens) has invaded Indonesian territory west of the Wallace Line: evidences from Java. *Knowledge & Management of Aquatic Ecosystems* 417: 39, https://doi.org/10.1051/kmae/2016026
Pattillo A (2010) Improving redclaw crayfish (*Cherax quadricarinatus*) aquaculture: Assessment of invasive impacts and production of all-male broods. Master's Thesis, Auburn University, Alabama, United States, 80 pp
Perez KE, Garcia Gamboa V, Schneider CM, Burks RL (2017) Resaca supports range expansion of invasive apple snails (*Pomacea maculata* Perry, 1810; Caenogastropoda: Ampullariidae) to the Rio Grande Valley, Texas. *Check List* 13: 2134, https://doi.org/10.15560/13.3.2134
Pienkowski T, Williams S, McLaren K, Wilson B, Hockley N (2015) Alien invasions and livelihoods: Economic benefits of invasive Australian red claw crayfish in Jamaica. *Ecological Economics* 112: 68–77, https://doi.org/10.1016/j.ecolecon.2015.02.012
Pinder A, Harman A, Bird C, Quinlan K, Angel F, Cowan M, Lewis L, Thillainath E (2019) Spread of the non-native redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868) into natural waters of the Pilbara region of Western Australia, with observations on potential adverse ecological effects. *BioInvasions Records* 8: 882–897, https://doi.org/10.3391/bir.2019.8.4.17
Romero X, Jiménez R (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, https://doi.org/10.1046/j.1365-2761.2002.00411.x
Sheehy MRJ (1992) Lipofuscin age-pigment accumulation in the brains of ageing field- and laboratory-reared crayfish *Cherax quadricarinatus* (von Martens) (Decapoda: Parastacidae). *Journal of Experimental Marine Biology and Ecology* 161: 79–89, https://doi.org/10.1016/0022-0981(92)90191-C
Simberloff D (2021) Maintenance management and eradication of established aquatic invaders. *Hydrobiologia* 848: 2399–2420, https://doi.org/10.1007/s10750-020-04352-5
Snovsky G, Galil BS (2011) The Australian redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868) (Crustacea: Decapoda: Parastactidae) in the Sea of Galilee, Israel. *Aquatic Invasions* 6: S29–S31, https://doi.org/10.3391/ai.2011.6.S1.007
Unestam T (1975) Defence reactions in and susceptibility of Australian and New Guinean freshwater crayfish to European-crayfish-plague fungus. *Australian Journal of Experimental Biology and Medical Science* 53: 349–359, https://doi.org/10.1038/icb.1975.40
Williams EH Jr., Bunkley-Williams L, Lilyestrom CG, Ortiz-Corps EA (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: 246–251
Wu D-L, Liu Z-Q, Huang Y-H, Lv W-W, Chen M-H, Li Y-M, Zhao Y-L (2018) Effects of cold acclimation on the survival, feeding rate, and non-specific immune responses of the freshwater red claw crayfish (*Cherax quadricarinatus*). *Aquaculture International* 26: 557–567, https://doi.org/10.1007/s10499-018-0236-4

Web sites and online databases

iNaturalist (2022) https://www.inaturalist.org/ (accessed 8 January 2022)
USFWS (2012) United States Fish and Wildlife Service. Australian redclaw (*Cherax quadricarinatus*): Ecological Risk Screening Summary. https://fws.gov/media/ecological-risk-screening-summary-redclaw-cherax-quadricarinatus-high-risk (accessed 1 March 2022)