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# The invasive Australian redclaw crayfish *Cherax quadricarinatus* Von Martens, 1868: a new threat for biodiversity in the Sierra Gorda Biosphere Reserve, Central Mexican Plateau

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## Abstract

The invasive Australian redclaw crayfish (*Cherax quadricarinatus*) has a long history of introduction in Mexico. Since its introduction in 1986 for aquaculture production purposes, it has been cultured in several regions of the country without considering the probability of accidental escapes and the threat to biodiversity. Here the presence of the Australian redclaw crayfish is reported for the first time in the Sierra Gorda Biosphere Reserve (SGBR), which harbors vast biodiversity in biological groups and ecosystems. Six males and one ovate female with a maximum total cephalothorax length of 73.7 mm and a weight of 66.7 g were collected. The presence of reproductively active individuals in this Protected Natural Area represents a new record of this invasive species in Mexico that adds to the list of non-native species within the SGBR. It also means a potential threat to the native aquatic biodiversity of the SGBR, given the resistance and dispersal capacity of this invasive species and the potential negative impacts on the ecosystem. A better understanding of the distribution and invasion dynamics of the redclaw crayfish is required to evaluate and develop management strategies to reduce its spread and potential impacts within the SGBR.

**Key words:** exotic species, protected natural area, crustaceans, risk, new record

## Introduction

Invasive species are one of the main threats to biodiversity, modifying community composition, ecosystem processes, and ecosystem services (Mačić et al. 2018). The effects on ecosystem processes are generally related to predation, parasitism, diseases, and habitat alterations; and the effects on ecosystem services are related to risks to public health and economic losses (Sala et al. 2000; Homans and Smith 2013; Kiruba-Sankar et al. 2018). On the other hand, freshwater ecosystems are especially vulnerable to

human activities that favor biological invasions (Angeler et al. 2014; Dudgeon 2019; Frederico et al. 2019). In this sense, one of the greatest threats to these ecosystems comes from the alien species introduction (Frederico et al. 2019).

Crustaceans constitute one of the most successful taxonomic groups of invasive species worldwide (Hänfling et al. 2011). The Australian redclaw crayfish (*Cherax quadricarinatus* Von Martens, 1868*)* is a freshwater decapod crustacean native to Queensland and the northern territories of Australia and southern Papua Island, New Guinea (Sagi et al. 1997; Mendoza-Alfaro et al. 2011). It has been introduced in more than 10 countries (Patoka et al. 2016; Nunes et al. 2017; Sze-man and Anthony 2020; Madzivanzira et al. 2021) as an easily cultured organism that could constitute an alternative food source (Bortolini-Rosales et al. 2007; Álvarez et al. 2014).

The first attempt to introduce the Australian redclaw crayfish for aquaculture in Mexico occurred in 1986 (Ponce-Palafox et al. 1999), and it is currently cultured in 16 of 32 Mexican States: Aguascalientes, Baja California, Baja California Sur, Chihuahua, Colima, Jalisco, Mexico City (CDMX), Michoacán, Morelos, Nuevo León, Oaxaca, Puebla, Sinaloa, Tamaulipas, Veracruz and Yucatán (Ponce-Palafox et al. 1999; Álvarez et al. 2014; Vega-Villasante et al. 2015; INAPESCA 2022). The Australian redclaw crayfish is considered an invasive species in Mexico and a feral organism in freshwater ecosystems, where the juveniles have been reported as active predators (Álvarez et al. 2014). Wild populations have been reported in Jalisco, Morelos, Nayarit, Nuevo León, San Luis Potosí, Sinaloa and Tamaulipas (Bortolini-Rosales et al. 2007; Álvarez et al. 2014; Vega-Villasante et al. 2015; Torres-Montoya et al. 2016; Rodríguez-Almaraz et al. 2018; Tapia-Varela et al. 2020) (for details see Supplementary material Table S1) (Figure 1A). Sightings of individuals in the wild have also been reported in Guerrero, Oaxaca, Quintana Roo, State of Mexico, Tabasco, and Yucatán (Naturalista 2022).

The Sierra Gorda Biosphere Reserve (SGBR) is one of Mexico's most important protected areas due to its habitats that harbor a diversity of biotic groups, including terrestrial and semi aquatic vertebrates, as well as 35 fish species, 23 amphibian species, and 83 families of aquatic macroinvertebrates (Rico-Sánchez et al. 2020). Within the SGBR there are zones with different protection categories: buffer zones and core zones (Carabias Lillo et al. 1999, 2000). The core zones harbor the best-preserved regions with almost pristine ecosystems with species of flora and fauna that require special protection (Carabias Lillo et al. 1999, 2000). This study aims to report the presence of several individuals of *Ch. quadricarinatus* collected within the SGBR.

## Materials and methods

The SGBR is a protected area in the Central Plateau of Mexico with an approximate extension of 383,500 ha. The SGBR occupies most of the

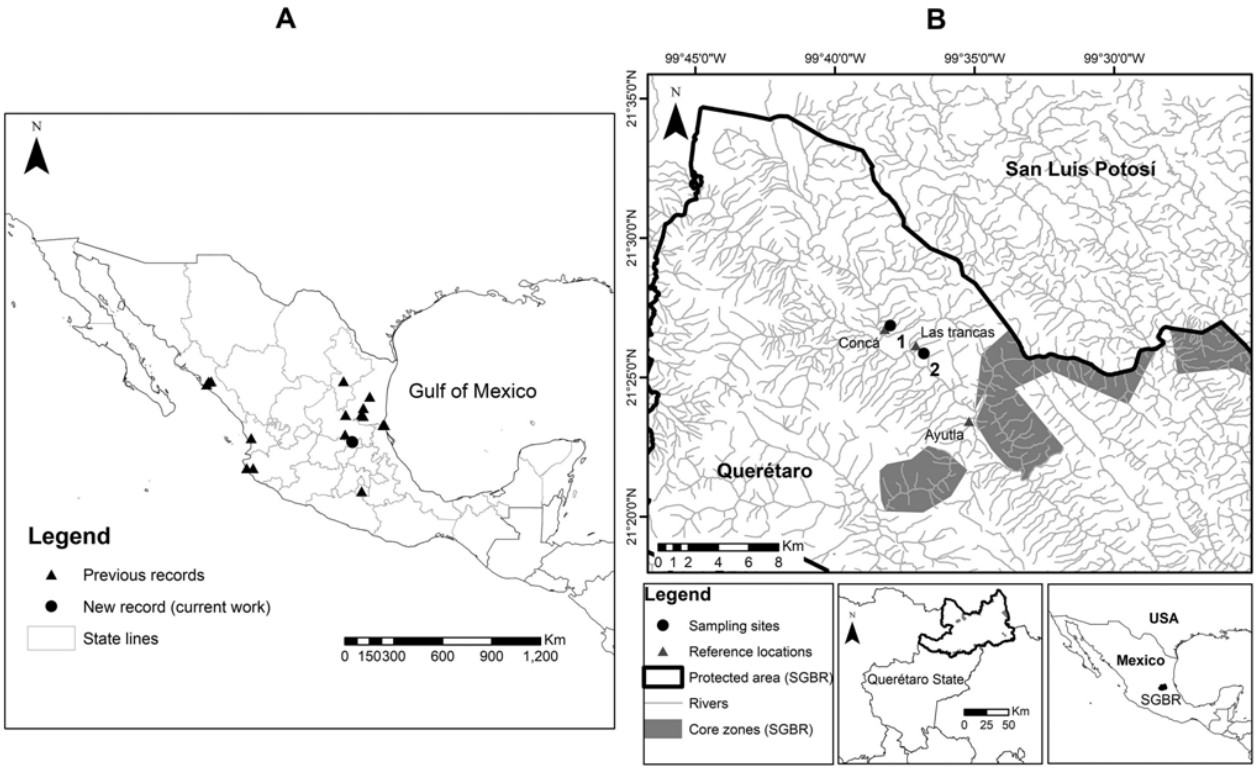


**Figure 1.** (A) Records of wild populations of Australian redclaw crayfish (*Cherax quadricarinatus*) in Mexico, and (B) sampling sites in the Sierra Gorda Biosphere Reserve, state of Querétaro, Central Mexican Plateau.

Sierra Gorda, which is part of the Sierra Madre Oriental and covers the northern half of the state of Querétaro, the west of the state of Guanajuato, and a small portion of San Luis Potosí. The SGBR belongs to the Pánuco River Hydrologic Region, which has two basins: Moctezuma River, which includes the Moctezuma River, Extóraz River, and Aztla River; and Tamuín River, which includes the Tampaon or Tamuín River, Santa María River, Verde River, and La Tinaja River (Carabias Lillo et al. 1999; Rico-Sánchez et al. 2020).

Individuals of the Australian redclaw crayfish were collected in the SGBR in May 2021, in places where local fishermen indicated its presence. Two sites were sampled: 1) "Árbol Milenario" site, in the locality of Concá (21°26′51.40″N; 99°38′1.03″W), and 2) "El Abanico" site, between the localities of "Las Trancas" and "Salitrillo" (21°25′51.31″N; 99°36′49.14″W), within the municipality of Arroyo Seco, Querétaro (Figure 1B). Both sites are located within the SGBR buffer zone, less than 10 km upriver from the core zone (Carabias Lillo et al. 1999). Locations are springs with clear waters, clay soils, and flat bottoms with organic mud and rolled pebbles, and they have recreational uses and serve as a water supply for nearby communities. The area sampled was approximately 20 $m^2$ for the Árbol Milenario site and 30 $m^2$ for the El Abanico site. Sampling was conducted directly with the support of hand nets (40 cm length, 0.5 cm mesh size), removing rocks and logs from the bottom, with an effort of one hour for each site. Temperature and pH measurements of the water were measured using a multiparameter probe

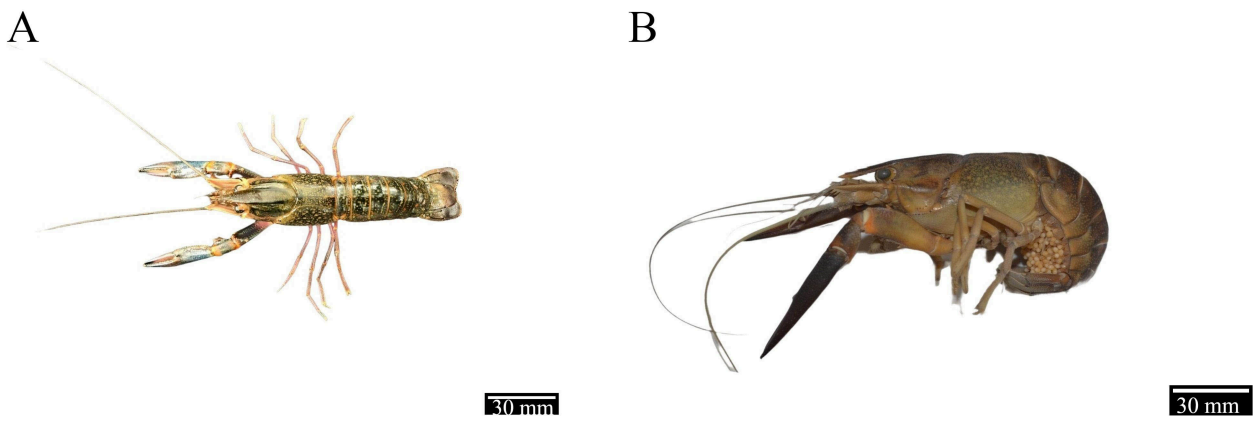


**Figure 2.** Invasive Australian redclaw crayfish (*Cherax quadricarinatus*) captured in the Sierra Gorda Biosphere Reserve, locality of Concá, Arroyo Seco, state of Querétaro, Central Mexican Plateau. (A) Dorsal view of a male at the time of capture. Photo by Martin Torres. (B) Lateral view of an ovigerous female. Photo by Joshua Salmerón.

**Table 1.** Sex, length, and weight of Australian redclaw crayfish specimens collected in the Sierra Gorda Biosphere Reserve, state of Querétaro, Central Mexican Plateau.

| Specimen | Site | Latitude (N) | Longitude (W) | Sex | Cephalothorax length (CL) (mm) | Total length (TL) (mm) | Weight (gr) |
|---|---|---|---|---|---|---|---|
| 1 | "El Abanico" | 21.4309 | −99.6137 | Male | 39.0 | 82.9 | 13.4 |
| 2 | "El Abanico" | 21.4309 | −99.6137 | Male | 40.0 | 82.8 | 14.9 |
| 3 | "El Abanico" | 21.4309 | −99.6137 | Male | 29.0 | 53.0 | 4.7 |
| 4 | "El Abanico" | 21.4309 | −99.6137 | Male | 24.1 | 53.5 | 3.2 |
| 5 | "El Abanico" | 21.4309 | −99.6137 | Male | 49.6 | 97.0 | 24.0 |
| 6 | "El Abanico" | 21.4309 | −99.6137 | Male | 15.0 | 30.5 | 0.5 |
| 7 | "Árbol Milenario" | 21.4476 | −99.6336 | Female | 73.7 | 148.9 | 66.7 |

(Hanna, HI 9828). Captured specimens were euthanized by placement into slurry ice and preserved in 80% ethyl alcohol solution after death.

The identification of the specimens was determined using the diagnosis described by Arias and Torralba-Burrial (2021), and they were deposited in the faunal collection of the Faculty of Natural Sciences of the Autonomous University of Queretaro. All specimens were weighed and sexed after preservation. Also, total length (TL) and cephalothorax length (CL) was measured, following Rodríguez et al. (2014) and Sedik et al. (2019).

## Results

We collected a total of seven individuals of the Australian redclaw crayfish. At the time of capture, most specimens showed blue-green body color, with red leg joints. Males exhibited the characteristic soft, red-colored patch along the outer margin of the propodus (Figure 2A). Specimens showed a TL range from 30.5 mm to 148.9 mm (Mean = 78.3; Standard deviation = 38.5), CL range from 15 mm to 73.7 mm (Mean = 38.6; Standard Deviation = 19.2), and weight ranges from 0.5 gr to 66.7 gr (Mean = 18.2; Standard deviation = 22.87) (Table 1). The only female specimen collected, with a total length of 148.9 mm and a weight of 66.7 g., carried 746 eggs (Figure 2B). The temperature and pH during field sampling ranged between 27.66 to 27.91 °C and between 7.2 and 7.6, respectively.

## Discussion

This study confirms the presence of wild populations of the Australian redclaw crayfish in the SGBR in Querétaro, representing a new record of this species in Mexico, thus increasing its distribution area. In addition, it increases the list of invasive species registered in the SGBR (Rico-Sánchez et al. 2020), constituting a potential risk for conserving aquatic biodiversity in the Central Mexican Plateau. Due to the species' presence in different states of Mexico and the hydrological connection with the United States of America and Guatemala, the biological invasion of the Australian redclaw crayfish puts North and Central American aquatic diversity at risk.

The color pattern of the captured specimens is consistent with that of mature individuals (Karplus et al. 2003; Ahyong and Yeo 2007; Arias and Torralba-Burrial 2021). Various authors relate the weight, size, and state of maturity of the Australian redclaw crayfish. Jones (1990) reports a weight of 30–70 g for early sexual maturity under optimal conditions. Males can also fertilize females when they reach a weight of 14–15 g and a cephalothorax length of 17 mm (Vazquez 2003). Vazquez and López-Greco (2010) argue that the characters that would indicate the beginning of sexual maturation in crayfish begin to differentiate after three months of age, corresponding to a weight of 6 g. Given the above evidence, most of the specimens collected in this study could be reproductive.

The presence of reproductive individuals of the Australian redclaw crayfish could indicate well-established feral populations in SGBR. Established populations of this species could bring numerous adverse effects on recipient communities, like competition for refuge and food with native species, and its displacing, shown in other regions (Mendoza-Alfaro et al. 2011; Torres-Montoya et al. 2016; Marufu et al. 2018; Yiwen et al. 2019). In addition, the Australian redclaw crayfish is a potential disease vector to native fauna and host to several parasitic microbes and invertebrates. The fungi *Aphanomyces astaci* Schikora, is responsible for the decline of native crayfish species in Europe and America. The fungi *Aeromonas hydrophila* (Chester, 1901) Stanier, 1943, quickly colonizes the intestinal tract of freshwater reptiles, amphibians, fish, and crustaceans, causing integumentary and systemic disease (Ahyong and Yeo 2007; Hayakijkosol et al. 2017; Martín-Torrijos et al. 2021). Viruses and bacteria include *Ch. quadricarinatus* bacilliform virus (CqBV), white spot syndrome virus (WSSV), *Escherichia coli* (Migula, 1895) Castellani and Chalmers 1919, and *Vibrio cholerae* Pacini, 1854 (Romero and Jiménez 2002; Hayakijkosol and Owens 2011; Álvarez et al. 2014).

The Australian redclaw crayfish can tolerate a wide range of environmental conditions, including wide variations in pH, temperature, and dissolved oxygen (Snovsky and Galil 2011; Haubrock et al. 2021). This species increased

sperm production at temperatures above 27 °C (Bugnot and López-Greco 2009), which translates into a higher probability of reproduction. The aquatic ecosystems' physical and chemical conditions in other locations where this species has been reported, are similar to this study. The findings of individuals in Morelos, San Luis Potosí, Tamaulipas, and Sinaloa, come from ecosystems connected to springs, streams, rivers, and irrigation channels, where warm temperatures remain stable for most of the year above 25 °C and with a pH that varies from 7.2 to 8 (Bortolini-Rosales et al. 2007; Álvarez et al. 2014; Torres-Montoya et al. 2016).

The Australian redclaw crayfish spread represents a latent threat to the native aquatic decapod crustaceans reported in the Reserve, including *Atya* sp. Leach, 1816 and *Macrobrachium* sp. Spence Bate, 1868 in Santa María River; and *Procambarus* sp. Ortmann, 1905 in the Jalpan River (Torres-Olvera et al. 2018; Rico-Sánchez et al. 2020). The currently spread can continue to the Santa María River, which flows into the core zone of the SGBR (Mendoza-Alfaro et al. 2011; Leland et al. 2012; Puky 2014; Norwegian Scientific Committee for Food Safety (VKM) 2016; Govedič 2017; Weyl et al. 2017; Tapia-Varela et al. 2020). A recently described species, endemic to the SGBR, *Procambarus xihui* Pedraza-Lara, Gutiérrez-Yurrita & De Jesus-Bonilla, 2021, could be particularly affected by the introduction of the redclaw crayfish (Pedraza-Lara et al. 2021). There are fish species that can predate *Ch. quadricarinatus* and could improve biological control such as the native fish Mexican tetra *Astyanax mexicanus* De Filippi, 1853, the Fleshylip buffalo *Ictiobus labiosus* Meek, 1904, the invasive species Rio Grande cichlid *Herichthys cyanoguttatus* Baird & Girard, 1854, the exotic fish Largemouth bass *Micropterus salmoides* Lacépède, 1802, the Common carp *Cyprinus carpio* Linnaeus, 1758, and the Nile tilapia *Oreochromis niloticus* Linnaeus, 1758.

It is worth mentioning that, within the SGBR, there are no public policies to reduce the risk of the introduction of aquatic species, nor has the potential negative impact that these may have on freshwater ecosystems and biodiversity been considered. Such is the case of the Largemouth bass, the Common carp, and the Nile tilapia, all introduced in the Jalpan River basin and classified as invasive species by the National Commission for the Knowledge and Use of Biodiversity in Mexico (CONABIO). The deliberate introduction of these species into the SGBR for fishing and economic purposes has been continuous since the Jalpan Dam construction and the fishing tournaments for largemouth bass improvements (Gutiérrez-Yurrita and Morales-Ortiz 2004; Mendoza-Sánchez 2019).

Introducing exotic aquatic species, such as the Australian redclaw crayfish, for commercial exploitation and human consumption must be subject to Mexican environmental regulations (NOM-000-ZOO 2009; NOM-059-SEMARNAT-2010). Due to its wide environmental tolerance and biological and ecological characteristics, *Ch. quadricarinatus* is optimal for aquaculture.

In Mexico, farms established without considering accidental escapes is highly common (Mendoza-Alfaro et al. 2011; Rodríguez-Almaraz et al. 2018). In the SGBR, the introductions of invasive species of both fish and crayfish are due to trade between aquaculture farms and government programs by the National Fisheries Institute of Mexico, even though the risk of organisms escaping into natural water bodies is high (INAPESCA 2018).

It is urgent to corroborate the presence of the Australian redclaw crayfish in other regions within the SGBR and the introducing ways and purposes. We recommend increasing sampling efforts in future studies to demonstrate the existence of established wild crayfish populations. We emphasize the need for a better understanding of crayfish distribution and invasion dynamics to assess and develop management strategies to reduce the spread and potential impacts within the SGBR and the country.

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## Authors' contribution

RCLD: research conceptualization; data analysis and interpretation; ethics approval; roles/writing – original draft; writing – review and editing. TOMJ: research conceptualization; sample design and methodology; investigation and data collection; roles/ writing – review and editing. DROY: research conceptualization; investigation and data collection; ethics approval; roles/writing – original draft; writing – review and editing. RHJP: research conceptualization; ethics approval; roles/writing – review and editing.

## Ethics and permits

Permit name: Nuevo registro del acocil australiano de quelas rojas *Cherax quadricarinatus* (Von Martens, 1868) en la Reserva de la Biosfera Sierra Gorda, Querétaro, México. Full name of agency: Comité de Bioética de la Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro. Permit number: 55FCN2021

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**Supplementary material**

The following supplementary material is available for this article:

**Table S1.** Records of wild populations of redclaw crayfish (*Cherax quadricarinatus*) in Mexico.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2023/Supplements/BIR_2023_Rodriguez-Cruz_etal_SupplementaryMaterial.xlsx