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ORIGINAL PAPER

# Feral populations of the Australian Red-Claw crayfish (*Cherax quadricarinatus* von Martens) in water supply catchments of Singapore

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**Abstract** The Red-Claw crayfish, *Cherax quadricarinatus* von Martens, is native to freshwater habitats of northern Australia and Papua New Guinea. Owing to its large size and suitability for aquaculture, *C. quadricarinatus* has been widely translocated around the world. Unfortunately, *C. quadricarinatus* is also recognised as invasive, having already established feral populations in South Africa, Mexico, Jamaica and Puerto Rico. The hardiness and conspicuous colouration of *C. quadricarinatus* has also made it popular in the aquarium trade worldwide, including Singapore. Here, we report the establishment of feral populations of *C. quadricarinatus* in the water supply catchments of Singapore.

**Keywords** *Cherax quadricarinatus* · Freshwater crayfish · Singapore · Feral · Introduction · Invasive · Aquarium trade · Water supply

The Red-Claw crayfish, *Cherax quadricarinatus* von Martens, is native to freshwater creeks and water bodies in northern Australia and Papua New Guinea (Lawrence and Jones 2002). The Red-Claw may reach a total length of about 250 mm and weigh up to 600 g. The body is conspicuously coloured with red and maroon highlights on a blue-green 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. The large adult size, rapid growth rate, tolerance of a wide environmental conditions, simple production technology and suitability for relatively high stocking densities, make *C. quadricarinatus* an ideal candidate for aquaculture (Merrick and Lambert 1991; Lawrence and Jones 2002). Consequently, 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). To date, *C. quadricarinatus* has been translocated to parts of Africa, Italy, Israel, the continental United States of America, Mexico, the Caribbean, Ecuador, Puerto Rico, Argentina, New Caledonia, China, Taiwan, Japan and Malaysia (see Harlioğlu and Harlioğlu 2006 and references therein). *Cherax quadricarinatus* is recognised as invasive and has already established feral populations in South Africa, Mexico, Jamaica and Puerto Rico (Williams et al. 2001; Zimmerman 2003; Mendoza

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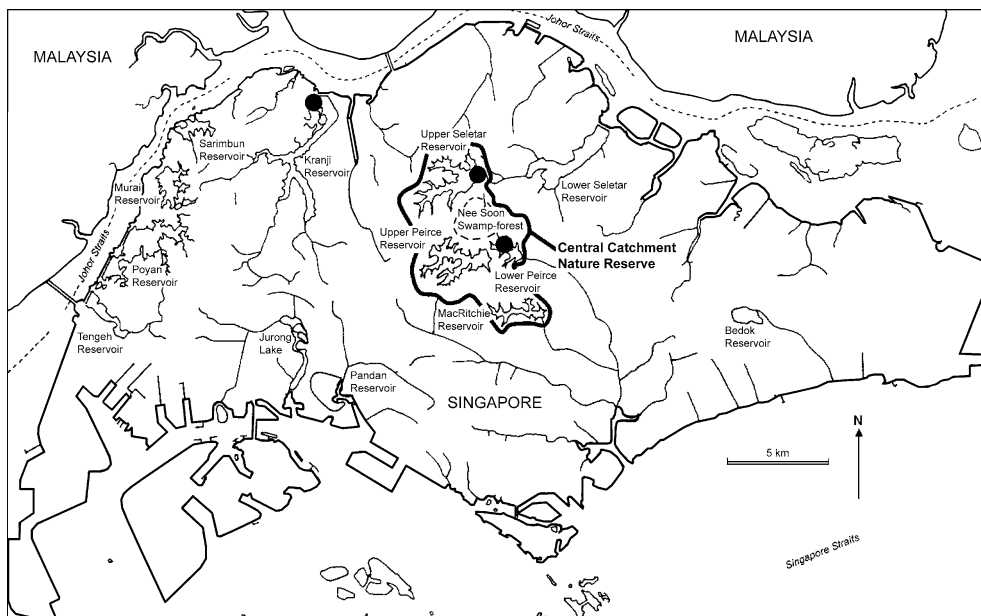
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2004). Here, we report the establishment of feral populations of *C. quadricarinatus* in Singapore.

In the last 6 years, sampling and observations in several water catchment reservoirs in Singapore consistently revealed the presence of *C. quadricarinatus*. Crayfish were sighted and/or collected from at least three of Singapore's major reservoirs, namely Kranji, Lower Peirce and Upper Seletar (Fig. 1) (present study; Timothy Pwee, Leong Tzi Ming and Benjamin Lee, personal communication). Voucher specimens are retained in the Raffles Museum of Biodiversity Research, National University of Singapore. Though large and conspicuously coloured, *C. quadricarinatus* was not recorded by numerous earlier surveys and studies of introduced freshwater species in Singapore (e.g. Ng et al. 1993; Ng 1999). Therefore, *C. quadricarinatus* is likely to be a recent introduction, probably becoming feral sometime between the late 1990s and early 2000s.

Singapore's reservoirs, both inland and coastal, have all been artificially created for use as water supply catchments through the damming of river drainages or river mouths. Though artificial, the forested catchments surrounding several of these reservoirs serve as important refugia for Singa-

pore's native freshwater biota. The Central Catchment Nature Reserve (Fig. 1) is the island's largest at around 3,000 ha and is a vital stronghold for Singapore's freshwater biodiversity (Ng 1999; Ng and Lim 1999; Balke et al. 1999; Yang et al. 1999). It encompasses the forested watersheds of four inland reservoirs (MacRitchie, Upper Peirce, Lower Peirce and Upper Seletar) as well as the only remaining freshwater swamp forest—Nee Soon Swamp Forest. Nee Soon Swamp Forest has extremely high conservation value for Singapore, containing the richest native freshwater fauna and flora on the island (Ng and Lim 1999). This includes *Parathelphusa reticulata* Ng, the most vulnerable of three endemic freshwater crab species (Ng 1999) and the highest diversity and number of locally rare or threatened water beetles (11 out of 17 species recorded) and semi-aquatic bugs (19 out of 27 species recorded) found on the island (Balke et al. 1999; Yang et al. 1999). Thus, the occurrence of *C. quadricarinatus* in Upper Seletar and Lower Peirce reservoirs is especially alarming because of the proximity of these two reservoirs to Nee Soon Swamp Forest, which lies between and has links to both their drainages.



**Fig. 1** Map of Singapore indicating water supply catchments and locations where *C. quadricarinatus* was collected from and/or observed (indicated by filled circle)

*Cherax quadricarinatus* is locally abundant. Ovigerous females are yet to be captured by us, but individuals of all sizes and sex, from juveniles to large adults, have been observed indicating that breeding populations are established in Singapore. We are yet to obtain quantitative population estimates, but sufficient numbers of *C. quadricarinatus* are present that they are frequently encountered by casual observers and regularly targeted by recreational fishers and visitors to the reservoirs (Fig. 2). The crayfish are typically caught from near the shore by hook and line, by baited stick, or hand net after individuals are spotted in the open or when otherwise concealed animals are disclosed by their waving antennae (DCJY, personal observation; Timothy Pwee, personal communication).

Trade and culture of aquarium species is a prime source of introduced freshwater species in Singapore (Ng et al. 1993). *Cherax quadricarinatus* is not presently cultured for human consumption in Singapore, but in the last decade it has become popular in the aquarium trade. As such, Singaporean populations of *C. quadricarinatus* probably derive from accidental or deliberate releases. Of the catchments containing *C. quadricarinatus*, Kranji reservoir is widely separated from Lower Peirce and Upper Seletar reservoirs, being neither connected by aquatic nor terrestrial



**Fig. 2** Red-Claw crayfish (*Cherax quadricarinatus* Von Martens) captured from Kranji reservoir by recreational fishermen in January 2006

dispersal corridors. Therefore, multiple independent releases or escapes of *C. quadricarinatus* have probably occurred. Other feral species established in Singapore through the aquarium trade include freshwater shrimps [*Macrobrachium lanchesteri* (de Man) and *M. nipponense* (de Haan)], freshwater fishes [e.g. the South American loricarid catfish, *Liposarcus pardalis* (Castelnau) and the Central American guppy *Poecilia reticulata* Peters) and the North American Red-Eared Slider (*Trachemys scripta elegans* (Wied))] (Chou et al. 2006). Other freshwater crayfish species are also common in the Singaporean aquarium trade, though none is yet known from the wild: the American *Procambarus clarkii* (Girard), the Australian *Cherax tenuimanus* (Smith) and *C. cainii* Austin and Ryan and two new species of *Cherax* originating from Papua New Guinea.

Numerous studies of introduced freshwater crayfish in Europe and North America show that they have negatively impacted species other than native crayfish, such as macrophytes, other macroinvertebrates (especially gastropods), amphibians and fishes (summarised by Lodge et al. 2000; Nyström 2002). Unfortunately, few data are presently available on the dynamics and ecological impact of translocated *C. quadricarinatus* populations. In the Ord River, Western Australia, where *C. quadricarinatus* has been recently introduced, the species appears to form a small component of the diet of predatory fish, though its trophic significance remains to be determined (Doupé et al 2004). In Mexico, where *C. quadricarinatus* is now feral, individuals are known to readily move both up and downstream, and juveniles are reportedly active predators (Mendoza 2004). 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 parvovirus-like virus infections are known from some aquacultured populations (Bowater et al. 2002; Romero and Jimenez 2002). Clearly, in Singapore as with elsewhere, more extensive monitoring is required to assess population size and structure and its environmental impacts. Currently, however, *C. quadricarinatus* appears to be limited to

the open-water habitats of the reservoirs proper, which appear to contain relatively few native species (Ng et al. 1993). The native freshwater decapod crustaceans, such as the freshwater prawn *Macrobrachium platycheles* Ou and Yeo and the endemic freshwater crabs *Johora singaporensis* Ng, *Irmengardia johnsoni* Ng and Yang and *Parathelphusa reticulata*, almost exclusively occupy the shaded, acid-water forest streams and swamps of the forested catchments (Ng 1999). As such, *C. quadricarinatus* would have had little opportunity to impact the strongholds of the native freshwater Crustacea. The reservoirs, however, are connected by drainages to the forest streams and swamps, which provide obvious dispersal corridors. Should *C. quadricarinatus* invade shaded acid-water forest streams and swamps, the consequences for native decapods could be dire.

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