Are we making the same mistake again? The redclaw crayfish, a prominent aquaculture species introduced worldwide

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The redclaw is a parastacid crayfish endemic to the tropical and subtropical freshwater ecosystems of north-eastern Australia and southern New Guinea. Given its broad environmental tolerance, fast growth, early maturation, high fecundity, gregariousness, general non-burrowing behavior as well as a high yield of 'tasty meat', it has become a target species for the aquaculture industry and pet trade. There are many known cases of species that have been moved elsewhere and have subsequently caused environmental and socio-economic problems in introduced areas. This review developed by researchers from Spain, Germany and the Czech Republic addresses many of the aspects related to this prominent aquaculture species and its potential environmental and socio-economic impacts.

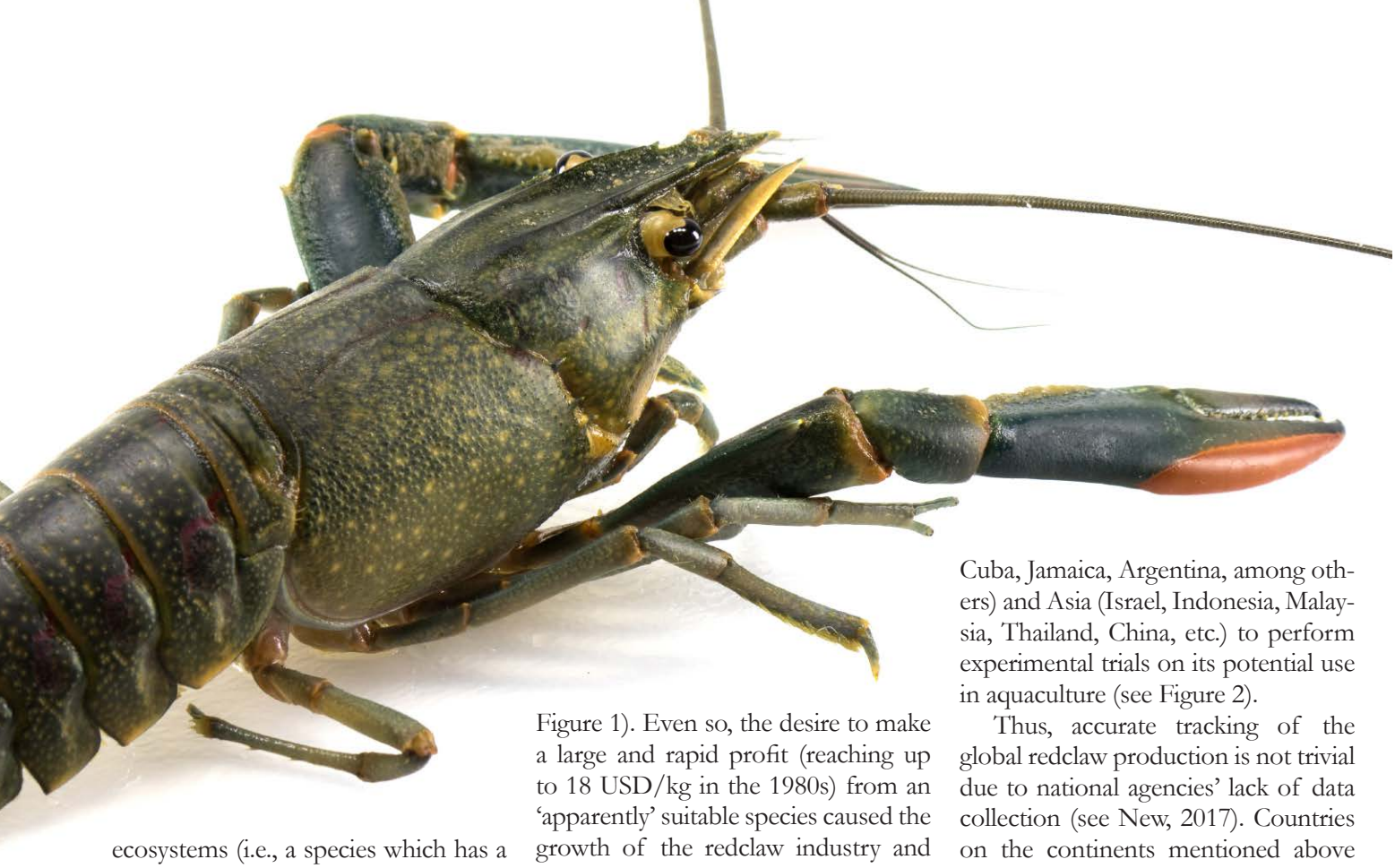
For centuries, humans have moved species from one place to another – far outside their native ranges. In the last decades, these translocations have been increased enormously due to globalization; this has led to the rise of the invasion biology discipline. Nowadays, there are many known cases of species that have been moved elsewhere and have subsequently caused environmental and socio-economic problems in introduced areas.

In the particular case of translocated crayfish species, what happened with the signal crayfish *Pacifastacus leniusculus*, and the red swamp crayfish *Procambarus clarkii* (i.e., broadly translocated across the globe to substitute the demand of declining native crayfish populations, and being used for aquaculture purposes, stocks, or for their capture into the wild), should serve as an example and warning of the dire consequences (see Petrusek et al., 2017; Oficialdegui et al., 2020). However, the case of the redclaw continues and –perhaps goes even further. In our recent review (Haubrock et al., 2021), we addressed many of the aspects related to this prominent aquaculture species and its potential environmental and socio-economic impacts.

The redclaw, a prominent crayfish species

The redclaw (also called red claw, red-claw, with or without the prefix 'Australian' or 'Queensland'; redclaw yabby; tropical crayfish; tropical blue crayfish; and blue lobster) is a parastacid crayfish (Decapoda: Astacidea: Parastacidae) endemic to the tropical and subtropical freshwater ecosystems of north-eastern Australia and southern New Guinea (Figure 1).

In its native range, redclaw often inhabits a wide range of habitats such as running waters, slow-moving streams, ponds, lakes, and lagoons. With generalist feeding habits, this crayfish species can, under optimal conditions, reach a size of up to ~25 cm and a weight of over 600 g, albeit wild individuals often remaining smaller. It reaches sexual maturity around nine months and a weight of 150 g. Females can spawn 500 eggs on average, and their maximum life span is four to five years. Most individuals are blue to bluish-green or olive-green, but several color morphs exist in the aquarium trade (see exhaustive review in Haubrock et al., 2021). Given its broad environmental tolerance, fast growth, early maturation, high fecundity, gregariousness, general non-burrowing behavior as well as a high yield of 'tasty meat', not only make redclaw a keystone species within freshwater



ecosystems (i.e., a species which has a large effect on the environment where it inhabits; Reynolds et al., 2013), but also a target species for the aquaculture industry and pet trade. Redclaw is a large-size and fast-growing crayfish species that, under optimal conditions (mainly temperature-dependent), can achieve a marketable size in a short time. Consequently, it is not uncommon that the aquaculture industry has appreciated this species for human consumption.

Introductions here, there, and everywhere

This crayfish species has been reared and grown out in Queensland farms and outside of its native range in bordering Australian states since the mid-1980s. By having the appearance of a lobster and biological features described above, the redclaw in aquaculture was soon considered a niche sector of the aquaculture industry, producing low volumes for local markets with accompanied economic interests for small entrepreneurs. However, it did not live up to early expectations and predictions, and production remained relatively low (see Figure 1). Even so, the desire to make a large and rapid profit (reaching up to 18 USD/kg in the 1980s) from an 'apparently' suitable species caused the growth of the redclaw industry and its expansion within the native range in Australia and other non-native regions around the world. For instance, redclaw was translocated to diverse islands in Oceania (New Caledonia, Fiji, or Samoa) and moved to several African countries (South Africa, Zambia, Zimbabwe, among others) for its use in aquaculture. It was even introduced in tropical and subtropical countries from the Americas (Mexico, Ecuador, Cuba, Jamaica, Argentina, among others) and Asia (Israel, Indonesia, Malaysia, Thailand, China, etc.) to perform experimental trials on its potential use in aquaculture (see Figure 2).

Thus, accurate tracking of the global redclaw production is not trivial due to national agencies' lack of data collection (see New, 2017). Countries on the continents mentioned above reached on average 150 tons per year for the last two decades, exceeding 400 tons in only a few years (see Figure 2). However, these data seem greatly underestimated since there are known aquaculture facilities and companies conducting wild animal captures in several countries with no apparent reporting to FAO (for more details, see Haubrock et al., 2021). Besides, this crayfish is also present in Europe,

The male of redclaw, *Cherax quadricarinatus*. Photo: 5snake5; source: Wikimedia Commons (CC BY-SA 4.0).

though mainly due to another introduction pathway – the pet trade. Today, redclaw is translocated to a total of 67 countries/territories, and established 'wild' populations exist in 22 countries (see Figure 2).

Consequences for ecosystem biodiversity

As a result of escapes from farms, aquarium releases, bait buckets for recreational fishing, or deliberate stocking, this species has colonized and spread considerably. Suppose the biological characteristics mentioned on this species are taken into account (see above). In that case, these are suitable for aquaculture production, but also make this species a severe environmental and socio-economic problem in non-native ecosystems. These impacts have only been studied in a few invaded areas. Still, previous experience with other invasive crayfish and the characteristics exhibited by the redclaw make this species a significant potential hazard to native environments when escaping from aquaculture facilities (e.g., earthen ponds). There cannot be any doubt that the past mistakes cannot be repeated; we have already made enough of them, for example, with the red swamp crayfish and signal crayfish. It is therefore unavoidable that we pay attention to the use of potential invaders such as aquaculture species. Aquaculture producers must implement a holistic approach to conduct adequate risk assessments and sustainable breeding in closed facilities to prevent accidental escapes and to safeguard freshwater biodiversity, especially in biodiversity hotspots of tropics and subtropics.

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Figure 1

FAO production (aquaculture and capture) of the redclaw, *Cherax quadricarinatus*, in the five continents where has been introduced since 1980s. Note that production in Oceania almost exclusively depends on aquaculture in the State of Queensland, Australia; and no production is reported in Europe. The only country which has reported captures from the wild is Ecuador in the Americas. Black solid and dashed lines show the total value (USD millions) and mean price (USD/kg), respectively.

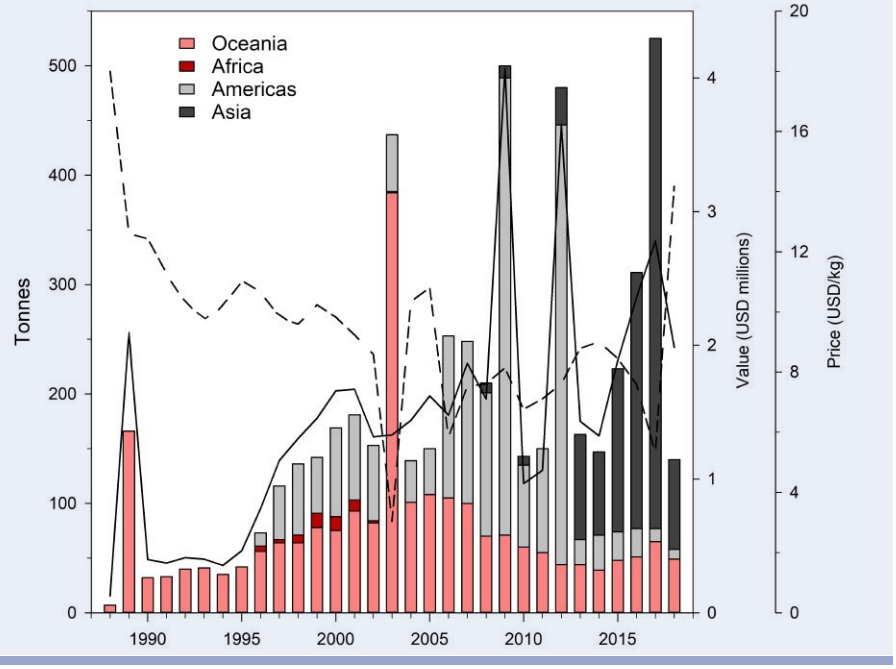
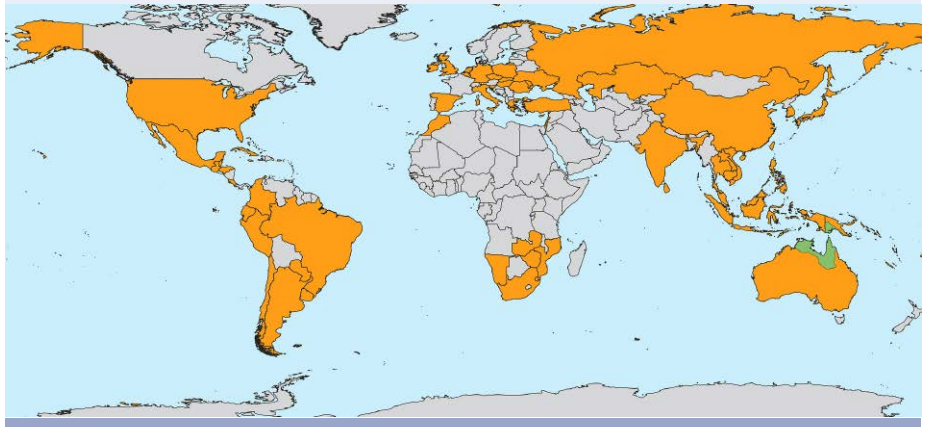


Figure 2

Countries where the redclaw has been introduced for diverse purposes (mainly aquaculture and pet trade) in ochre, while the native range of redclaw is shown in green. Note that redclaw has been also introduced into small islands such as Martinique, Fiji, Samoa, Mauritius, or La Réunion which are not visible at the global scale.



Earthen ponds dedicated to aquaculture redclaw crayfish and fish species in Lombok, Indonesia. Photo: Jiří Patoka.