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Review on the global distribution of wild population of Australian Redclaw Crayfish, *Cherax quadricarinatus* (von Martens, 1868)

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The redclaw crayfish (*Cherax quadricarinatus*) is an aquatic species native to the northern Australia and southern New Guinea . The invasion of this species worldwide was mainly associated with the aquaculture activities, ornamental pet trading and deliberate or unintentional release into the wild. This review highlighted the first report, distribution and route of introduction of *C. quadricanatus* worldwide. We also include brief discussion of the region where the crayfish were detected. In this review, we realized most of the invasion of this species mainly started with aquaculture activity and farming which open the opportunity for others possibilities of escape. *C. quadricarinatus* capabilities of surviving in different regions and wide range of environment were briefly discussed in this review. The impacts of invasion were compiled according to the reported research articles.

Keywords: Distribution, Freshwater crayfish, Invasive,

INTRODUCTION

The redclaw crayfish (*Cherax quadricarinatus* von Martens, 1868) is a species originated from northern Australia and south-eastern Papua New Guinea (Naqiuddin et al. 2016). Ability of *C. quadricarinatus* to grow and reproduce, their capability to tolerate wide range of water quality, their omnivorous character (Holdich 2002; Snovsky and Galil 2011 by Marufu et al. 2018) and attractive colours makes them as an ideal species for both aquaculture and aquarium industry (Naqiuddin et al. 2016). The redclaw has been translocated to various locations around the world including Southern Europe (D' Agaro et al. 1999; Koutrakis et al. 2007; Gozlan, 2010), Eastern and Southern Africa (Nakayama et al. 2010; De Moor, 2002), the Americas (Medley et al. 1994; Wickins and Lee, 2002; Vazquez and López Greco, 2007; Romero, 1997; Volonterio, 2009), the Caribbean (Medley et al. 1994; Vazquez, 2008), the Middle East (Karplus et al.1998), Eastern and South East Asia (Medley et al. 1994; He et al. 2012; Chang, 2001; Alimon et al. 2003; Edgerton, 2005) by various introduction routes.

To date through assessment information of The International Union for Conservation of Nature's (IUCN) Red List of Threaten Species, *C. quadricarinatus* is categorized as least concern (LC) animal and population trend of this species remains unknown due to insufficient availability of population data . Wide spreading of this species mainly in tropical region generally associated with the suitability of the condition that favors as their habitation for foraging base and establishment. This species is found in a wide variety of habitats across its native area, including flowing rivers, lagoons, and lakes (Jones, 1990). Since the turn

of the twentieth century, redclaw has successfully established its range and population in a number of nations beyond its original habitat, where it is regarded as an invasive or nuisance species (Williams et al. 2001; De Moor 2002; Ahyong and Yeo, 2007). Invasion of redclaw may lead to biotic interaction (predation and competition) as well the potential disease transmission frequently to other indigenous freshwater decapod crustaceans (Foster and Harper, 2006; Madzivanzira et al. 2020).

The objective of this review is to summarize and analyzed information of *C. quadricarinatus* introductions worldwide, their pathway of introduction into each country, spreading in wild, distribution and any reported impacts with brief historical of first introduction. Better understanding of nature and magnitude of the environmental impacts generated, ultimately will avoid further introductions of *C. quadricarinatus* into non-native environment with proper management.

MATERIALS AND METHODS

Information retrieval

Data retrieval were done with the adoption of electronic databases such as World of Science (WOS) and also Scopus. The inclusion and exclusion criteria were consistent with those of John et al. (2018), in that primary associations were employed separately or in conjunction with two or more events and region to screen published resources from different countries. The keywords used eventually discovered several documents mostly in Web of Science (n = 69) and Scopus (n = 9). After exclusion criteria which removed untraceable article, invalid citation and duplicated words, total of 83 reputable and reliable sources including thesis and conference reports (n = 5) were gathered for further review. The information mainly restricted to freshwater crayfish, global occurrences and wild population. After second exclusion, the final library encompassing the information on freshwater crayfish specifically to *C. quadricarinatus* on introduction pathway (ornamental, pet shop, research purposes and aquaculture), global occurrences of *C. quadricarinatus* recorded, invasion in wild population and consequences and challenges associated to non-native freshwater crayfish to environment and community either directly or indirectly.

Table 1: Keywords in constructing library information on *C. quadricarinatus*

Primary association	Country	Events
Cherax quadricarinatus	Malaysia	Ornamental
Freshwater crayfish	Indonesia	Aquaculture
Invasive	Taiwan	Hobbyist
Wild Population	Hungary	Pet trade
Alien	Mexico	Deliberate release
First record	Jamaica	Unintentional release
Distribution	Puerto Rico	
Socio Economic	South Africa	
	Slovenia	
	United State	

RESULTS AND DISCUSSION

The worlwide distribution of *Cherax quadricarinatus* wild populations

The occurrence of wild populations of *C. quadricarinatus* were reported mostly in Asia continent in term of number of individuals caught and detected. Wild population of redclaws can be found in almost all type of watercourses such as river (Arias and Torralba-Burrial, 2021), lake (Patoka et al. 2016), reservoirs (Ahyong and Yeo, 2007), stream (Azofeifa-Solano et al. 2017) and even in shallow drainage system (Norshida et al. 2021). Convenience of suitable habitation especially in tropical region of Asia which imitates their native region obviously facilitate the growth and survival of this species. *C. quadricarinatus* is eurythermic species. Lethal temperature limits for juvenile redclaw ranging from 10°C until 35°C (King, 1994). Adult crayfish can survive in water as cold as 3°C for a brief duration, but they cannot survive in water below 10°C for an extended duration (Semple et al. 1995). Thus, temperature has a critical role in determining the redclaw's survival and proliferation.

In North America the distribution of wild captured redclaws can be found in places with tropical to arid climate zones. The establishment of redclaw in wild habitat were reported in Mexico, Martinique Island, Puerto Rico, the United State, Jamaica and Costa Rica. Most of the places reported were having high water temperature (>22°C) (Bortolini et al. 2007) and this condition permits the survival, optimal growth and reproduction of redclaw.

Even though *C. quadricarinatus* limiting factor is mainly temperature, the species are now has been recorded at temperate region in Europe (Jaklič & Vrezec, 2011). The availability of thermal hot springs and climate change which lead to the increasing temperature from 0.3 to 1.0°C per decade has led to climate-linked invasion (Walther et al. 2002). Thermal hot springs provide optimal temperature for the survival, spawning, egg and juvenile development of many warm-water species including redclaws (King, 1994; Jones, 1995; Meade et al. 2002). The distribution of *C. quadricarinatus* in wild habitat around the world are mapped in Figure 1 and the detail list of the countries, habitat, and route of introduction are tabulated in Table 2.

Asia

In Asia region, the presence of redclaws' wild population was reported in Malaysia (Naqiuddin et al.2016; Norshida et al. 2021), Indonesia (Patoka et al. 2016), Singapore (Ahyong and Yeo, 2007; Belle and Yeo, 2010), Thailand (Chaichana and Wanjit, 2017) and China (Lau and Yau, 2020).

In Malaysia, wild population were documented in Machap dam and Benut River (Johor), Ayer Keroh Lake and Timun river (Melaka), Puchong Perdana Lake (Selangor) and streams in Suai (Sarawak) by Naqiuddin et al. (2016) and Besut, Terengganu by Norshida et al. (2021). Redclaw crayfish is locally known as freshwater lobster in Malaysia due to its lobster-like appearance. Although the exact year of the redclaw's entry into Malaysia is uncertain, commercial-scale culturing operation of this species has been recorded since 2003 in Malaysia's southern peninsula (Alimon et al. 2003). Malaysia has been recorded as the main producer of redclaw with increasing trend in production from 2012 until 2017 (FAO, 2020). Naqiuddin et al. (2016) stated that the population of redclaw crayfish has attract the interest of the locals, who see it as a way to supplement their income. Cultures are generally grown for food, with a target length of 6 to 8 inches, but high demand for juveniles prompts a greater emphasis on breeding rather than grow out activities. Naqiuddin et al. (2016) reported that the species were available around Johor since 1980s but accidentally released into Machap dam after flooding event in 2006. Development of hatcheries and small-scale culture facilities of redclaw also had been recorded in several states in Malaysia including Kelantan, Terengganu, Perak, Pulau Pinang and Negeri Sembilan which might speed up the spread of redclaw in the waterbodies. Spreading of *C. quadricarinatus* are probably due to the unintentional escape from holding facilities and aquarium pet trade industries, which similar to previous report in other country in Israel, Mexico, Puerto Rico and Singapore (Karplus et al. 1998; Williams et al. 2001; Ahyong and Yeo 2007; Bortolini et al. 2007 and Belle et al. 2011).

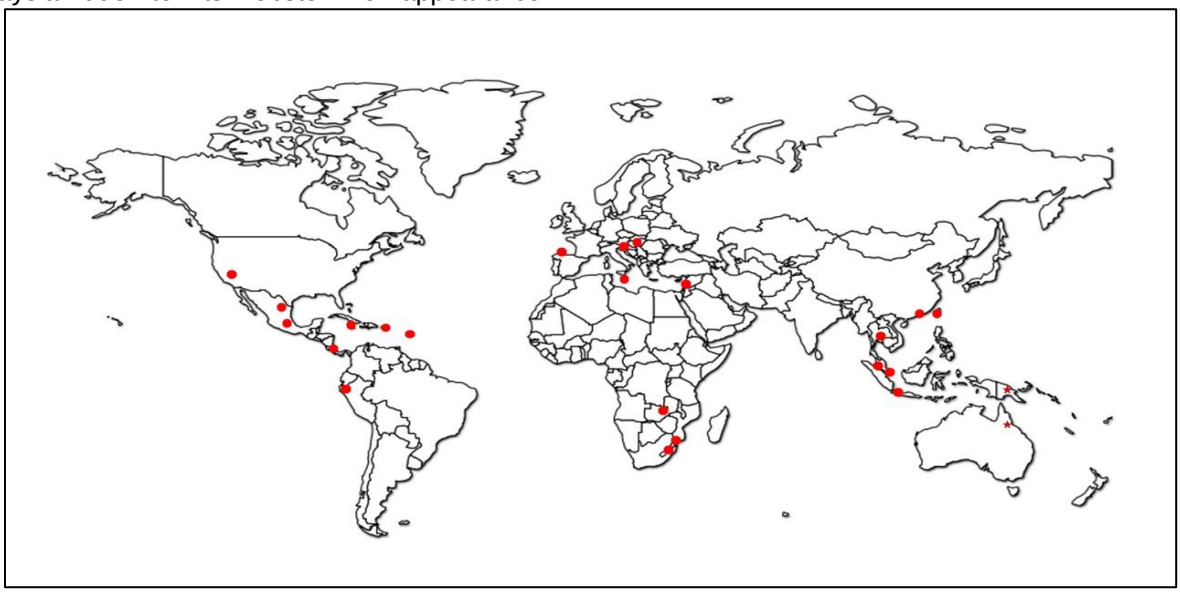

Figure 1: World Map Distribution of *Cherax quadricarinatus.* Red dotted labels refer to detected introduced crayfish area and red star refer as native origin of the species.

Table 2: Report on the presence of *C. quadricarinatus* wild population in various country.

Continent	Country/region	Habitat	Route	Number of Individuals detected	Author(s)	Publication Year
Asia	Malaysia	Lake River Stream Reservoir	Aquaculture	Benut River : 25 Ayer Keroh Lake : 2 Puchong Perdana Lake : 10 Streams in Suai : 136	Naqiuddin et al.	2016
		Drainage Felda Tenang	Deliberate release	6	Norshida et al.	2021
	Indonesia Natural lake: Cilala Lake and Lido Lake	Lake	Aquaculture Deliberate/ unintentional Release Ornamental	Cilala Lake: 1 Male 3 Female Lido Lake: 1 Male 3 Female	Patoka et al.	2016
	Singapore Reservoirs	Reservoir Kranji Reservoir,Lower Peirce Upper Seletar reservoirs	Accidental/Deliberate release Aquarium trade	Not stated	Ahyong and Yeo	2007
		Lake;Bukit Batok Town Park	Deliberate release	8	Belle and Yeo	2010
	Thailand	Reservoir	Aquaculture and Aquarium trade	Not stated	Chaichana and Wanjit	2017
	Taiwan	Farm	Aquaculture and research purpose	Not stated	Hsieh et al.	2016
	Hong Kong, China	Stream pool Reservoir	Intentional release	49	Lau and Yau	2020
Europe	Maltese Archipelago, Italy: Nadur (pond - island of Gozo), Italy Fiddien and Wied Qlejgha (island of Malta),Italy	Reservoir	Aquarium trade Aquaculture	6 observed 4 caught 2 observed	Deidun et al.	2018
	Hungary	River	Deliberate release	3 adult	Weiperth et al.	2019
	Spain	River (Nora River-Iberian Peninsula)	Aquarium trade	7	Arias and Torralba-Burrial	2021
	Slovenia	Oxbow lake Topla	Aquarium trade (1990) Aquaculture	15	Jaklič and Vrezec	2011
America	United State Lake Balboa	Lake	Aquaculture and aquarium release	1	Morningstar et al.	2020
	Puerto Rico	River Reservoir	Aquaculture (1997)		Williams et al.	2001
	Jamaica	River	Aquaculture	Not stated	Pienkowski et al.	2015
	Mexico	River Morelos; Recreational aquatic park Les Estacas (LE) Tamaulipas; Llera de Canales, Gómez Farías,	Research program (1995) Aquaculture	Morelos: 619 (January) 403 (February) Tamaulipas: 19	Bortolini et al.	2007

		Xicotén-catl, Loma Alta				
	Martinique Island	Stream Closed water body	Aquaculture (2004)	111 (56 female and 55 male)	Baudry et al.	2020
	Costa Rica (Caribbean Drainage)	Stream	Unintentional release from holding facilities Aquaculture	7	Azofeifa-Solano et al.	2017
Africa	South Africa and Swaziland	River Reservoir	Aquaculture	577 (wet season) 267 (dry season)	Nunes et al.	2017
	Morocco	(Fish farm in Tangier region)	Aquaculture (2002)	Not stated	Madzivanzira et al.	2020

As in Sarawak, exact time for first introduction is uncertain, however the population appears to progress in the region between Bintulu and Miri as reported by Johan et al. (2012). In addition, the spreading of redclaw in the wild within East Coast of Peninsula Malaysia was first reported by Norshida et al. (2021). In this study six juvenile redclaws were found in the drainage area of a small village in Besut, Terengganu. The authors speculated that most probably the adult redclaws do exist in the sampling area or in the adjacent waterbodies which connecting to the drainage system. The findings suggested that the introduction of redclaws in the area are still new and probably due to unintentional release from aquarist or prospective farmers, because there is no aquaculture facilities in the vicinity of the sampling area.

In Indonesia, wild populations were documented in Lido Lake and Chilala Lake located in West Java Province by Patoka et al. (2016). The introduction of redclaw in West Java Province is caused by intentional release due to people's intention for future harvests. The authors of report are predicting negative impact of the introduction in term of competitive interaction with native species with economical value such as *Macrobrachium dacqueti* and *Macrobrachium rosenbergii* (Wowor and Ng. 2007)

In Singapore, the population of *C. quadricarinatus* were documented in several reservoirs (Ahyong and Yeo, 2007) and an urban pond (Belle and Yeo, 2010). The introduction was likely attributed by multiple independence release by aquarist as in Singapore the species is not cultured as food but popular as ornamental pet. The redclaws were commonly sold with price range of S$1.50 for juveniles to S$5.00 for adult individuals (Belle and Yeo, 2010). The occurrence of redclaws were alarming as two reservoirs are in proximity to the only freshwater swamp, Nee Soon Swamp Forest, which hold high conservation value and native flora and fauna on the island (Ng and Lim, 1999).

In Thailand, wild population of *C. quadricarinatus* were documented in Pra Prong reservoir by Wanjit and Chaichana (2013). It was stated that the introduction occurred as a result of deliberate introduction. Since 2006, redclaw have been brought into Thailand for Royal Project Research to improve rice farmers' revenue. Most of the commercial scale culture located in Thai provinces including Bangkok (central), Kanchanaburi (western), Chiangmai (northern) and Sakaew (eastern) (Soowannayan et al. 2015).

In China, wild population of *C. quadricarinatus* were documented in Hong Kong by Lau and Yau (2020). A total of 49 crayfish were detected and caught from a stream pool and reservoir in Pok Fu Lam Country Park. Hong Kong consisted of native freshwater decapods but not native crayfish (Dudgeon, 1999). The introduction of redclaw in Hong Kong is associated with intentional release, escaping event from the aquaculture facilities and also being released after imported for educational purposes (Hobbs et al. 1989; Gherardi, 2010).

In Taiwan and Vietnam, *C. quadricarinatus* are known to be an important aquaculture commodity (Dung, 2005; Hsieh et al. 2016). In Taiwan, redclaws has been introduced to the country for research and aquaculture purposes since 1990s. The redclaw aquaculture industries growing rapidly over the past decade in Pingtung County and statistical information by the industry showing profitable output of redclaw production annually around 1800 tons with commercial value of US$ 30 million in 2013 (Hsieh et al. 2016). However, in both countries, no report on the wild population is yet available.

America

The presence of wild redclaws in reservoirs and rivers was documented in Puerto Rico. Illegal aquaculture activities are suspected of bringing the alien species into the country, and multiple large escapes are suspected of spreading it to the wild. The main spread could be linked to the flooding caused by Hurricane Georges in 1998 (Williams et al. 2001).

In Mexico, wild populations of redclaws were reported in two states, Morelos and Tamaulipas. Wild redclaws were captured in natural waterways, river, dam and irrigation canals. The introduction of redclaw in Mexico was firstly for the purpose of experimental cultures in 1995, followed by commercial aquaculture activities. The spreading to the wild were speculated happened due to the escapes from open earthen ponds (Bortolini et al. 2007).

In the United States, redclaw was reported in Lake Balboa, Los Angeles, California. The data of the occurrence was contributed by scientist to The Nonindigenous Aquatic Species Program (NAS) database and published by Morningstar et al. (2020). The NAS database was established as a monitoring platform and allows the contribution of people from all background to involve in reporting the findings of non-native species in the United States.

As in the Carribeans, wild populations of

redclaws were reported in Martinique Island and Costa Rica. In Martinique Island, first introduction of this species starts in 2004 attributed to boost the aquaculture industry in the island that show depletion due to ecotoxicological problems especially in giant freshwater prawn culture, *Macrobrachium rosenbergii.* Translocation of this species since its introduction and after escapes or intentional release, this crayfish is now well established in three streams and one reservoir (Baudry et al. 2020). Nunes et al. (2017) reported high dispersal capabilities of this species with an average dispersal rate of 6.6 km/year. The redclaw was said to be well established in the Martinican hydrobiological networks involving 16 populations identified since its first introduction in 2004 with 10 new population discovered since previous survey in 2015. Crayfish are important in the socio-economic aspect of the people in the island. Locals sell redclaws at high price as 24 euros/kilo and it is valued as food. Thus, intentional introduction is high as people deliberate the redclaws into the ponds and watercourses.

In Costa Rica, wild population was documented by Azofeifa-Solano et al. (2017) in Caribbean drainage (stream). *C. quadricarinatus* was introduced in 1985 and present in northwestern Pacific drainage. History of introductions suggest that public access to live crayfish and poor technical crayfish production usually leads to releases or escapes into the wild (Lodge et al. 2012). Presence of this species may be related to unintentional release from the holding facilities plus people intention for benefit from these resources lead to increased translocation to other rivers.

Africa

According to Van den Berg and Schoonbee (1991) and Boyko (2016) three Australasian Parastacidae species, the Australian redclaw crayfish (*Cherax quadricarinatus*), the smooth marron (*Cherax cainii*) and the yabby (*Cherax destructor*), as well as a single North American Cambaridae species, the red swamp crayfish (*Procambarus clarkii*), have been introduced to continental Africa. The introduction was for aquaculture research purposes. Due to several constraints in South Africa, passionate farmers who have been unable to develop aquaculture ventures in the country develop them in neighbouring Swaziland (De Moor, 2004). In South Africa, the first wild sample was taken in 2002, and proliferated as a result of escapes from aquaculture operations in Swaziland (Nunes et al. 2017). Apart from redclaws, P. clarkii has developed wild populations in a number of countries (Schoonbee, 1993; Van Rooyen, 2013).

Europe

In European region, the presence of wild populations was reported in Italy (Deidun et al. 2018), Hungary (Weiperth et al. 2019), Spain (Arias and Torralba-Burrial, 2021) and Slovenia (Jaklič and Vrezec, 2011). In Italy, wild population was documented in Nadur Pond and Wied Qlejgha. The introduction of this crayfish was driven by the decline of indigenous crayfish species, *Astacus astacus* due to crayfish plague (Ninni, 1865). According to Kouba et al. (2014), the primary avenues for the introduction and establishment of redclaw in Europe are through aquarium trade and marketing of redclaw for fish and human food. Additionally, this species has been shown to be capable of naturalising, reproducing populations, and even producing progeny in introduced regions; carrier of a non-indigenous temnocephalan flatworm parasite that may impact native species (Du Preez and Smit, 2013).

In Hungary, according to Weiperth et al. (2019), *C. quadricarinatus* was first recorded in wild within the whole Carpathian Basin. This species was captured in a side arm of Danube River, Kopaszi-gát in Budapest, Fényes-forrás near Tata and Harkány outflow named Melegvíz-csatorna. As *C. quadricarinatus* is not commercially produce for human consumption in Hungary, its discharge may probably due to the deliberate release or accidentally mediated by the hobbyist.

In Spain, wild population were documented in Nora River, Iberian Peninsula by Arias and Torralba-Burrial (2021). Nora river crosses agricultural, industrial and also peri urban areas with rapid urbanization nearby due to its closeness to the capital city of Asturias. According to the author, all specimen collected could be potentially mature and therefore reproductively active. Introduction of non-indigenous species derived from the recreational fishing and/or aquarium release. Definitely, trade of ornamental aquatic pets has been considered as the main pathways of crayfish introduction into Europe (Chucholl, 2013). Although this new locality does not represent an optimal habitat for this species, frequent continuous presence of redclaw since 2013 may lead to an important risk to the ecosystem health with the present of commensal

organism and pathogens, thus becoming a largescale problem (Elliott, 2003; Greenberg and Palen, 2019).

In Slovenia, wild populations were documented in natural river oxbow lake Topla with thermal hot water spring in eastern Slovenia. Even though the species is known to be invasive in tropical and subtropical region, this is the first record documented from the temperate region due to its unique water temperature regime from the underground hot spring (Šajna et al. 2007). According to Holdich et al. (2009), redclaw specimens had already been found in the wild of Europe countries before, but these occurrences were short-termed and probably representing to released individuals. The adult redclaw found with temperature range from 21 to 31 ◦C that which is optimal for the growth and development (Meade et al. 2002).

Introduction Routes

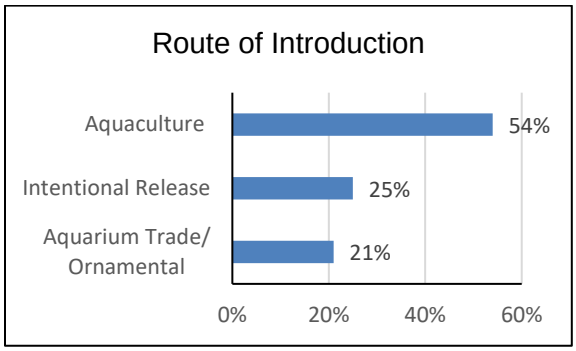

Figure 2: Route of Introduction

Based on the graph, we can conclude that the aquaculture business plays a key part in the introduction route of non-indigenous species *C. quadricarinatus* worldwide, accounting for 54%, 25% of purposeful release, and 21% from aquarium commerce and ornamental purposes. However, the invasion is unlikely to occur with only one method of entry. According to Carlton and Ruiz (2005), redclaw was introduced by numerous paths and is classified as a 'polyvectic' species.

The majority of redclaw distribution in tropical regions was caused by inadvertent releases or escapes from aquaculture facilities. The establishment of wild populations in this region was vigorous since most of the habitats provide suitable conditions for redclaws to develop and multiply.

The emergence of the aquarium trade piques the curiosity of aquarium enthusiasts, which may lead to the introduction of redclaw into non-native ranges (Chucholl, 2013). In Europe and countries where *C. quadricarinatus* is not farmed for food but is marketed as an ornamental product, dissemination to wild habitat is usually related with deliberate or unintentional discharge into local waterbodies by hobbyists or the general public. We can see that the introduction routes of non-indigenous species into the wild are most likely linked and unlikely to occur via a single pathway.

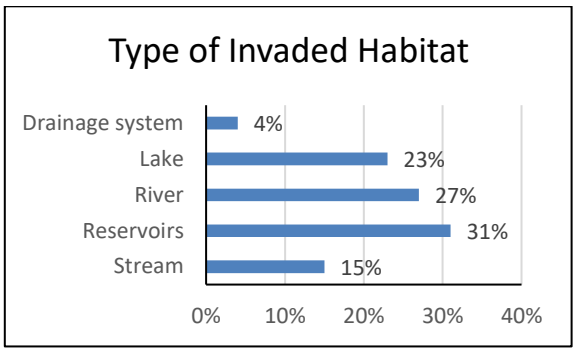

Figure 3: Type of Invaded Habitat by *C. quadricarinatus*

In general, redclaw crayfish were found in a variety of freshwater ecosystem waterbodies, including rivers (Arias and Torralba-Burrial, 2021), reservoirs (Ahyong and Yeo, 2007), streams (Azofeifa-Solano et al. 2017), lakes (Patoka et al. 2016), and drainage systems (Norshida et al. 2021). *C. quadricarinatus* is a burrowing species that is adaptable of a broad variety of habitats, ranging from fast-flowing rivers and coastal streams to slower-moving upper reaches of rivers, lakes, lagoons, and billabongs (Wingfield, 2002). This explains why this species can survive in such a wide variety of habitats. Redclaw, on the other hand, appears to prefer rocky areas for foraging, exploration, and self-preservation during the moulting period (Souty-Grosset et al. 2006). Additionally, Nunes et al. (2017) noted that the species thrives in irrigation dams which may act as a source of range expansion. Reservoirs are well-known as hotspots for the establishment and spread of aquatic invasive species (Beatty, 2019). By functioning as a 'stepping stone,' artificial reservoirs enhance the likelihood of invasion into natural waterbodies (Muirhead and MacIsaac, 2005). Johnson et al. (2008) found that imported species are more likely to occur in impoundments than in natural lakes.

Implication of the introduction of *Cherax quadricarinatus* in non-native region

The introduction of alien species such as

crayfish and fish into natural ecosystems may result in ecosystem service failures by reducing the abundance of native species through competitive environment and predation (Khaleel et al. 2021), increasing the cost of harvesting (Lodge et al. 2012), altering the ecosystem food web (Khaleel et al. 2020), and altering habitats (Gherardi and Holdich, 1999; Lodge et al. 2006). As a consequence, biological invasion is one of the most devastating stresses on freshwater environments on the globe (Rahel and Olden, 2008). The presence of introduced species can change the distribution pattern and behaviour of native species, alter shelter and microhabitat use, limit activity, and so interfere with foraging behaviour, all of which can impair native species' growth and survival rates (Lodge et al. 2012; Milinski and Heller, 1978; Rahel and Stein, 1988; Twardochleb et al. 2013). However, research on the impact of *C. quadricarinatus* introduction and invasion is currently limited. To date, only several authors reported the possible impact from the introduction of redclaws in many parts of the world.

C. quadricarinatus aggressiveness was said to be a threat to local freshwater prawn, *Macrobrahium rosenbergii*. Based on the preliminary result from large scale experiment on the effect of this redclaw in new tropical environment, Williams et al. (2001) suggested that *C. quadricarinatus* could indeed compete with local freshwater shrimps and replace them. Apart from that, in South Africa *C. quadricarinatus* has been discovered to be a host for non-native temnocephalan flatworms, which may be transferred to indigenous decapods such as crab, *Potamonautes unispinus* (Du Preez and Smit, 2013; Tavakol et al. 2016).

According to Douthwaite et al. (2018), synodontids and *C. quadricarinatus* appear to share similar geographical and nutritional niches, and the inverse relationship between their catch rates indicates competition. A study on interspecific interactions between redclaw crayfish and Mozambique tilapia by Chivambo et al. (2019) reveal that tilapia may have an advantage in competition for food whereas crayfish may have an advantage in competition for shelters on the bottom. Crayfish are known for their aggressive behaviour, which includes chelipeds rising, strike positions, and moving towards tilapia (Chivambo et al. 2019). Crayfish may interfere with tilapia reproduction by interfering with males' construction of spawning pits on the substrate. Crayfish are also known to be effective predators of eggs and larval fishes (Dorn and Mittelbach, 2004; Karjalainen et al. 2015).

C. quadricarinatus has also been found to be vulnerable to crayfish plaque and the white spot syndrome virus (WSSV). WSSV can be spread to redclaw through cohabitation or feeding on WSSV-infected giant tiger shrimp, according to Soowannayan and Phanthura (2011). Farmers face a greater danger of cross infection due to the close proximity of redclaw and shrimp farmed farms. Redclaws, which are known to be a resilient species, could be the disease's vector. As a result, interactions between redclaws and native species may be linked to disease outbreaks in native species.

CONCLUSION

In conclusion, the distribution of wild population of *C. quadricarinatus* can be traced in in Asia, Africa, Europe and America continents. Aquaculture industry was recognized as the main introduction route of *C. quadricarinatus* worldwide followed by the ornamental in aquarium trade. Intentional or deliberate release into the wild are associated with the economic important of the species in the region but more common among aquarist or ornamental redclaw keepers. With temperature as the most important limiting factors, the distribution of *C. quadricarinatus* are more deliberate in tropical climate zones, however, establishment in temperate countries were recorded in warm waterbodies with the influence of thermal spring. Studies on the impact of the introduction, dispersion and establishment of wild population are scarce. Thus, more research should be done to fill the gaps in the future.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Ahmad Safuan S wrote the manuscript, Norshida I design the review and wrote the manuscript, Ahmad-Syazni, K, review and editing the manuscript. All authors read and approved the final version.

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