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INTRODUCTION OF INVASIVE PEACOCK BASS (*Cichla* spp.), ITS RAPID DISTRIBUTION AND FUTURE IMPACT ON FRESHWATER ECOSYSTEM IN MALAYSIA

Aliyu Garba Khaleel[1,2], Norshida Ismail[1], Kamarudin Ahmad-Syazni[1*]

[1] *University Sultan Zainal Abidin, Faculty of Bioresources and Food Industry, School of Animal Science, Besut Campus 22200, Terengganu, Malaysia*
[2] *Kano University of Science and Technology, Faculty of Agriculture and Agricultural Technology, Department of Animal Science, Wudil, P.M.B. 3244 Kano State, Nigeria*

*Corresponding Author: ahmadsyazni@unisza.edu.my

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ABSTRACT

Malaysia is recognised among the mega-diversity countries with the abundance of various freshwater species. Malaysian freshwater biodiversity is under threat after the introduction of an invasive peacock bass. The presence of this predator could challenge the coexistence of the native species. In the current review, the most important aspects regarding peacock bass threats to the biodiversity future of local species are addressed. Four non-native species of peacock bass are presently recognised in Malaysia. To date, the peacock bass species expand to all parts of Peninsular Malaysia with no records yet found in Kelantan and Borneo. Invasion success is more susceptible in Malaysian lakes (84.38%) compared to the dams, rivers and reservoirs. The mode of rapid expansion of this species is highly connected to the sport fishing and anglers. A propagule pressure, favourable habitat, prey abundance and feeding behaviours are responsible factors for the successful establishment of this species in Malaysia. The species are generalist feeders and piscivorous in nature. It is difficult to eradicate peacock bass since it provides physical jobs (recreation and tourism). However, the damage the species will cause in future is unpredictable. At this point, proper management of this species must be implemented to reduce its population. This could be achieved through updating checklists of freshwater bodies, improving monitoring systems and public awareness.

How to Cite

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INTRODUCTION

Globally, human beings brought enormous impacts on the Earth's environment and its biological diversity through various anthropogenic activities (Havel et al., 2015; Liew et al., 2016). Convention on Biological Diversity (2010) defined invasive species as "species whose introduction and spread outside their natural past or present distribution threaten biological diversity". Aquatic systems had already suffered great losses and countless non-native fish invasions which have outcompeted indigenous species (Yan et al., 2001). This resulted in the transformation of many aquatic environments (Yong et al., 2014). The introduction percentages of invasive species were increasing rapidly worldwide (Chiron et al., 2009). This occurs mostly due to the accidental and deliberate introduction by destroying the bio-geographical barriers via long-distance trades (Carpio et al., 2019). Invasive species can cause detrimental effects after their successful establishment in an environment outside their native range. Such effects include the extirpation or extinction of native species populations through various mechanisms (Clavero and García-Berthou, 2005). Indigenous prey species usually suffer proportionally from invasive predators, possibly because of what is described as 'prey naïveté' (Sih et al., 2010).

Malaysia is among the twelve mega-diversity countries in the world (Chong et al., 2010), with the total surface area of inland freshwater bodies and wetlands including rivers, swamps, dams, lakes, reservoirs and paddy fields of 45,459 km^2 (Yusoff and Gopinath, 1995). Biodiversity is greater in freshwater ecosystems per surface area in comparison with marine and land ecosystems (Miranda et al., 2019). Biodiversity in Malaysia is now facing serious threats from the invasive species especially in freshwater aquatic systems (Department of Fisheries Malaysia, 2010; Hashim et al., 2012). Simberloff et al. (2013) reported that the invasive species from different types of taxonomic groups are susceptible to transform many freshwater habitats. This invasion has a significant number of actual and possible effects on the population structure and functions of the ecosystems (Havel et al., 2015). Streams, reservoirs and lakes are reported to be highly susceptible to suffer loss of biodiversity with major threats resulting from adjustments in land use and the introduction of invasive species (Liew et al., 2016).

According to Rahim et al. (2013), the history of invasive fish species in Malaysia could be traced from the early 20^{th} century and probably started with the Southern Chinese migration into the country. Recently, the National Committee of Invasive Alien Species Malaysia (NCIASM, 2018) reported a total record of 130 invasive species ranging from those in agriculture, forestry, fisheries, marine sector, poultry and wildlife. Khairul Adha (2012) has earlier reported a total of 42 alien fish species being introduced for various purposes into Malaysian fisheries and freshwater bodies. The number of invasive fish species in Malaysia is increasing, which is connected to the continued fast growth in aquaculture, aquarium and recreational fish sector, developing interest in angling as well as the increasing needs for fish as a protein source (Rahim et al., 2013). The invasion process of the invasive species involves various stages, starting with the first introduction followed by local expansion from one location to another through the vectors (Yeo and Chia, 2010). They added that most species do not survive along the journey. However, about 10-50% of the species make successful changes to the corresponding stages of introduction, phase of establishment and turned invasive. Due to these facts, biodiversity conservation researchers in Malaysia focused more on the introduction and impact of general invasive species (Khairul Adha, 2012; Hashim et al., 2012; Rahim et al., 2013). Furthermore, those studies neglected the effects of a specific invasive species, especially those concerning the freshwater habitats. This review therefore focuses on the introduction, mode of expansion, occupied habitats and future impacts on native species of one of the most piercing predators and top invasive species in Malaysia freshwater bodies, peacock bass (*Cichla* spp.). This will aid in understanding the pathways of their expansion techniques and possible ways of controlling them before disrupting the structure of the freshwater bodies. There is very little documentation published on this species in Malaysia, therefore it is important to place some of those views on paper.

METHOD OF DATA COLLECTION

In the current review, several approaches were employed to access the relevant information regarding peacock bass species in Malaysia. The data obtained include a compilation of available published literature (scientific papers, technical reports and books), unpublished literature (thesis, monographs), data from Fish Base and Invasive Aquatic Species Databases (Guerrero, 2014; Piria et al., 2017; Ćaleta et al., 2019). Contact interactions were made with concerned persons from the Department of Fisheries Malaysia and local anglers (Latini and Petrere, 2018). Information from national newspapers and publicly televised programs were also sourced. To gather more information about the current distribution of peacock bass across Malaysia, additional data were also generated through a field survey carried out by the authors of this study. This includes a visit to the fish markets, lakes, reservoirs, rivers and aquarium shops (Yong et al., 2014; Smederevac-Lalić et al., 2019).

An overview of peacock bass

Cichla species are commonly referred to as peacock bass in English, tucunaré in Portuguese or ikan raja in Malay, making up the main voracious piscivorous fish of the Cichlidae family originated from the Amazon

(Marques et al., 2016). Peacock bass are an aggressively active piscivores that consume a wide range of prey and tend to ingest the whole prey that can pass their gape sizes (Zhao et al., 2014). They are highly prolific (spawning approximately 2000-3000 eggs per brood) and reproduction occurs all year round with a peak during the rainy season (Moura et al., 2000; Braga and Rebêlo, 2017). There is a high resemblance in peacock bass species which creates ambiguity in identifying them using the morphological classification method. To clear the species taxonomic issues, fifteen species of peacock bass are now recognised (Kullander and Ferreira, 2006), as shown in Fig. 1. All fifteen species of peacock bass originated from the Amazonian region (Willis et al., 2012). General features of peacock bass were described in previous studies (Kullander and Ferreira, 2006; Willis et al., 2012; Golani et al., 2019). Yet, molecular identification method is proven to be the best in identifying peacock bass species (Willis et al., 2012; Khaleel et al., 2020a).

Invasion history of peacock bass in Malaysia

Kampar is a district in Perak, Malaysia with a history of producing the largest amount of tin in the world (Tan and Sze, 2017). In the 1980s, the tin industry collapsed and most of those tin mines were abandoned (Yusof et al., 2001). These former mining areas were later becoming a habitat to an immense diversity of freshwater species and become a heaven for anglers (Saat et al., 2014; Bolan et al., 2017). It is strongly believed that the introduction of peacock bass to wild habitat in Malaysia was started from the release of the species in Kampar Lake in the early 1990s by some anglers for sport fishing (Khairul Adha, 2006). No information available regarding how peacock bass was introduced from the Amazon to Malaysia. However, previous study by Rahim et al. (2013) claimed that it was likely introduced through the aquarium industry (Fig. 2). Neighbouring countries such as Singapore and Thailand bordered with Malaysia also reported the invasion of peacock bass species (Ng and Tan, 2010a; Suvarnaraksha, 2017). Singapore is one of the world's largest countries, leading the aquarium trade (Yeo and Chia, 2010). Transfers of aquatic species are common between Malaysia and Thailand (Perry et al., 2010) and Singapore (Ng and Tan, 2010b). However, there are no records showing peacock bass species have been introduced into Malaysia from these neighbouring countries. Moreover, there is a missing record on the invasion data available especially for those imported through aquarium industries of these countries. In contrast, peacock bass species found in Vietnam are reported to be exported from Singapore (U.S. Fish and Wildlife Service, 2018). Khairul Adha (2012) reported that the peacock bass species kept expanding to various reservoirs and lakes in the southern and middle parts of the Peninsular Malaysia. Presently, peacock bass is normally seen in various lakes, dams and reservoirs due to their frequent breeding habits.

Fig 1. General features and morphology of 15 recognised *Cichla* species (Photo Credit: Willis et al., 2012)

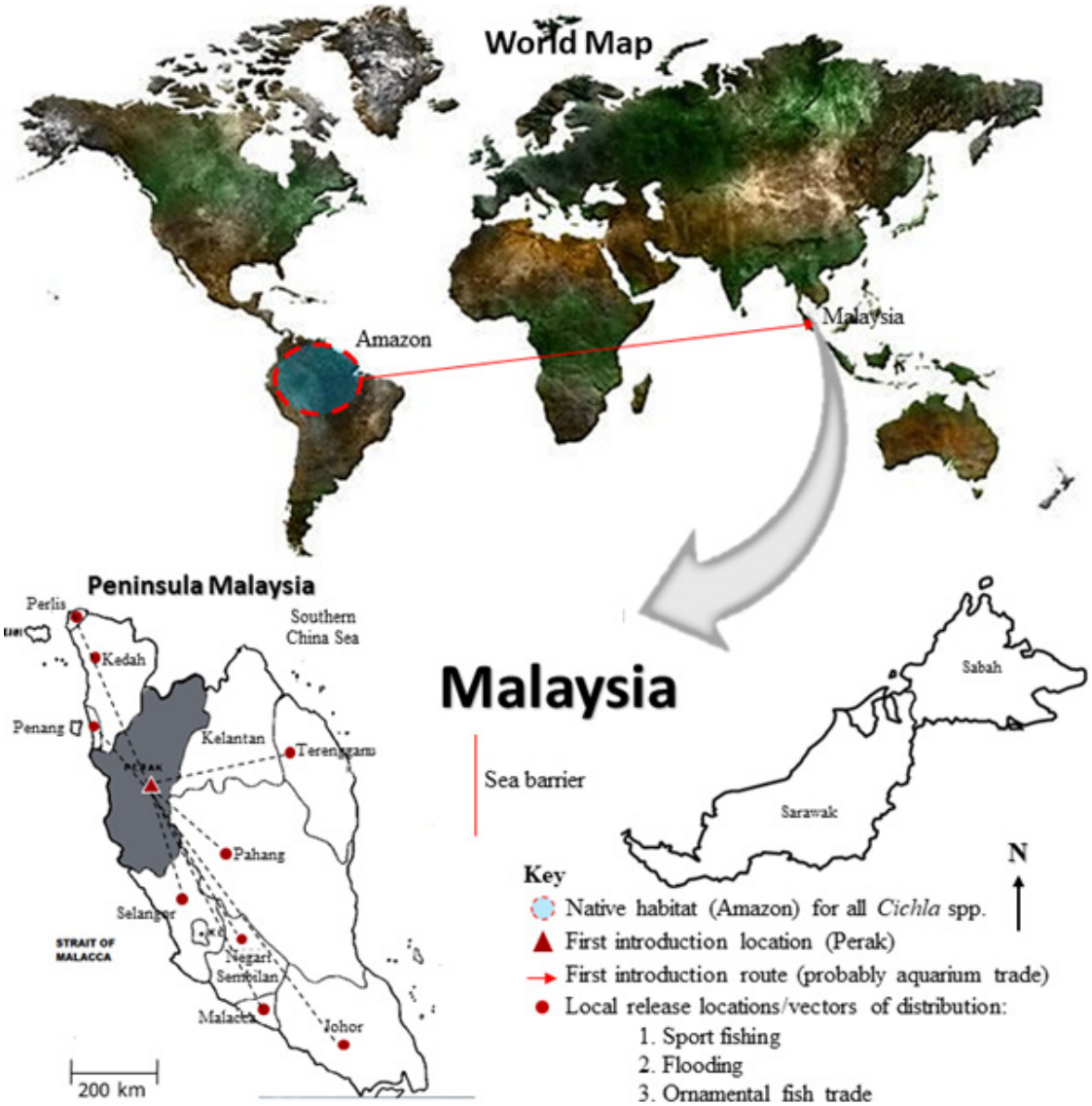

Fig 2. World map showing the Amazon, a native habitat of all *Cichla* species, the first introduction location and possible vectors of distribution in Malaysia (speckyboy.com)

Peacock bass species present in Malaysia

Cichla ocellaris, Cichla monoculus, Cichla orinocensis and *Cichla temensis* are the prominent species of peacock bass reported in Malaysia as identified on the basis of their morphology (Chong et al., 2010; Hashim et al., 2012; Sultana and Hashim, 2016; Tan and Sze, 2017; Abdullah et al., 2018; Ng et al., 2018). Fig. 3 showed the clear pictures of peacock basses observed from a few lakes and reservoirs in Malaysia. However, the molecular identification technique approach is necessary to obtain more valid and accurate information about these species across the invaded habitat. Khaleel et al. (2020a) recently isolated the COI gene of mitochondrial DNA of peacock bass collected from Telabak Lake located in Terengganu. The DNA barcode findings revealed peacock bass' true taxonomy as *C. ocellaris*.

Distribution of peacock bass in Malaysia freshwater

Based on the current search, peacock bass invaded all Peninsular Malaysia with no record found yet in Kelantan, Sabah and Sarawak (Table 1). The invasion is successfully higher in the lakes (84.38%), followed by dams, rivers and reservoirs (Fig. 4A). The survival and predation rates of this species are higher if the water is clear (Espínola et al., 2014), which is a typical nature of most lakes in Malaysia. Low percentage of peacock bass observed in dams and rivers might be due to lower water transparency levels which could not favour the peacock bass hunting and survival (Resende et al., 2008). As earlier mentioned, the abundance of peacock bass is higher in Perak (first introduction area) and constituted about 25% of the invaded states (Fig. 4B). Majority of these invaded water bodies in Perak are inter-connected and fish might easily

migrate from one location to another (Ng et al., 2018). The popular teams of anglers and top aquarium shops in Malaysia are commonly based in Perak, Selangor and Johor, which might be the reason for high peacock bass abundance as well.

Agents aiding peacock bass distribution in Malaysia

Here the forces that help the expansion and distribution of peacock bass in Malaysia are described. The listed agents could be operating either alone or simultaneously.

Sport fishing

Rahel and Smith (2018) described sport fishing or angling as one of the deliberate pathways that encourage invasive species to invade new habitats. Peacock bass natural aggressiveness, attacking and striking ability made it the best candidate that attracts anglers attention or sport fishing (Barroco et al., 2017). Angling is the main activity that helps peacock bass expansion in Malaysia. Recreational sport fishing and angling are now becoming great hobbies among Malaysians with peacock bass as a favourite catch (Rahim et al., 2013). Thus, result in the intentional release of this species by anglers into the open water bodies for their increasing desire to catch fish. Now, these species are becoming more popular as many aquarium shops, groups, websites and a team of anglers advertise catching guides for this species. In addition, they also establish game festivals, competitions and trophies for the peacock bass catch. Edwards et al. (2016) categorise anglers into boat and canal bank anglers. The authors further explained that the latter engaged four times more in catching peacock bass than the former from a study conducted in Florida. The same phenomenon was observed in Malaysia with mostly canal bank anglers due to the vegetative nature of some water environment, high cost of boat rent and safety reasons. In Brazilian Pantanal, professional native anglers were linked to the introduction of peacock bass into the stream of Caramujo from a collapsed fish pond located near the stream (Ortega, 2015).

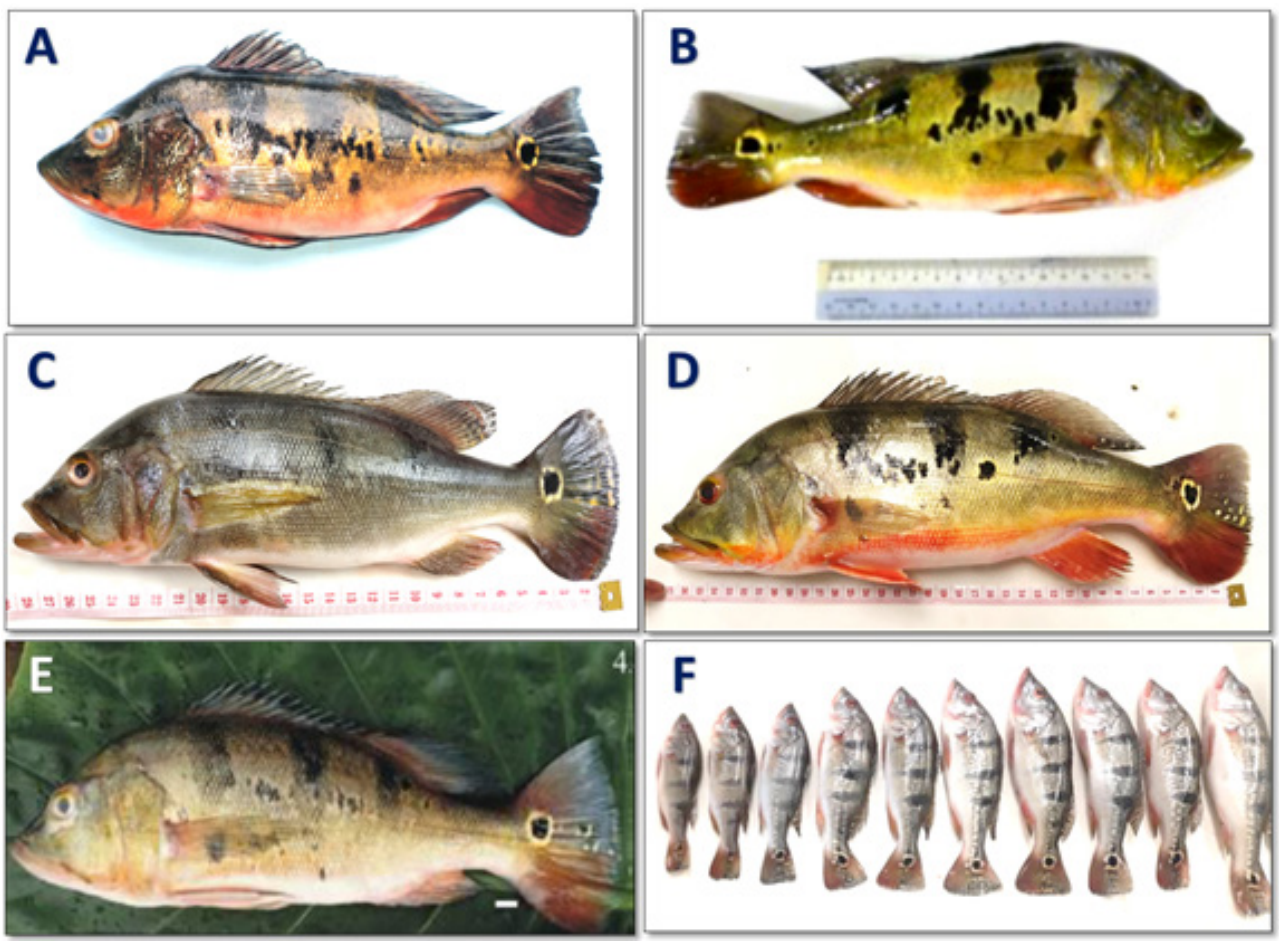

Fig 3. Peacock bass captured from various freshwater bodies in Malaysia. ***A:*** *C. monoculus* discovered in Perak displays un-ocellated bars on the body, with a lateral and dark lateral blotch discontinued (after Ng et al., 2019). ***B:*** *C. ocellaris* from Tasik Raban Perak (after Desa and Aidi, 2013) ***C:*** *Cichla* sp. from Timah Tasoh Perlis. ***D:*** *Cichla* sp. from Tasik Telabak, Terengganu (after Khaleel et al., 2020a). ***E:*** *C. orinocensis* from the Kampar River catchment Perak (after Ng et al., 2018). ***F:*** *Cichla* sp. from Tasik Prima Selangor

Table 1. Freshwater bodies with reported cases of peacock bass in Malaysia

Location	Vector	Coordinates	Reference
Kelantan	-	-	Record not yet found
Pahang			
Taman Pasif	Unknown	3°48'52.5"N 103°21'33.1"E	This study
Lombong Chendering	Anglers	3°46'44.9"N 103°14'48.8"E	This study
Terengganu			
Tasik Telabak	Anglers	5°37'56.9"N 102°28'24.5"E	Khaleel et al., 2020a
Selangor			
Tasik Prima	Anglers	2°59'42.6"N 101°36'08.5"E	This study
Tasik Biru Kundang	Anglers	3°15'04.4"N 101°31'31.2"E	This study
Taman Tasik Kota Kemuning	Unknown	3°00'05.0"N 101°32'12.6"E	This study
Taman Tasik Semenyih	Anglers	2°56'56.8"N 101°51'57.5"E	This study
Tasik Holiday Villa, Subang	Unknown	3°04'52.7"N 101°35'54.3"E	This study
Negeri Sembilan			
Tasik Empangan Gemencheh	Unknown	2°34'50.1"N 102°20'28.6"E	This study
Tasik Kampung Juaseh	Unknown	2°46'55.3"N 102°19'05.5"E	This study
Melaka			
Taman Rekreasi	Unknown	2°11'22.4"N 102°14'55.4"E	This study
Tasik Ayer Keroh	Unknown	2°16'25.7"N 102°18'07.5"E	This study
Empangan Jus	Anglers	2°26'32.7"N 102°22'19.5"E	This study
Tasik UiTM Jasin	Anglers	2°13'35.4"N 102°27'13.2"E	This study
Tasik Chinchin	Anglers	2°16'32.2"N 102°28'50.5"E	This study
Johor			
Sultan Iskandar Reservoir	Unknown	1°33'23.9"N 103°54'03.8"E	This study
Tasik Dahila, Gudang	Unknown	1°28'24.7"N 103°54'14.4"E	This study
Sungai Layang	Unknown	1°34'17.9"N 103°57'14.0"E	This study
Tasik Merdeka	Unknown	1°52'47.7"N 102°56'41.8"E	This study
Tanjung Laboh	Anglers	1°44'47.2"N 102°59'24.9"E	This study
Tasik Indahpura, Kulai	Unknown	1°37'52.0"N 103°35'45.1"E	This study
Perak			
Tasik Temenggor	Unknown	5°33'20.1"N 101°19'17.5"E	Yap et al., 2016
Tasik Chenderoh	Anglers	4°58'12.4"N 100°57'28.4"E	Hashim et al., 2012
Sungai Kampar	Unknown	4°28'15.2"N 101°16'31.2"E	Ng et al., 2018
Tasik Kampar	Anglers	4°20'17.1"N 101°08'26.3"E	Tan and Sze 2017
Tasik Kapal 7	Unknown	4°23'47.8"N 101°03'11.1"E	Saat et al., 2014
Tasik Raban	Anglers	4°59'53.2"N 100°56'56.4"E	Desa and Aidi 2013
Clearwater Sanctuary Golf Resort	Unknown	4°29'42.6"N 101°03'33.7"E	This study
Beng Lenggong (Mini Amazon)	Unknown	5°01'00.4"N 100°59'09.3"E	This study
Perlis			
Empangan Timah Tasoh	Anglers	6°33'57.5"N 100°13'02.7"E	Zulkefli 2017
Kedah			
Kulim Hi-tech Park	Unknown	5°26'34.5"N 100°33'52.8"E	This study
Pulau Pinang			
Pantai Kamloon	Unknown	5°33'54.7"N 100°26'40.4"E	This study
Sabah	-	-	Record not yet found
Sarawak	-	-	Record not yet found

It is noticed that most anglers in Malaysia engage in catch and release of peacock bass. However, other anglers and fishermen especially from Timah Tasoh in Perlis were seen to catch and sell or/and eat.

Natural disaster

Flooding is another factor that helps many aquatic species escape, expand and expose to natural water bodies from fish ponds/cages (Casimiro et al., 2018; Khaleel et al., 2019). A prolonged rainfall and heavy precipitation during the monsoon season cause a higher level of floods (Ahmed et al., 2018). In Malaysia, the flood is common and happens almost every year during the monsoon season (October-March), seldom causing serious damages (Mohammed et al., 2018). Severe floods cause physical destruction to aquaculture facilities and controlling predatory fishes to enter the wild environments is more difficult during the monsoon period (Ahmed et al., 2018).

In Malaysia, outdoor earth ponds, fiberglass and concrete ponds are predominantly used to raise ornamental fishes (Ng, 2016) which are becoming more vulnerable during the flooding period. A previous study on swamp eel *Monopterus albus* explained how flooding is playing a major role in fish movement and relocation across East Coast Peninsular Malaysia (Ahmad-Syazni et al., 2017). Ortega (2015) reported that peacock bass was discovered for the first time in lower sites of the Pantanal stream after a major flood occurred in Brazil. Other invasive species, such as clown featherback *Chitala ornata* in the Philippines which was first introduced into the river, were later found in the lakes after flooding caused by typhoon (Guerrero, 2014).

Ornamental fish trade

The blooming market in ornamental fish with a multibillion-dollar industry is now a relatively stable and strong global growth (Dey, 2016). Annually, about two billion live ornamental fishes are transported around the world, with freshwater fish coming from breeding practices making 90% of the total market (Chan et al., 2019). According to the Department of Fisheries Malaysia (2006), Malaysian aquarium fish sector evolved in the 1950s and developed significantly due to the high demand that continues for over the past 20 years. As a result, the rates of unintentional and deliberate releases of invasive freshwater aquarium fishes into natural aquatic habitat increased rapidly (Rahim et al., 2013). Recently, Malaysia recorded a total of 259 ornamental fish exporters (Department of Fisheries Malaysia, 2016; Ng, 2016). The majority of these invasive fish species are introduced through aquarium trade (Gubiani et al., 2018).

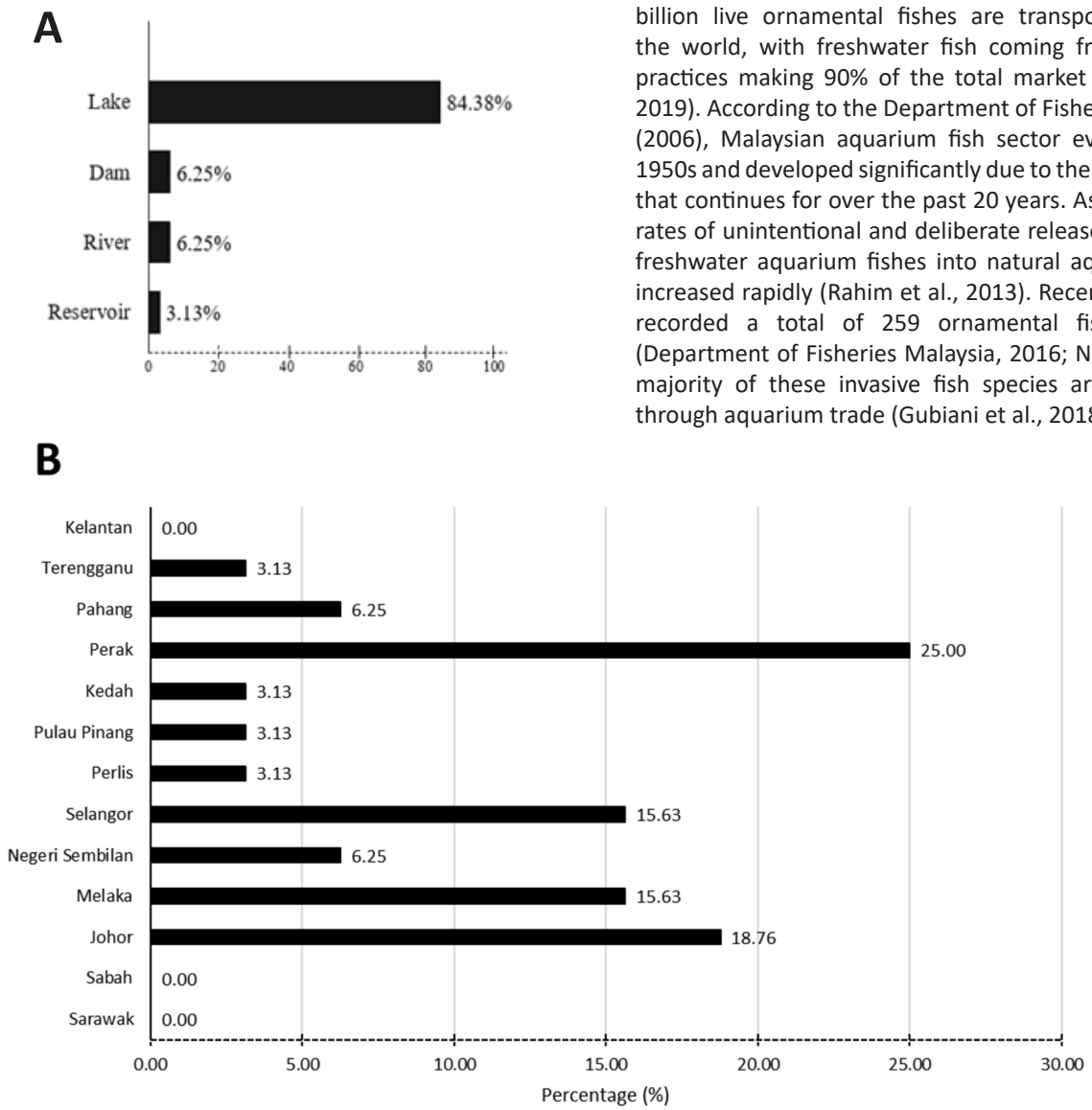

Fig 4. Percentage distribution of invasive peacock bass in Malaysia: (A) Freshwater bodies, (B) States

Peacock bass is a prominent and qualified ornamental fish among live aquatic species associated with the trans-boundary movement for their attractive body colour pattern (Magalhães and Jacobi, 2013). Most aquarium shops in Malaysia are engaging in selling or buying peacock bass. Currently, a young angler who caught a peacock bass of about 1 kg weight was observed at Lombong Chendering in Pahang. The angler directly sold the fish to a nearby aquarium pet shop in the state. Similarly, despite declaring the importation of peacock bass as illegal in Israel, species were recently found in Lake Kinneret (Golani et al., 2019). The study further explained that commercial fish traders smuggled juveniles as aquarium pets and they later escaped or were released from aquariums.

Factors responsible for the successful establishment of peacock bass in Malaysia

Propagule pressure

The success or failure of invasive species establishment in a newly invaded habitat is highly determined by propagule pressure (Cassey et al., 2018). Propagule pressure is an overall number of individuals of a species introduced, which includes the number of release/introduction events (propagule number) and the number of individuals introduced in a propagule number (propagule size) (Pigot et al., 2017). Propagule pressure intensifies the invasion capacity of aquatic invasive species by exposing area (demographical location) with suitable environmental conditions (Gallardo and Vila, 2019). Additionally, high propagule pressure can enable establishment. Different peacock bass species reported in Malaysia on the base of morphological identification could be a possible evidence that multiple introduction events might have occurred. However, studies on peacock bass genetic diversity and propagule pressure are necessary for more clarification on their invasion success in Malaysia. Possibly, hybridization between peacock bass species, originated from different native populations, might also happen. Previous research showed that peacock bass was successfully established in the south-eastern Brazil region, despite the fact that lower propagule pressure and low genetic variations were observed (Carvalho et al., 2014).

Habitat

Peacock bass originated from the Amazon, a tropical area that holds the world's largest freshwater biodiversity (Jézéquel et al., 2020). The Amazon is characterised with warm temperature, high humidity and rainfall with monsoon season starting from December until February (Boers et al., 2017). In their native environment, peacock bass usually lives in shallow littoral lakes and river habitats, requiring highly transparent water, lentic area and warm temperatures for both reproductive and feeding reasons (Espínola et al., 2014; Franco et al., 2017). Malaysia is also a tropical country that shares a common climatic factor with the Amazonian region (Table 2). An updated world Köppen-Geiger climate classification map further confirmed a similarity match between Malaysia and the Amazonian region (Peel et al., 2007). A place like Kampung Beng Lenggong popularly known as Mini Amazon in Perak is more like an Amazon prototype (Rasoolimanesh et al., 2016). Mini Amazon is a peacock bass hotspot that attracts both local and international tourists. With these similarities, peacock bass requires limited time to acclimatize and establish in the Malaysian freshwater habitats.

Table 2. Similarity of environmental and climatic factors between the Amazon and Peninsular Malaysia

Factors	Amazon	Peninsular Malaysia
Geographical zone	Tropical	Tropical
Vegetation zone	Forest	Forest
Season	Rainy/Dry	Rainy/Dry
Torrential rainfall	Monsoon	Monsoon
Weather condition	Humid and warm	Humid and warm
Annual rainfall	1,500—3,000 mm	2,420 mm
Temperature	25.8 °C—27.9 °C	22.1 °C—29.5 °C
Humidity	77% — 88%	84% — 88%

Reproduction

In general, peacock bass are highly prolific characterised with multiple spawning per year (Braga and Rebêlo, 2017). They are sedentary species showing high parental care, guarding eggs until all fry hatch and mature. Spawning takes place on submerged tree trunks and branches in lakes or reservoirs and they dig a mini hole in the bottom of the river (Braga and Rebêlo, 2017). This is to ensure the safety and survival of the eggs from external danger. Looking at the reproductive nature of peacock bass, the egg hatchability success and fry survival rate is high. The species can establish easily and take over the water like recently reported from Empangan Timah Tasoh in Perlis (Zulkefli, 2017).

Prey availability

Small peacock bass primarily feeds on macro-invertebrates and zooplanktons, but individuals of as little as 50 mm can start to prey on small fishes, and at the size of 200 mm they become fully piscivorous (Neal et al., 2017). Mature peacock bass grows much bigger in several reservoirs with approximately 1 m total body length with over 12 kg weight and usually feeds on fishes (Winemiller, 2001; Aguiar-Santos et al., 2018). Zhao et al. (2014) added that peacock bass consumes a wide range of prey "generalist piscivorous" and can ingest the whole prey that can pass

their gape sizes. The species has a developed swimming ability that enables them to swim and became an effective hunter (Aguiar-Santos et al., 2018). Prey is normally caught by stalking or ambush with cannibalism nature (Brejão et al., 2013; Pereira et al., 2017; Khaleel et al., 2020b). There is a limited study on the trophic ecology of peacock bass in Malaysia. However, stable isotope approach study in Chenderoh Lake Perak confirmed higher trophic position and predatory nature of peacock bass (Yap et al., 2016). Similarly, a recent study by Khaleel et al. (2020b) on the DNA barcoding revealed the prey items in the stomach of peacock bass. Seven prey species were discovered including *Cichla ocellaris, Pristolepis fasciata, Parambassis ranga, Rasbora trilineata, Cyprinus carpio* and *Cyclocheilichthys enoplos*. Peacock bass can easily have access to a wide range of prey which enables their establishment and enhances production. This might be due to wide freshwater species diversity in Malaysia (Hashim et al., 2012; Ng et al., 2018). This is a reason for describing peacock bass as a highly predator and generalist feeder with an opportunistic feeding behaviour (Khaleel et al., 2020b).

Stress resistance

Catch and release in sport fishing causes fish to display complex responses, ranging from complete survival and minimal sub-lethal effects to exceedingly high mortality rate levels (up to 90%) with other extensive effects like depressed reproduction, feeding and immune response (Arlinghaus et al., 2007). However, a recent study on peacock bass found that the stress caused by catch and release normally lasted for a short period and injuries from the hooks did not affect their survival rate or feeding ability (Thomé-Souza et al., 2014; Barroco et al., 2017). Barroco et al. (2017) added that death is normally caused by predation due to loss of blood and external injuries caused by angling hooks. There is an increased pressure among tourists and anglers toward peacock bass catching in Malaysia. Mohd et al. (2015) reported that most anglers in Malaysia freshwater are engaging in catch and release. In June 2017, there was a decrease in water level caused by irrigation water released, and a prolonged hot and dry season in a lake at West Coast Peninsular Malaysia led to the mass mortality of fish species (Abdullah et al., 2018). Peacock bass and catfish were less affected, while other species such as wild tilapia and river barb were severely affected with their dead bodies floating on water surfaces. Other studies showed peacock bass high resistance towards heavy metals, especially those collected from areas with a history of mining such as Perak and Selangor (Saat et al., 2014; Tan and Sze 2017).

Predators

Interactions between invasive predators and their competitors and predators determine an invasion success (Sih et al., 2010). The chances of invasive predator to successfully establish in a new environment reduces with an increase in competitors (Svenning et al., 2014). In Malaysia, there is no report of any predatory aquatic species prey/hunting on peacock bass. Peacock bass might be one of the top predators in most of the invaded freshwater habitats in Malaysia. For instance, through a preliminary observation on the gut content of peacock bass species, they are also consuming snakehead fish (*Channa* spp.) which is among the fiercest predators in the freshwater habitat of Malaysia. Similarly, the absence of predators and natural competitors has been documented in the successful invasion of peacock bass in the central Brazilian Paranaíba River (Ferraz et al., 2011). Peacock bass has a good quality meat which triggers its commercial fishing in various invaded areas in the world (Winemiller, 2001; Vieira et al., 2009; Silva et al., 2013). However, the consumption rate of peacock bass is too low in Malaysia as many people consider them as an ornamental fish species. This could aid in promoting their reproduction and establishment success in the invaded habitats.

Impact of peacock bass on native species biodiversity

High predatory nature and heavy feeding habit on native species make peacock bass became a merciless invasive species that destroys and occupies an invaded ecosystem when successfully established (Silva et al., 2013; Franco et al 2017). In invaded habitat, negative impacts have been documented for invasive peacock bass including population reduction and extinction of native fish species (Zaret and Paine, 1973; Pelicice and Agostinho, 2008; Franco et al 2017; Sharpe et al., 2017). There is little/no data and checklist on species biodiversity in most peacock bass invaded freshwater habitats in Malaysia. For this reason, it is very difficult to understand the true impact of this piscivorous fish on native species. However, local fishermen in the various locations are reporting less fish landing mass due to the existence of peacock bass in the water (Zakaria, 2017; Zulkefli, 2017; Khaleel et al., 2020a). The income generation of these local fishermen decreased drastically as their livelihood depends solely on fishing activities. Other fishermen reported catching more peacock bass than preferred local fishes with high market value.

Conservation challenges

Peacock bass are successfully established in many freshwaters in Malaysia as mentioned earlier. Piscivorous feeding nature on live prey is the main challenge regarding the management of this species. Until now, various kinds of research on artificial feeding trials were conducted for intensive culture of peacock bass, but yielded less desired results with too much production cost as live species were also included in feeds (Kubitza and Cyrino, 1997; Moura et al., 2000; Cyrino and Kubitza, 2003). Therefore, their intensive culture is challenging for owners, therefore left with no option but to release them into open water. According to NCIASM (2018), "peacock bass is listed in Fisheries Regulations (Prohibition of Import, etc., for Fish)

Amendment 2011, Fisheries Act 1985 as a prohibited species to import, sale, culture and keep in Malaysia". But hobbyists continue to distribute them locally to various open water bodies. Also, insufficient data on the biodiversity of many invaded lakes could lead to misleading information on the actual effect of this species on native species biodiversity. Malaysia's natural environment is one of its typical blessings for tourist attractions (Gani et al., 2017). Ecotourism is reasonable tourism relied on natural resources that mainly encourages conservation whilst boosting economic development (Aznan et al., 2017). The authors added that uncontrolled tourism could lead to the further release of such invasive species.

CONCLUSIONS AND FUTURE PLANNING

Ideas on how sustainable management of this resource could be attained were presented. The present findings and recommendations are successful with the full cooperation of fishermen and some anglers, not on the scientific level only but also on the level of fisheries. Eradicating peacock bass in Malaysia is nearly impossible as the species was already established together with several other consequences. Peacock bass provides physical jobs and emotional benefits for thousands of citizens. However, the damage this species will cost to Malaysia's freshwater biodiversity in the future is unpredictable. The impact will also affect several fishermen who heavily depend on fishing activities for their income generation and livelihood. Therefore, conservation measures need to be put in place to rescue the native species against this high predatory fish. The species already passed the appropriate stages for effective invasive species control which includes prevention, early detection and eradication stages (Carpio et al., 2019). The final stage left to apply is a proper management control through the following recommendations: (1) Checklist and accurate data of Malaysian freshwater bodies should be up to date for accurate risk assessments; (2) Applying modern technology such as geographic information system model (GIS) and environmental DNA technique (eDNA) to improve the conventional monitoring system and predict future expansion of the species; (3) Reduce the species population size by encouraging citizens to catch and consume; (4) Regulation and law enforcement, with proper monitoring and control of the local transfer of this species by hobbyists, anglers and ornamental fish traders by the relevant government agencies; (5) General public awareness regarding the impact of this species on aquatic native species biodiversity; (6) Finally, education of anglers could be a good way to protect species not to be translocated to new aquatic habitats.

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UNOS INVAZIVNOG PAUN GRGEČA (*Cichla* spp.) NJEGOVA BRZA DISTRIBUCIJA I BUDUĆI UTJECAJ NA SLATKOVODNI EKOSUSTAV U MALEZIJI

SAŽETAK

Malezija je prepoznata kao zemlja visoke razine raznolikosti s obiljem različitih slatkovodnih vrsta. Malezijska slatkovodna bioraznolikost ugrožena je nakon uvođenja invazivnog paun grgeča (*Cichla* spp.). Prisutnost ovog grabežljivca mogla bi ugroziti suživot autohtonih vrsta slatkovodnog ekosustava u Maleziji. U preglednom radu obrađeni su najvažniji aspekti u vezi s prijetnjama paun grgeča budućoj biološkoj raznolikosti lokalnih vrsta. Trenutno su u Maleziji prepoznate četiri lokalno neprisutne vrste paun grgeča. Do danas, vrste paun grgeča raširile su se u sve dijelove Malezijiskog poluotoka, s još nezabilježenim pronalaskom u Kelantanu i Borneu. „Invazivnom uspjehu" podložnija su malezijska jezera (84,38%) pri usporedbi s rijekama i rezervoarima. Brzi način širenja ove vrste izrazito je povezan sa sportskim ribolovom i ribolovcima. Način razmnožavanja, povoljno stanište, brojnost plijena i ponašanje pri ishrani odgovorni su čimbenici uspješnog uspostavljanja ove vrste u Maleziji. Vrste su, prema hranidbenoj prirodi, generalisti i ribojedi. Paun grgeča je teško iskorijeniti u Maleziji, između ostalog, i zbog toga jer je kroz doprinos gospodarstvu povezan sa zapošljavanjem ljudi (kroz rekreativni ribolov i turizam). Moguća šteta koju će vrsta uzrokovati na slatkovodnim ekosustavima u budućnosti je nepredvidljiva. U ovom trenutku preporuča se primjena pravilnog upravljanja ovom vrstom kako bi se smanjila njena populacija. To bi se moglo postići ažuriranjem popisa slatkovodnih površina u državi, poboljšanjem sustava praćenja stanja (monitoringom) i podizanjem svijesti o navedenoj problematici.

Ključne riječi: očuvanje biološke raznolikosti, slatkovodni ekosustavi, invazivne vrste, paun grgeč, Malezija

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