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The Influence of Alien Fish Species on Native Fish Community Structure in Malaysian Waters

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Abstract

Introduction of alien fish species has resulted in major global change, harming native species and communities throughout the world. The main objectives of this review were to examine the species composition, ecology, and distribution of alien fish species in natural water bodies and evaluate the role and contribution of alien fish species through aquaculture to socio-economic development in Malaysia. The rate of introduction and the number of alien fish species introduced into local habitats have greatly increased since the early twentieth century. A statistical analysis of habitat differences among native fish species in Malaysia indicated that differences in fish assemblage structure in various sites was associated with differences in physical habitat. However, the occurrence of alien species has not only changed the structure of native ichthyo-fauna groups but has also caused ecological damage and economic harm to local fishermen. At present, alien fish species inhabit diverse environments including highland and isolated streams, rivers, rice fields, swamps, drainage areas, dams and reservoirs, lakes created from former mining areas, and estuaries in Malaysia. The examination of species composition, distribution and movement of alien fish in natural habitats revealed that these species have seriously spread and are now distributed in diverse aquatic habitats of Malaysia. This in turn provided evidence that there are no restrictions or limitations to the spreading of alien fish species in the natural habitats of Malaysia.

Key words: alien fish species, Malaysia, native fish fauna

Introduction

Human facilitation of the movement of living organisms across continents has caused profound alteration in the ecology of relocated species and the communities to which they have been introduced (Callaway *et al*., 2006). In addition, the rate of increase and the scale of these movements is rapidly becoming a major focus of ecologists, conservation biologists and resource managers around the world (Williamson, 1996) in part due to the fact that the introduction of alien fish or exotic species are causing and may cause further threats to native biodiversity (Fernando, 1991; Dudgeon, 2003). The globalization and growth in the volume of trade and tourism, coupled with the emphasis on free trade, provide more opportunities for fish species to be spread both deliberately and accidentally (Welcomme, 1984; Jenkins, 1996; Cohen and Carlton, 1998; Casal, 2006; Sampson *et al*., 2009). These factors may exert tremendous pressure on the population and diversity of aquatic organisms, particularly on native fish fauna.

Experiences throughout the world have shown that a number of problems may arise following the introduction of a new species. These include the following: disruption of the receiving environment; predation and interspecific competition; overcrowding and stunting; genetic degradation; introduction of parasites and disease; and extinction of many native species (Zaret and Paine, 1973; Taylor *et al*., 1984; Welcomme, 1988; Jianqing *et al*., 1996; Bedarf *et al*., 2001; Johnson *et al*., 2006; Gaygusuz *et al*., 2007; Amundsen *et al*., 2009).

However, the issues of alien fish species in the freshwater environment in Malaysia were greatly undervalued and have not received much attention (Othman and Hashim, 2003). Indeed, a comprehensive study on species composition, ecology, habitat preference and distribution of alien species in Malaysia is still scarce (Khairul Adha, 2012). Although there are no detailed studies

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have yet appeared in the literature that have focused on the ecology and distribution of alien fish in Malaysia, the presence of alien fish in Malaysian waters has been recorded by Herre and Myers (1937), Herre (1940), Tweedie (1952), Department of Fisheries Malaysia (1958; 1959), Alfred (1961), Mohsin and Ambak (1983), Ang *et al*., (1989), Inger and Chin (1990), Kottelat *et al*. (1993), Khan *et al*. (1996), Ali (1998), Lim and Tan (2002), Chan (2004), Salam and Gopanith (2006), Atack (2006), Esa *et al*. (2006) and Khairul Adha *et al*. (2009). After Lim and Tan (2002) there have been no serious efforts to compile, record and estimate the number of imported exotic fish species in Malaysia. Chong *et al*. (2010), only cited Lim and Tan (2002) in the recording of 24 alien fish species in Malaysian freshwaters. However, Khairul Adha (2012) has recently, conducted comprehensive studies including field surveys and observations on species composition, ecology, habitat distribution and the relative abundance of alien fish species across a variety of habitats in Malaysia. Indeed, it is essential to record and document the number of fish species, the history and reasons for their introduction, and the current status of alien fish species in Malaysian waters.

History of alien fish introduction in Malaysia

Malaysia has had a long history of introduction of alien fish species. The introduction of alien fish species in Malaysia began as early as the twentieth century, along with the immigration of the southern Chinese (Mohsin and Ambak, 1983; Ang *et al*., 1989; Ali, 1998). Subsequently, after World War II, many alien fish species were introduced by the Department of Fisheries, semi-government bodies, private sectors and individuals either for aquaculture, recreational fisheries or the aquarium fish industry (Ang *et al*., 1989; Khairul Adha *et al*., 2010).

The major modes of the spread of alien fish species into Malaysia include deliberate introduction for aquaculture, the improvement of fisheries (stocking), the aquarium trade, sport fishing, and biological control (Department of Fisheries Malaysia, 1958; 2004; 2010, Mohsin and Ambak, 1983; Ang *et al*., 1989; Inger and Chin, 1990; Hanafi *et al*., 1995; Chan, 2004; Salam and Gopinath, 2006). The pathways of unintentional introductions of alien fishes in rivers, lakes and wetlands include escape or release from fish farms, use as fish bait, and disposal of unwanted pet aquarium fishes (Mohsin and Ambak, 1983; Salam and Gopinath, 2006; Chong *et al*., 2010). The trend has continued with several new species and new introductions of established species being discovered from time to time.

Aquaculture of alien fish species

Freshwater fish culture began among farmers in Malaysia more than 50 years ago. However, over the last two decades, freshwater aquaculture production in Malaysia as well as Asia in general has increased dramatically (Khairul Adha, 2011). Thus, great efforts are being made to domesticate new species and improve production traits of commercially important aquatic species (Ang *et al*., 1989; Khairul Adha, 2012). Many freshwater fish fingerlings, particularly from alien fish species such as Indian and Chinese carp, Javanese carp, catfish and red tilapia have been raised for aquaculture expansion, and have been released into public bodies of water throughout the country by the Department of Fisheries in order to sustain fish stocks and encourage recreational fisheries (Department of Fisheries Malaysia, 1955; 1990; 2009; Hanafi *et al*., 1995).

Khairul Adha (2012) has recorded 27 species or 64.3% of alien fish as being introduced for aquaculture development in Malaysia (Figure 1). This finding agrees with Casal (2006) and De Silva *et al*. (2006; 2008) and suggests that aquaculture activities were a gateway for species introduction globally. The statistical analyses from Annual Fisheries Statistics from 1955 to 2009 showed that alien species form a very important component in inland fisheries aquaculture production and value in Malaysia (Khairul Adha, 2011; 2012). In fact, the success and effectiveness of techniques for the improvement of large-scale artificial breeding and culture of a variety of alien fishes has increased the number of introduced aquaculture fish species as well as fish fry production in Malaysia (Hanafi *et al*., 1995; Khairul Adha *et al*., 2011). For example, the number of species, the production of alien fry and the total number of alien fish species released in public water bodies were significantly higher when compared with native fish species within the last 40 years (Khairul Adha, 2012).

This industry will continue to expand and aquaculture will be of growing importance for regional food security and national development in the Asia-Pacific region (Mather, 2008). Thus, programs for extensively restocking fish species by the government fisheries department in freshwater bodies has deliberately increased the number alien fish species in rivers, lakes created through mining activities, dams, natural lakes and rivers throughout the country since the 1950's (Department of Fisheries Malaysia, 1955; 2008; 2009; Hanafi *et al*., 1995). These are some of the main causes

of the introduction, translocation and spread of alien fish in various habitats in Malaysian water.

Ecology, distribution and the establishment of alien fish species in Malaysia

The intentional introduction of new fish species for aquaculture, recreational fisheries stocking enhancement, biological control and the aquarium fish industry has also led to the widespread establishment of alien species in local ecosystems (Marchetti *et al*., 2004a,b; Ruesink, 2005). Many studies have demonstrated that native fish communities in Malaysian tropical streams and rivers are structured (Inger and Chin, 1990; Choy *et al*., 1996; Martin-Smith, 1998; Zakaria *et al*., 1999; Samat *et al*., 2002; Amir Shah *et al*., 2009) and influenced by several distinct biogeographic zones (Mohsin and Ambak 1983; Inger and Chin, 1990; Zakaria-Ismail, 1994; Ahmad *et al*., 2006). However, Khairul Adha (2012) found that, with the introduction of alien species to natural habitats, changes have occurred in the structure of icthyo-faunal groups based on the difference in habitat. The study showed that alien species not only inhabit the lower streams but are also found in the upper stream habitat. In addition, these alien species have successfully survived in extreme habitats with turbid and slow flowing water, high temperature, a lower pH value and lower oxygen concentration (Beamish *et al*., 2003; Khairul Adha, 2009). This indicated that alien fish can tolerate a wide range of environmental conditions and finally become established in wild habitats.

Comprehensive studies on the species composition, ecology, habitat distribution and relative abundance of alien fishes across a variety of habitats by Khairul Adha (2012) in Malaysia, provided evidence that there are no restrictions or limitations of dispersal of alien fish species in natural habitats in Malaysia. For instance, alien species such as *Oreochromis mossambicus, Oreochromis niloticus, Tilapia zillii* and *Cyprinus carpio*, were found in highland streams approximately 1000 m above sea level at Kelalan River in Sarawak, Borneo (Khairul Adha *et al*., 2010). Nyanti *et al*., (1998) also found that *O. niloticus* and *O. mossambicus* fish inhabited in rice fields and rivers in the Bario Highland. This finding demonstrated that humans are the main source for the spread and translocation of alien fish for aquaculture development and stocking enhancement in various habitats throughout Malaysia. According to McKinney (2001; 2006), humans increased the rate and scale of these movements and are accountable for many introductions of alien species in all types of ecosystems.

The accidental release of the labyrinth fish, *Helastoma temminckii,* from a pond of the Agriculture Development Centre as well as from a farmer's pond into the Baram river system in 1963 (Hans and Morshidi, 2000; Esa *et al*., 2006) caused the population of this labyrinth fish to become established and thrive in lakes, rivers and swamp areas in the Baram basin of north Sarawak (Murtedza *et al*., 2000; Nyanti *et al*., 2006) and in other areas such as in Balai Ringin and the Samarahan Division in the south of Sarawak (Scott, 1989; Esa *et al*., 2006; Khairul Adha *et al*., 2009). The domination of *H. temminckii* in Loagan Bunut National Park (Nyanti *et al*., 2006), the Bakong River (Murtedza *et al*., 2000) and in the black water habitat of the Batang Kerang (Khairul Adha *et al*., 2009; 2010) area in Sarawak may threaten the diversity of native species and spark competition for food, habitats, spawning, and refuge (Morgan *et al*., 2004; Becker *et al*., 2005). This omnivorous fish primarily grazes on benthic algae, a variety of aquatic plants, zooplankton and insects (Kotellat *et al*., 1993; Mohsin and Ambak, 1983), and can tolerate low dissolved oxygen and low pH (Khairul Adha *et al*., 2004). According to Lodge *et al*. (1998) and Marchetti (1999) the domination of alien fish species has caused widespread decline of and has even contributed to the extinction of indigenous fishes in California. Murtedza *et al*., (2000), Khairul Adha *et al*., (2009) and Khairul Adha, (2012) found that *H. teminckii,* which formed a major part of the fish catch in the Bakong River and the Batang Kerang floodplain, was not favored by the local fishermen. Introductions of alien species for aquaculture development sometimes prove to be economic failures as the species introduced were not accepted by the local population because of their unfavorable taste (Pullin and Lowe-McComell, 1982).

Recreational fishing has provided the second major reason for the introduction and establishment of alien fish species in Malaysia. As one prominent example, the peacock bass or *Cichla ocellaris* species was deliberately introduced in Peninsular Malaysia and was released into a lake made from a former mining area by irresponsible anglers in the early 1990s for sport fisheries (Khairul Adha, 2006). Although Chong *et al*. (2010), described the peacock bass as good sport fish, the impact of these fish on native fish is not known locally. These fish were not only found in the ex-mining lake in the northern part Perak state but also in other artificial lakes and reservoirs in the middle and southern parts of Peninsular Malaysia (Khairul Adha, 2012). This *Cichla* species is a voracious predator, feeding on a wide range of prey, capable of greatly modifying ecosystems where introduced and dis-

playing complex reproductive strategies (Gomiero and Braga, 2004; Novaes *et al*., 2004). Uncontrolled spread and unintentional release of this species into freshwater habitats within Peninsular Malaysia could have a negative impact on the aquatic ecology of its new home. Every effort should be taken to eradicate the occurrence of this species from Malaysian water bodies. Indeed, to protect native fish diversity the management authorities should focus on preventing the introduction of these kinds of species in the first place because the eradication after establishment is usually not possible (Lodge *et al*., 1998).

According to Ang *et al*. (1989) and Rohan (1994) most carp species from India and China do not breed naturally in Malaysian and Sri Lankan waters and stocks are maintained by artificial reproduction. Although most Indian carp and China carp species are unable to establish a population and do not breed locally, the Fisheries Department of Malaysia however, continues to release a large number of these non-indigenous fish into the natural environment by repeated stocking with artificial reproduction (Department of Fisheries, 1955; 2010). However, many studies have shown that introduced carp species has destroyed aquatic vegetation (Crivelli, 1983; King and Hunt, 1967), and disturbed spawning and nursery areas of native fish (Ross, 2001). Presently, no scientific studies have been conducted to determine whether the introduction of carp species has potentially caused harmful impacts on vegetation and native fish populations in Peninsular Malaysia (Khairul Adha, 2012). Instead, efforts have been made to promote carp species for aquaculture ponds and also to continue releasing carp species into natural habitats in order to meet market demands.

In addition, the status and condition of alien fish species such *Collosoma* sp., *Clarias gariepinus, Clarias macrocephalus* and *Pangiasus* spp. found in local habitat is unknown (Khairul Adha, 2012). However, Pallewatta *et al*. (2003) has shown that *Clarias gariepinus* and *Pangasius* spp compete with local species for food and eat almost everything they encounter.

The aquarium fish industry that was established in the 1950s has significantly increased in the last 20 years due to high demand (Department of Fisheries Malaysia, 2006). As a result of the rapid expansion of the aquarium industry, the number of accidental and intentional releases of alien freshwater aquarium fish into freshwater habitats has increased. Although a large number of alien aquarium fish has been introduced, the documentation on the number of imported exotic aquarium fishes recorded in Malaysia is presently almost unavailable. In fact, there is no scientific documentation on the ecological and biological impacts of these alien species on native fish fauna in Malaysia. However, the presence of some 34 species of aquarium fish has been noted by Ang *et al*. (1989). According to Fuller *et al*. (1999) and Rixon *et al*. (2005), the aquarium fish industry has been responsible for the introduction of many fish species into areas where they are not native.

The lack of restriction and the uncontrolled trade in the aquarium fish industries therefore not only has the potential for changing the aquatic habitat communities through predation and food competition with native species (Flecker and Townsend, 1994; Moyle *et al*., 1986) but also poses the possibility that these alien fish species will cause economic harm to the local fishermen by destroying their fishing nets (Khairul Adha, 2012). According to Jefferine *et al*. (2007) and Khairul Adha *et al*. (2010) the occurrence of several size classes of sucker mouth catfishes *Hypostomus plecostomus* in the Serting and Sarawak rivers in Peninsular Malaysia and Borneo, respectively, might indicate that species is firmly established. The local fishermen reported that the occurrence of a high population of species from the family Lorricaridae in the Sarawak River has reduced their commercial fish catch as this species destroys their fishing nets when too many armored catfish are trapped in the nets, eventually causing economic harm to local fishermen (Khairul Adha, 2012). According to Colautii *et al*. (2006a,b) invasion of alien species can have adverse effects on economically important goods, such as reduced yields of natural resources. Miglietta and Lessios (2009) stated that some alien invasions have dramatic economic and ecological consequences. For example, Pimentel *et al*. (2000; 2001) estimated the total damage and control costs of about $137 billion USD per year for all alien species in the United States. At present, no specific studies in Malaysia have examined the importance of invasive species for economic reasons, such as introduced fish for aquaculture development or introduced species that have naturally established themselves in local environments. Understanding the magnitude of economic costs associated with the introduction of alien species is important for environmental policy and management and also for the development of national economies (Colautti *et al*., 2006a).

Current status of alien fish introduction in Malaysia

Based on the most recent field surveys and reviewed literature, it is estimated that a total of 42 alien fish spe-

cies have been recorded as being introduced to Malaysian waters (Khairul Adha, 2012) (Table 1). This total can be broken down as follows: 27 species or 64.3% of the fish were introduced for aquaculture development; 8 species (19.0%) were aquarium fish; 6 species (14.3%) were introduced for recreational fisheries; 1 species (2.45%) was introduced for biological control purposes (Fig. 1).

The number of alien fish species - including the hybrid recorded by Khairul Adha (2012) - are almost twice as many as the number of species catalogued in Lim and Tan's study of 2002. The 2012 study showed that the rate of introduction and number of alien fish introduced into local habitats has tremendously increased in the last nine years. According to Casal (2006) and Welcomme (1984), globalization together with rapid growth of trade and tourism has offered more opportunities for fish species to be spread both intentionally and accidentally. The increased number of alien fish introduced into Malaysia is attributed to the rapid growth in the aquaculture, recreational and aquarium fish industries, an increasing interest in sport fishing and also in the increasing demand for fish as a source of protein.

Furthermore, the massive growth of the human population has significantly correlated with the introduction of alien fish diversity (McKinney, 2001; 2006). The population of Malaysia, which was only 9 million in 1963, had increased to 27.6 million (32.6%) by 2010 (Department of Statistics, Malaysia 2011). As the population increases, the native fish resources alone are not adequate in meeting the needs of local populations throughout the country. Consequently, there has been a dramatic increase in the number of fish introduced into Malaysia, especially for aquaculture development, in order to meet the local demand for fish as a source of cheap protein (Khairul Adha, 2012).

In the time since the *Barbonymus gonionotus*, *Trichogaster pectoralis* and *Oreochromis* species were introduced more than 50 years ago, these fish have successfully adapted and have demonstrated their ability to breed naturally in the wild, now being well distributed in local environments (Mohsin and Ambak 1983). The presence of popular aquarium fish, such as sucker mouth catfishes, *H. plecostomus* and the Peacock bass or *C. ocellaris,* in rivers and ex-mining lakes, might indicate that these two species are probably well established and self maintained locally (Khairul Adha, 2012). Alien fish

Table 1. List of the occurrence of alien freshwater fish species that has been introduced into Malaysia.

Family and Species	Common name	Introduced from	Reason for introd introduction
Arapaimidae			
Arapaima gigas	`Pirarucu'	South American	Aquarium
Belontiidae			
Betta splendens	Siamese fighting fish	Thailand	Aquarium
Trichogaster pectoralis	Skinned gouramy	Thailand	Aquaculture
Centrarchidae			
Micropterus salmoides	Largemouth bass	Florida	Recreational
Characidae			
Colossoma sp.	Red promfet	Taiwan	Aquaculture
Cichlidae			
Etroplus suranensis	Green chromide	Sri Lanka	Recreational
Oreochromis mossambicus	Mozambique tilapia	Indonesia	Aquaculture
Orochromis niloticus	Nile tilapia	Thailand	Aquaculture
Oreochromis urolepis hornorum	Nile tilapia	Na	Aquaculture
O. hornorum and *O. mussambicus* Hybrid	Na	Aquaculture	
Cichla ocellaris	Peacock Bass	South America	Recreational
Cichla monoculus	Peacock Bass	South America	Recreational
Red tilapia hybrid	Tilapia	Thailand	Aquaculture
Tilapia zillii	Redbelly tilapia	Na	Aquaculture
Clariidae			
Clarias macrocephalus	Broadhead catfish	Thailand	Aquaculture
Clarias gariepinus	African catfish	Na	Aquaculture

Family and Species	Common name	Introduced from	Reason for introd introduction
Cyprinidae			
Barbonymus gonionotus	Java barb	Indonesia	Aquaculture
Carassius auratus auratus	Gold fish	China	Aquaculture
Ctenopharyngodon idella	Grass carp	China	Aquaculture
Hypophthalmichthys nobilis	Bighead carp	China	Aquaculture
Hypophthalmichthys molitrix	Silver carp	China	Aquaculture
Cyprinus carpio	Common carp	China	Aquaculture
Cyprinus carpio specularis	Mirror carp (hybrid)	China	Aquaculture
Cirrhinus chienensis	Chinese mud carp	China	Aquaculture
Mylopheryngodon piceus	Black carp	China	Aquaculture
Carassius sp *x Cyprinus* sp.	Japanese carp	China	Aquaculture
Catla catla,	Catla	India	Aquaculture
Cichlidae			
Lobeo rohita	Rohu	India	Aquaculture
Cirrihinus cirrhosus	Mrigal	India	Aquaculture
Gobiidae			
Rhinogobius giurinus	Barcheek Goby	China	Aquarium
Helostomatidae			
Helostoma temminckii	Kissing gouramy	Thailand	Aquarium
Lepisostidae			
Lepisostius spatula	Alligator gar	USA	Aquarium
Loricariidae			
Hypostomus plecostomus	Armored Catfish	South America	Aquarium
Pterygoplichthys pardalis	Amazon sailfin catfish	South America	Aquarium
Salmonidae			
Oncorhynchus mykiss	Rainbow trout	Scotland	Recreational
Salmo gairdneri	Rainbow trout	New Zealand	Recreational
Pangasiidae			
Pangasius pangasius	Yellotail catfish	Na	Aquaculture
Pangasius hypopthalmus	Striped catfish	Thailand	Aquaculture
Poeciliidae			
Poecilia reticulate	Guppy	Na	Aquarium
Poecilia sphenops	Molly	Na	Aquarium
Gambusia affinis	Mosquito fish	Na	Biological control
Terapontidae			
Scortum Barcoo	Jade perch	Australia	Aquaculture

Information compiled from Herre (1937;1940), Tweedie (1952), Department of Fisheries Malaysia (1953; 1955; 1956; 1957; 1970; 1985; 2000; 2004; 2009; 2010),), Hickling (1960), Johnson (1967;1968), Chen *et al*. (1969), Mizuno and Furtado (1982), Mohsin and Ambak (1983), Welcomme (1984;1988), Khoo *et al*. (1987), Chuah and Nor Azman. (1988), De Silva (1989), Robert (1989), Inger and Chin (1990), Thalatiah and Ibrahim (1992), Kotellat *et al*. (1993), Lim *et al*. (1993), Zakaria-Ismail (1994;1997), Kotellat and Lim (1995), Hanafi *et al*. (1995), Khan *et al*. (1996), Garibaldi, (1996) FAO, (1997), Ali (1998), Nyanti *et al*. (1998; 2006), Froese and Pauly (2008; 2010), Hans and Morshidi (2000), Leh (2000), Murtedza *et al*. (2000), Lim and Tan (2002), Chheng *et al*. (2004), Ahmad and Khairul Adha (2006), Hoong (2006),The Star (2008), Hamid and Zainudeen (2009), Khairul Adha *et al*. (2009; 2010), Chong *et al*. (2010), Khairul Adha (2011). (Na = species data not available) * *Helostoma temminckii* native to Peninsular Malaysia but introduced fish to Sabah and Sarawak.

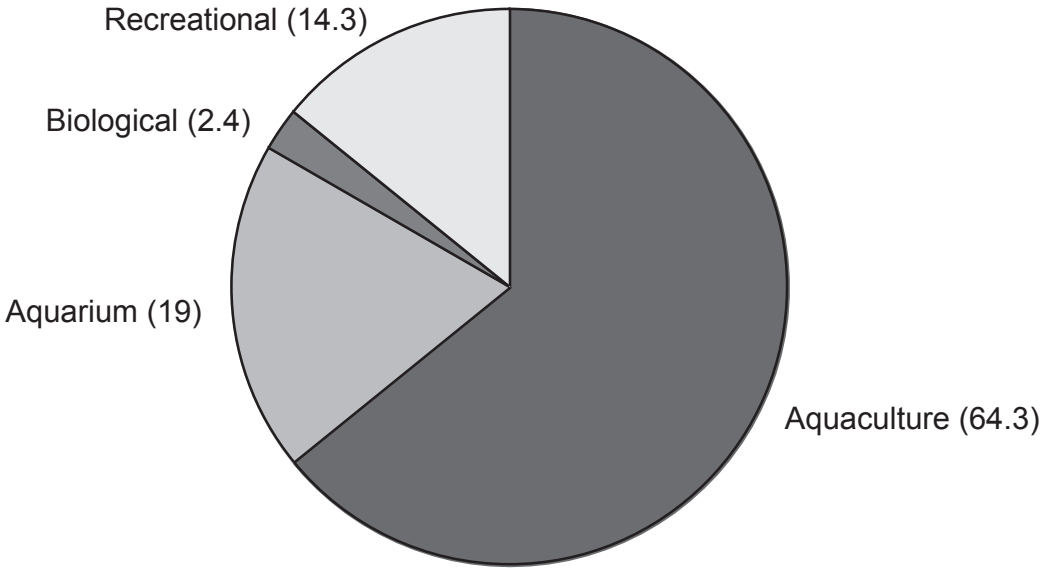

Fig. 1. The percentages (%) of alien fish families that have been intentionally and unintentionally introduced into Malaysia since the 1900s for aquaculture development, the aquarium fish trade, recreational fisheries and biological control (After Khairul Adha, 2012).

species may be especially likely to become established when they are introduced in large numbers of individuals or introduced repeatedly (Alpert, 2006). Indeed, the Fisheries Department of Malaysia continues to release a large number of these alien fish into the natural environment for restocking enhancement in public bodies of water throughout Malaysia. The successful adaptation and establishment of these alien species generally are characterized by the following factors: becoming large and abundant in their native range; maintaining a high genetic variability; subsisting on a broad diet; having a short generation time; and being able to move freely from place to place (Sala *et al*., 2000; Ehrlich, 1989).

Although some studies have concluded that alien fish species have numerous adverse effects on native fish and aquatic systems (Joshi and Sebastian, 2006; Miller and Crowl, 2006; Fuller *et al*., 1999) others suggest that it is still premature to suggest that the occurrence of alien species in Malaysia has had a significant effect on native fish fauna (Khairul Adha, 2012). Simberloff (1981) concluded that alien species had "no effect" in 77% of various native communities examined. According to Gido and Brown, if environmental conditions are favorable, alien species can exploit unoccupied environmental space and coexist with native species (Simberloff, 1981), resulting in an increase in total species richness (Gido and Brown, 1999).

Khoo *et al*. (1987) reported that river regulation and pollution, siltation, damming, illegal fishing methods, and overfishing have all caused a sharp decline in the catches of inland capture fisheries in Malaysia. Currently, Hamzah (2011) showed that the development of oil palm plantations had caused deterioration of water quality that finally lead to a decline in fish diversity in the Batang Kerang floodplain. In addition, Khairul Adha (2012) observed that alien fish species have successfully survived in poor quality water that is unsuitable for some native fish fauna. McDowall (1990) showed that the decline in the abundance of native species and the domination of some alien fish species is related to the habitat degradation and water quality deterioration. A strong relationship between the occurrence of alien species and a degraded aquatic habitat has lead to frequent use of alien fishes as indicators of biological integrity and river health (Kennard *et al*., 2005).

Indeed, biodiversity is facing dramatic changes that have resulted in the loss of species in addition to the reduction in the distribution and abundance of native species, mainly related to anthropogenic impacts such as habitat loss, pollution, climate change, and the overexploitation of resources as well as the introduction of alien fish species (Welcomme, 1988; Simberloff, 2003; De Silva and Funge-Smith, 2005).

Conclusion

Assessments of the species composition, ecology, habitat preference and distribution of alien species and the role of alien fish in aquaculture development in Malaysia have pointed attention to the importance of

preventing and controlling the introduction and spread of alien species. The intentional introduction of alien fish species for various purposes and the unintentional introduction of alien species have both contributed to the current widespread distribution and establishment of alien species in local ecosystems. It has been shown that the rate of introduction and the number of alien fishes introduced in local habitats has greatly increased since the early twentieth century.

Alien fish species have been introduced to and now inhabit diverse habitats including highland and isolated streams, rivers, rice fields, swamps, drainage areas, dams and reservoirs, lakes made from former mining areas, and estuaries in Malaysia. Furthermore, the occurrence of alien species has changed the structure of indigenous icthyo-faunal groups in accordance with differences in habitat. Alien fish species potentially influence the diversity, structure of fish assemblages and the composition of the native fish community. There have been no restrictions or limitations to the spread of alien fish species in natural habitats in Malaysia.

The spread, movement and distribution of alien fish in local habitats in Malaysia have been contributed to by many factors, including the following: (i) Aquaculture development, including stocking enhancement in public bodies of water; (ii) the aquarium fish industry's accidental and intentional release of alien species into public bodies of water; (iii) Recreational fishing activities; (iv) Natural disasters such as flooding that enabled fish species to accidentally escape from pond/cage culture into rivers and, (v) Biological control. In addition, local religious beliefs, such as those of followers of Buddhism also contribute to the increased number of non-indigenous fish species in rivers. This all goes to show that human beings are the main vector for the spread and translocation of alien fish species in Malaysia.

Although alien fish species have become the main reason for the loss of biodiversity in aquatic habitats and have had numerous adverse effects on native fish and aquatic systems, anthropogenic disturbances such as the degradation of natural habitats and deforestation, and the overexploitation of aquatic resources are probably the primary causes behind the decline of freshwater fish populations in Malaysia. Therefore, it is still early to suggest that the occurrence and establishment of alien species in Malaysia has had a significant impact on the decline of the native fish fauna.

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