Invasive Alien Fish Species in Freshwater of the Continents
M. Sultana and Z. H. Hashim
School of Biological Sciences, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia
*Corresponding author: muneera.islam2010@gmail.com

Abstract
This review article presents the updated information of freshwater Invasive Alien Species (IAS) of fishes of the continents to understand the homogenate progression in global freshwater ecosystems and the leading pathways of freshwater IAS fish introduction throughout the continents. North America contains 45 freshwater invasive fish species within 18 families, which is the most profuse off all other continents, whereas, Australia possesses the lowest amount of freshwater IAS fish, 18 species under 8 families. Besides, Asia retains 41 freshwater IAS fish under 14 families and Europe acquires 32 species under 18 families. The uppermost spreader IAS fish family is Cyprinidae followed by Cichlidae subsequently. Nine common fishes (Carassius auratus, Cyprinus carpio, Onchorynchus mykiss, Oreochromis mossambicus, Poecilia reticulata, Salmo salar, Salmo trutta and Salvelinusfontinalis) turned out invasive in all the continents (without Antarctica). Among IAS introduction pathways, aquaculture causes the highest percentage of freshwater IAS introduction in all continents. Aquaculture root 25% of IAS fish introduction in Africa, 21% in Asia, 19% in Australia, 20% in Europe, 19% in North America and 19% in South America. There is hardly any documentation on freshwater IAS fishes of Antarctica. Therefore, future research consideration may be designed.

Key words: Aquaculture, Freshwater fish invasion, Introduction pathways, Invasive fish, Homogenization

Introduction
The unintentional and deliberate introduction of species to ecosystems, along with other frequent anthropogenic goings-on swaying our environment, has taken place since antiquity (Hughes, 2003; Francis, 2012). When such introductions cause economic and/or ecological harm or adversely affect human health, are classified as IAS. Therefore, in the 21st century, IAS are categorized as “eco-warrior” amongst the noteworthy coercions of the global biodiversity (Pimentel et al., 2000, 2005; Pejchar and Mooney, 2009). Likewise, the biodiversity of global freshwater ecosystem is defined alarming because of its declining rate; which is mostly allied with the existing and potential impacts of IAS (Sala et al., 2000; Vörösmarty et al., 2010). Amongst aquatic organisms, freshwater fishes are one of the absolute introduced taxa around the world (624 species: Gozlan, 2008) and this introductions as well as corresponding ruthlessness of influences can be occurred to a countless extent in ecosystems (Zedler and Kercher, 2004). In accordance with Moyle and Leidy(1992), approximately 20% of the freshwater fish species of the world (ca. 1800 species) are already extinct or in serious declining phase due to IAS introduction. Irrefutably, the vicissitudes caused by IAS are so massive, ecologists have commented that we are inward bound a different era, “The Homogenece” (a term apparently coined by Gordon Orians in the mid-1990s; Rosenzweig, 2001), in which all continents will be connected as a “New Pangaea” through the alike biota. Both or either establishment of non-indigenous species and loss of native biodiversity are lessening dissimilarities among regional biota, which can be referred to as biotic homogenization (Rahel, 2002). However, to look at the broad image of global IAS fishes, it is perceived that the remaining information on freshwater IAS in a continental screen is not adequate to picture the overall process of homogenization. There are hardly any documents, for instance, for Antarctic region and only an insufficient number of data of freshwater IAS for South America. Hence, a compilation of current status of freshwater IAS amongst continents is obligatory at this instant. To fulfill the aforementioned issue, this paper summarized IAS fish in freshwater (including diadromous) in the continents of the world including their introduction pathways.

Methodology
All the concerned data of present study was compiled from an extensive variety of sources i.e. online database and published articles. Global Information Resources such as Invasive Specie Specialist Group (ISSG), Global Invasive Species Database, FAO and published articles on Introductions of Aquatic Species (DIAS), and some National and Regional Informational Resources such as The Biological Record Centre (BRC), Regional Biological Invasions Centre Information System (RBIC), United States Geological Survey Non-indigenous Aquatic Species (USGS NAS), www.nonnativespecies.org, www.invasive.org, www.invasivespeciesinfo.gov and etcetera databanks were used to collect information on freshwater IAS fish species for each and every continent. To overview the updated status of the topic, all facts and figures have been presented in a core table (Table 1).
| Family          | Scientific name | Common name         | Native continent           | Introduced continent/turned IAS in | Introduction pathways to new continent                          |
|-----------------|-----------------|---------------------|-----------------------------|-----------------------------------|-----------------------------------------------------------------|
| Esocidae        | *Esox lucius*   | Northern pike       | North America, Europe, Asia | Africa, Asia, Europe, North America | Unknown                                                          |
| Centrarchidae   | *Micropterus salmoides* | Largemouth bass | North America               | Africa, Asia, Europe, North America, South America | Aquaculture, sport fishing, angling |
| Channidae       | *Channa argus*  | Northern snakehead  | Asia                        | Africa, Asia, Europe, North America | Aquaculture, fishing/hunting, live food trade, pet/aquarium trade |
|                 | *Channa marulius* | Great snakehead    | Asia                        | Asia, North America                | Live food trade, pet/aquarium trade                             |
| Cichlidae       | *Cichla ocellaris* | Butterfly peacock bass | Tropical America             | Asia, Europe, North America, South America | Stocking                                                        |
|                 | *Cichlasomaurophthalmus* | Mayan cichlid     | North America               | Asia, North America                | Pet/aquarium trade, spread aided by fishermen                   |
|                 | *Oreochromis aureus* | Blue tilapia       | Africa, Asia                | Africa, Asia, Europe, North America, South America | Aquaculture, biological control agent for aquatic vegetation, stocking |
|                 | *Oreochromis mossambicus* | Mozambique tilapia | Africa                      | Africa, Asia, Australia, Europe, North America, South America | Aquaculture, natural dispersal, pet/aquarium trade, taken to botanical garden/zoo |
|                 | *Oreochromis niloticus* | Nile tilapia       | Africa                      | Africa, Asia, North America, South America | Aquaculture, live food trade, stocking                           |
|                 | *Oreochromis spp.* | Tilapia             | Africa, Asia                | Africa, Asia                       | Aquaculture, intentional unofficial release                     |
|                 | *Tilapia mariae* | Spotted tilapia    | Africa, Australia, North America | Africa, Asia                        | Aquaculture                                                      |
| Genus/Male Name | Common Name | Habitat | Distribution | Use |
|-----------------|-------------|---------|--------------|-----|
| *Tilapia zillii* | Zilli’s tilapia | Africa, Asia, Europe, North America | Unknown |
| *Clarias batrachus* | Walking catfish | Asia, Asia, Europe, North America | Aquaculture, pet/aquarium trade |
| *Alosapseudoharengus* * | Alewife | North America, North America | Aquaculture, natural dispersal, smuggling, purposely introduced |
| *Misgurnusanguillicaudatus* | Oriental weather loach | Asia, Australia, Europe, North America | Pet/aquarium trade, live food trade |
| *Carassius auratus* | Goldfish | Africa, Asia, Australia, Europe, North America, South America | Pet/aquarium trade, ornamental fish |
| *Ctenopharyngodon idella* | Grass carp | Africa, Asia, Europe North America, South America | Aquaculture, live food trade, biological control agent for aquatic vegetation |
| *Cyprinella lutrensis* | Red shiner | North America, North America | Bait release |
| *Cyprinus carpio* | Carp | Eurasia, Africa, Asia, Australia, Europe, North America, South America | By acclimatization societies, aquaculture, ornamental purpose, commercial/ recreational fisheries, pet/aquarium trade |
| *Hypophthalmichthys molitrix* | Carp | Africa, Asia, Europe North America, South America | Aquaculture, landscape/faunal Improvement, live food trade |
| *Hypophthalmichthys nobilis* | Bighead carp | Africa, Asia, Europe North America, South America | Aquaculture, landscape/fauna improvement, aquaculture, live food trade |
| *Leuciscus idus* * | Ide | Europe, Asia, | Pet/aquarium |
| Genus                  | Common Name          | Distribution          | Gobionomy                |
|-----------------------|----------------------|-----------------------|--------------------------|
| **Phoxinusphoxinus**   | Common minnow        | Eurasia, Europe       | Natural dispersal, stock by angling organizations, smuggling by anglers |
| **Rutilusrutilus**    | Roach                | Europe, Asia          | Natural dispersal, stock by angling organizations, smuggling by anglers |
| **Scardiniuserythrophthalmus** | Rudd              | Asia, Europe, North America | Stocking for recreational angling, smuggling by anglers |
| **Tincatinca**        | Doctor fish          | Africa, Asia, Europe  | Ship ballast water, ship/boat hull fouling |
| **Gobiidae**          |                      |                       |                          |
| **Acanthogobiusflavimanus** | Spotted goby, Yellow fin goby | Asia, Australia, North America | Ship ballast water, ship/boat hull fouling |
| **Neogobiusmelanostomus** | Round goby          | Asia, Europe, North America | Ship ballast water |
| **Tridentiger trigonocephalus** | Chameleon goby     | Asia, Australia, North America | Live food trade, ship ballast water, ship/boat hull fouling |
| **Ictaluridae**       |                      |                       |                          |
| **Ameiurus nebulosus** | Brown bullhead       | North America         | Ignorant possession by commercial fishermen, stocking |
| **Pylodictisolivaris** | Flathead catfish     | North America         | Stocking |
| **Latidae**           |                      |                       |                          |
| **Lates niloticus**   | Nile perch           | Africa, North America | Aquaculture, landscape/final improvement |
| **Loricariidae**      |                      |                       |                          |
| **Glyptoperichthysgibbiceps** | Sailfin pleco     | South America         | Pet/ aquarium trade |
| **Pterygoplichthys anisitsi** | Southern sailfin catfish | South America | Live food trade, pet/aquarium trade, accidental release |
| **Pterygoplichthys disjunctivus** | Vermiculated sailfin catfish | South America | Live food trade, pet/aquarium trade, accidental release |
| Family                     | Species                        | Trade/Release                  |
|---------------------------|-------------------------------|--------------------------------|
| Pterygoplichthys spp.     | Sailfin catfish               | South America Live food trade, pet/aquarium trade, accidental release |
| Pterygoplichthys multiradiatus | Sailfin catfish               | South America Live food trade, pet/aquarium trade, accidental release |
| Pterygoplichthys pardalis | Sailfin catfish               | South America Live food trade, pet/aquarium trade, accidental release |
| Moronidae                 | Morone americana ***          | White perch North America North America Through the Erie and wetland canals, stocking |
| Percidae                  | Gymnocephalus cernuus         | Ruffle Asia, Europe Asia, Europe, North America Contaminated bait, ignorant possession, ship ballast water |
|                         | Percafluviatilis              | European perch Europe Africa, Asia, Australia, Europe Stocked as a sport fish |
| Petromyzontidae           | Petromyzon marinus            | Lamprey North America North America Natural dispersal, used as bait, ship/boat hull fouling |
| Poeckiliidae              | Gambusia affinis              | Western mosquito North America Africa, Asia, Europe, North America, South America Biological control agent for mosquitoes, transported by ship, taken to botanical garden/zoo |
|                         | Gambusia holbrooki            | Eastern mosquito North America Africa, Asia, Australia, Europe Biological control agent for mosquitoes, pet/aquarium trade |
|                         | Phalloceros caudimaculatus    | Spot tail mosquito South America Africa, Australia, South America Pet/aquarium trade, smuggling |
|                         | Poeciliareticulata            | Guppy South America Africa, Asia, Australia, Europe, North America, South America Biological control agent for mosquito, pet/aquarium trade, use in genetic research |
| Fish Family | Species | Geographic Range | Pathways |
|------------|---------|------------------|----------|
| Salmonidae | *Onchorynchus mykiss* | North America, Africa, Australia, Europe, North America, South America | Acclimatization on society, aquaculture, landscape/faunal improvement |
| | *Salmo salar* | North America | Aquaculture, fish farms/ aquaculture industries |
| | *Salmo trutta* | Europe, Africa, Asia | Aquaculture, stocking |
| | *Salvelinus fontinalis* | North America | Aquaculture |
| | *Salvelinus namaycush* | North America | Stocked for recreational fisheries |
| Synbranchidae | *Monopterus albus* | Asia | Live food trade |

**Note:** * Refers to diadromous fish; *** refers to semi-diadromous fish; all information of table 4 was compiled from Global Invasive Species Database; Courtenay *et al.*, 1989; Wooten & Lydeard, 1990; Page & Burr, 1991; Kailola *et al.*, 1993; McDowall, 2000; Elvira, 2001; Hajjar, 2002; Nico & Fuller, 2004; Courtenay & Williams, 2004; Gomiero & Braga, 2004; Simberloff & Gibbons, 2004; Nguyen & Nakorn, 2004; Linholm *et al.*, 2005; Canonico *et al.*, 2005; Page & Robins, 2006; Hubilla *et al.*, 2008; Nico *et al.*, 2009; Franch *et al.*, 2008; Kottelat & Freyhof, 2008; Mendoza *et al.*, 2009.

**IAS freshwater fishes of Africa**

Africa harbors a well-diversified freshwater ichthyofauna, resulting from a long history of complex climatic and geological events (Lévêque, 1997). Here, the phenomenon ‘IAS’ is recent (approximately 150 years old), compared to other continents (Chenje & Mohamed, 2006), this time factor may, however, be a reflection of the deficiency of records. Africa has received 14 IAS fish from all continents except Australia and Antarctica (Table 2). The most abundant invasive fish family presents in this continent is Cyprinidae (consists of 8 species); subsequently Cichlidae (consists of 6 species); Salmonidae (5 diadromous species); and Poeciliidae (4 species) (Table 3). Invasive fish had been introducing here by several pathways. Of them, ‘aquaculture’ is a very operative purpose (25%), followed by pet aquarium trade (17%), regional faunal improvement or ‘acclimatization society’ (12%) and the least is smuggling (2%) (Fig.1).
**Fig. 1.** Percentage of freshwater IAS fish introduction pathways in Africa

### Table 2. Number of interchanged IAS fish from donor continents to recipient continents

| Recipient continent | No of invasive fish species spread from native continent |
|---------------------|--------------------------------------------------------|
|                     | Africa | Antarctica | Asia | Australia | Europe | NA | SA |
| Africa              | -      | -          | 14   | 0         | 7      | 8  | 2  |
| Antarctica          | -      | -          | -    | -         | -      | -  | -  |
| Asia                | 7      | -          | 9    | -         | 5      | 4  | 2  |
| Australia           | 3      | -          | 17   | 0         | -      | 11 | 2  |
| Europe              | 4      | -          | 19   | 0         | 8      | -  | 6  |
| NA                  | 7      | -          | 10   | 0         | 3      | 9  | -  |
| SA                  | 5      | -          | -    | -         | -      | -  | -  |

**note:** NA = North America; SA = South America; No available information for Antarctica. IAS fish from the same continental range are excluded. Species with two or more native continents were tallied more than once.

**IAS freshwater fishes of Asia**

Asia is host to an enormous amount of freshwater ichthyofauna with tremendous species richness and high levels of endemism (Braatz et al., 1992). Despite home to 36% of the world’s freshwater resources (UNEP database), Asia’s most freshwater ecosystems are, however, under grave threat, and so does the biodiversity in it. Introduction of IAS, which is almost ubiquitous, is one of the root causes of this threat (Dudgeon, 2000). According to World Invasive Species Database, 41 IAS fish within 14 families remains in Asian freshwater (Table 4). Family Cyprinidae and Cichlidae entail with 8 species each, which are the most abundant invader fish family in this continent (Table 3). A wide range of human activities are responsible for IAS fish expansion here, arising from intensive aquaculture (21%), followed by the pet/aquarium trade (17%), live food trade (12%) and fish stocking (10%) (Fig.2).

**IAS freshwater fishes of Australia**

Australia possesses an adequate quantity of diversified and unique freshwater fish fauna, although the components of the fauna are fairly small compared to other continents (363 species within 35 families) (Allen, 1989; Page & Brooks, 1991). However, from the 18th century, Australia has been subjected to species arriving from elsewhere. Ecologists have often revealed that Australia has received far more invading species than the number of Australian species invaded elsewhere in the world (Table 2). Australia possesses 18 freshwater invasive fish species within 8 families (Table 4). Unlike other continents, ‘aquaculture’ configures the maximum percentage (19%) of introducing IAS fishes. ‘Pet/aquarium trade’ holds little lesser position (17%) than aquaculture (Fig.3).

**IAS freshwater fishes of Europe**

Amendments of freshwater systems through species introduction have an elongated history in Europe, on tracked before the 20th century (Freyhof & Brooks, 2011). But this issue intensified here after mid-19th century by several ‘acclimatization societies’ (Copp et al., 2005) that was mostly liable for bringing IAS fish from outside of the continent for faunal improvement. As conscripted by World Invasive Species Database, the number of freshwater invasive fish species in Europe is 32 contained by 13 families (Table 4). The most intensive family of invader fish is Cyprinidae (comprises 10 species), followed by the diadromous family salmonidae (5 species) (Table 3). In description of introduction paths, it can be summarized that the most ostentatious pathway of invasive fish introduction here is ‘aquaculture’ (21%), followed by ‘pet/aquarium trade’ (17%) (Fig.4).
North America has a broad array of freshwater ecosystems within a multitude of habitats resulting rich assemblages of fishes reside; more than 1200 freshwater fish species within 50 families (Page & Brooks, 1991; Abell, 2000). The freshwater habitats and the astonishing biodiversity in it of this continent are, however, facing unprecedented threats from a range of sources; one of which is introduction of IAS from all over the world (Abell, 2000). It can be concised from Tables 1, 2 and 3 that North America consists of 45 freshwater invasive fish species within 18 families, which is the most profuse off all other continents (Table 4). Among 9 different ways, the most frequent pathways of fish introduction here include ‘aquaculture’ (19%), followed by ‘pet/aquarium trade’ (17%) and ‘live food trade’ (15%) (Fig.5).

IAS of freshwater in North America

North America has a broad array of freshwater ecosystems within a multitude of habitats resulting rich assemblages of fishes reside; more than 1200 freshwater fish species within 50 families (Page & Brooks, 1991; Abell, 2000). The freshwater habitats and the astonishing biodiversity in it of this continent are, however, facing unprecedented threats from a range of sources; one of which is introduction of IAS from all over the world (Abell, 2000). It can be concised from Tables 1, 2 and 3 that North America consists of 45 freshwater invasive fish species within 18 families, which is the most profuse off all other continents (Table 4). Among 9 different ways, the most frequent pathways of fish introduction here include ‘aquaculture’ (19%), followed by ‘pet/aquarium trade’ (17%) and ‘live food trade’ (15%) (Fig.5).

IAS freshwater fishes of South America

As with many other bunches of flora and fauna, freshwater endemic and invader fishes of South America is far from fully known, as because decades of poor monitoring and the lack of specific studies have limited our knowledge in this regard (Pompeu et al., 2012). However, introduction of IAS are identified as one of the widespread consequences across the continent for incessant loss of freshwater fish species here (Reis et al., 2003; Barletta et al., 2010), even before the whole species diversity of this continent is acknowledged. This continent acquired most IAS fish from Asia and North America, 10 and 9 species respectively (Table 2). The most abundant invasive species exists from both the family Cyprinidae and Loricariidae (6 species from each family) and consequently, 5 species from each family Salmonidae and Cichlidae (Table 3). ‘Aquaculture’ is the most dominant pathway of fish introduction in this continent (19%), followed by ‘pet/aquarium trade’ (18%) and ‘live food trade’ (15%) (Fig.6).
Table 3. Number of existing freshwater IAS fish per family among continents

| Family         | Asia | Europe | North America | South America | Africa | Australia | Antarctica |
|----------------|------|--------|---------------|---------------|--------|-----------|------------|
| Centrichidae   | 1    | 1      | 1             | 1             | 1      | n/a       | 2          |
| Channidae      | 2    | 1      | 2             | n/a           | 1      | n/a       | 2          |
| Cichlidae      | 8    | 4      | 7             | 5             | 6      | 2         | 2          |
| Claridae       | 1    | 1      | 1             | n/a           | n/a    | 1         | 1          |
| Clupeidae      | n/a  | n/a    | 1             | n/a           | n/a    | n/a       | 1          |
| Cobitidae      | 1    | 1      | 1             | n/a           | n/a    | 1         | 1          |
| Cyprinidae     | 8    | 10     | 9             | 6             | 8      | 4         | 4          |
| Esocidae       | 1    | 1      | 1             | n/a           | 1      | n/a       | 1          |
| Gobiidae       | 3    | 1      | 3             | n/a           | n/a    | 2         | 2          |
| Ictaluridae    | 1    | 1      | 2             | 1             | n/a    | n/a       | 1          |
| Latidae        | n/a  | n/a    | 1             | n/a           | 1      | n/a       | 1          |
| Loricariidae   | 4    | 1      | 5             | 6             | n/a    | n/a       | 1          |
| Moronidae      | n/a  | n/a    | 1             | n/a           | n/a    | n/a       | 1          |
| Percidae       | 2    | 2      | 1             | n/a           | 1      | 1         | 1          |
| Petromyzontidae| n/a  | n/a    | 1             | n/a           | n/a    | n/a       | 1          |
| Poeciliidae    | 3    | 3      | 2             | 4             | 4      | 3         | 3          |
| Salmonidae     | 5    | 5      | 5             | 5             | 5      | 4         | 4          |
| Synbranchidae  | 1    | n/a    | 1             | 1             | 1      | 1         | 1          |
| **Total species** | **41** | **32** | **45**         | **29**        | **29** | **18**    | **18**     |

Table 4. Comparison of existing number of freshwater fish species and their families inherent in within continents along with the no of freshwater invasive fish species with families

| Continent       | Existed freshwater fish species | Existed family | No. of IAS fish species | No of invader family | Reference/s                                           |
|-----------------|---------------------------------|----------------|-------------------------|----------------------|-------------------------------------------------------|
| Africa          | 2836                            | 74             | 29                      | 10                   | IUCN.org; Kottelat & Whitten, 1996; Dudgeon, 2000; issg.org |
| Asia            | 3500                            | 105+           | 41                      | 14                   | Kottelat & Whitten, 1996; Dudgeon, 2000; issg.org      |
| Australia       | 363                             | 35             | 18                      | 8                    | Allen, 1989; Page & Brooks, 1991; Allen et al., 2002; issg.org |
| Europe          | 546                             | 24             | 32                      | 13                   | Page & Brooks, 1991; Kottelat & Freyhof, 2007; issg.org |
| North America   | 1200+                           | 50             | 45                      | 18                   | Page & Brooks, 1991; issg.org                         |
| South America   | 6025                            | 71             | 29                      | 8                    | Reis et al., 2003; issg.org                           |

Note: No available information on Antarctic region

**Discussion**

It is affirmed from the above study that among continents, North America possesses the uppermost number of freshwater invasive fish species; 41 species within 18 families (Table 4), whereas Australia possesses the lowermost number; 18 invasive fish species within 8 families. This review clarified that all IAS fish interchanges (give-and-take) took place within five common continents viz. Asia, Europe, North America, South America and Africa. No invasive species winged from Australia to another continent, by contrast fish introduction happened in Australia from all other continents (without Antarctica). Among continents, Asia dispersed the highest extent of invasive fish in every single continent whereas South America shakes out the lowest to all. Observing at Table 2, it is evidently realized that Asia sprinkled the highest amount of IAS fish per continent; 19 species to North America, 17 species to Europe, 14 species to Africa, 10 species to South America and 9 species to Australia. Species that turn out to be legend invaders and propagate in every continents (without Antarctica) are Carassius auratus, Cyprinus carpio, Onchorynchus mykiss, Oreochromis mossambicus, Poecilia reticulate, Salmo salar, Salmo trutta and Salvelinus fontinalis.
This is may be because some of them are fast-growing (e.g., *Cyprinus carpio*), so vastly used for aquaculture, some of them have robust flexibility (e.g., *Salmo salar*), so they can survive in adverse environment and become hostile. *Hypophthalmichthys* spp. and *Oreochromis niloticus* circulated in five different continents without Australia and Antarctica. The species *Gambusia* spp. is introduced in every continent mostly for biological control purpose (controlling mosquito population). It is revealed that the most effective introduction pathway of freshwater invasive fish species is ‘aquaculture’, which causes the highest percentage of introduction in every single continent (Fig 1). Aquaculture rooted 25% IAS fish introduction in Africa, 21% in Asia, 19% in Australia, 20% in Europe, 19% in North America and 19% in South America. Thereby approaches ‘pet/aquarium trade’ and ‘live food trade’ possessed the subsequent potent pathway.

**Future research potentials**

Firstly, research on Asian freshwater invasion by IAS fish has been largely neglected in comparison to other regions (Peh, 2010). To improve biological invasion research in Asia, it is important to address questions on natural history, taxonomy and ecology of the IAS fishes of this region (e.g. Peh, 2002; Peh & Sodhi, 2002; Yap et al., 2002; Yap, 2003). Basic natural history information and supporting baseline data are still
urgently needed as a ground work before strategies for surveying, eradicating and managing biological invasion (Peh, 2010). Secondly, in Antarctic region, there are closely nil research based on freshwater fish diversity, distribution and fish invasion. To understand the trends of freshwater fish diversity and distribution, investigation and a compilation of recent data is a burning issue at this instant. Thirdly, there is an arising indication in invasion ecology that beyond the biological invasions in any ecosystem, there are stimuli of native species diversity and abundance (Peh, 2010). From the Table 4, within continents where there presents high abundance of freshwater fish, IAS of fish emerged there in. Therefore, together with the information of IAS, vigorous documents of diversity and distribution of native species from every continent as well as every biogeographic region is crucial.

Conclusions
The world these days faces a foremost challenge. That is, on the one hand, public outcry at the undesirable detrimental consequences in ecology of several IAS; on the other hand, there is the irrefutable and significant contribution of some IAS fishes to an undeniable need, for instance, food fish requirements. The growing field of invasion science at the moment, poised at a crossroads where ecology and public perception meets, meanwhile is increasing. Therefore, other than focusing on cultivating hybrid (e.g. carp), predatory (e.g., bass and trout) and fast-growing fishes (e.g., tilapia), we should emphasise on culturing, trading, stocking and consuming fish, which has potential to balance the ecosystem. Side by side, we necessitate a number of workout strategies that could address both needs, i.e. cope with wide-reaching hunger and poverty, and simultaneously, deal with and pledge us sustainable use of world’s freshwater resources. Thus, the homogenization process could be defended and delayed.

Acknowledgement
This review paper is a part of M.Sc. research which is funded through a postgraduate funding program “USM fellowship scheme” awarded by Universiti Sains Malaysia; USM Research University Grant (RUI: 1001/PBIO/811248) and USM short term research grant (304/PBIO/6312132).

References
Abell, R. A. (Ed.). (2000). Freshwater ecoregions of North America: a conservation assessment (Vol. 2). Island Press.
Allen, G. R. (1989). Freshwater fishes of Australia.
Barletta, M.; Jaureguizar, A. J.; Baigun, C.; Fontoura, N. F.; Agostinho, A. A.; Almeida-Val, V. M. F. D. and Corrêa, M. F. M. (2010). Fish and aquatic habitat conservation in South America: a continental overview with emphasis on neotropical systems. J. Fish Biology, 76(9), 2118-2176.
Braatz, S.; Davis, G.; Shen, S. and Rees, C. (1992). Conserving biological diversity. A strategy for protected areas in the Asia-Pacific Region. World Bank Technical Paper 193: 1–66.
Canonico, G. C.; Arrthington, A.; McCravy, J. K. and Thieme, M. L. (2005). The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine and Freshwater Ecosystems, 15(5), 463-483.
Chenje, M. and Mohamed-Katerere, J. (2006). Invasive alien species. Africa Environment Outlook, 2, 331-347.
Copp, G. H.; Bianco, P. G.; Bogutskaya, N. G.; Eros, T.; Falka, I.; Ferreira, M. T.; Fox, M. G.; Freyhof, J.; Gozlan, R. E.; Grabowska, J.; Kovac, V.; Moreno-Amich, R.; Naseka, A. M.; Penaz, M.; Povz, M.; Przybylski, M.; Robillard, M.; Russell, I. C.; Stakenas, S.; Sumer, S.; Vila-Gispert, A. and Wiesner, C. (2005). ‘To be, or not to be, a non-native freshwater fish?’ Journal of Applied Ichthyology, 21(4), pp242–262.
Courtenay Jr, W. R. and Robins, C. R. (1989). Fish introductions: good management, mismanagement, or no management. Reviews in Aquatic Sciences, I(1), 159-172.

This review paper is a part of M.Sc. research which is funded through a postgraduate funding program “USM fellowship scheme” awarded by Universiti Sains Malaysia; USM Research University Grant (RUI: 1001/PBIO/811248) and USM short term research grant (304/PBIO/6312132).

Courtenay, W. R. and Williams, J. D. (2004). Snakeheads (Pisces, Channidae): a biological synopsis and risk assessment (Vol. 1251). US Geological Survey.
Dudgeon, D. (2000). Conservation of freshwater biodiversity in Oriental Asia: constraints, conflicts, and challenges to science and sustainability. Limnology, 1(3), 237-243.
Elvira, B. and Almodóvar, A. (2001). Freshwater fish introductions in Spain: facts and figures at the beginning of the 21st century. Journal of fish Biology, 59(sA), 323-331.
Franch, N.; Clavero, M.; Garrido, M.; Gayà, N.; López, V.; Pou-Rovira, Q. and Queral, J. M. (2008). On the establishment and range expansion of oriental weather fish (Misgurnus anguillicaudatus) in NE Iberian Peninsula. Biological Invasions, 10(8), 1327-1331.
Francis, R. A. (2012). Handbook of Global Freshwater Invasive Species.
Freyhof, J. and Brooks, E. (2011). European red list of freshwater fishes. IUCN, International Union for Conservation of Nature and Natural Resources.
Fuller, P. L. (2003). Patterns and Pathways. Invasive species: vectors and management strategies, 123pp.
Fuller, P. and Nico, L. (2004). USGS Nonindigenous Aquatic Species Database.US Geological Survey. Accessed.
Gomiero, L. M. and Braga, F. M. S. (2004). Feeding of introduced species of Cichla (Perciformes, Cichlidae) in Volta Grande reservoir, river Grande (MG/SP). Brazilian Journal of Biology, 64(4), 787-795.
Gozlan R. E. (2008). Introduction of non-native freshwater fish: is it all bad? Fish and Fisheries 9, 106–115.
Hajjar, R. (2002). Introduced species summary project: Ruffe (Gymnocephalus cernuus). Columbia University.

Hubilla, M.; Kis, F. and Primavera, J. (2008). Janitor fish Pterygoplichthys disjunctivus in the Agusan Marsh: a threat to freshwater biodiversity. Journal of Environmental Science and Management, 10(1).

Hughes, J. D. (2003). ‘Europe as consumer of exotic biodiversity: Greek and Roman times’, Landscape Research, 28 (1), 21–31.

Kailola, P. J. (1993). Australian fisheries resources. Bureau of Resource Sciences, Dept. of Primary Industries and Energy; Fisheries Research and Development Corp.

Kottelat, M. I. and Freyhof, J. (2008): Handbook of European Freshwater Fishes.Kottelat, Cornol, Switzerland & Freyhof, Berlin, Germany.

Lévêque, C. (1997). Biodiversity dynamics and conservation: the freshwater fish of tropical Africa. Cambridge University Press.

Lindholm, A. K.; Breden, F.; Alexander, H. J.; CHAN, W. K.; Thakurta, S. G. and Brooks, R. (2005). Invasion success and genetic diversity of introduced populations of guppies Poecilia reticulata in Australia. Molecular Ecology, 14(12), 3671-3682.

McDowall, R. M. (2000). The Reed field guide to New Zealand freshwater fishes.

Mendoza-Palmero, C. A.; Sereno-Uribe, A. L. and Salgado-Maldonado, G. (2009). Two new species of Gyrodactylus von Nordmann, 1832 (Monogenea: Gyrodactylidae) parasitizing Girardinichthys multituberculatus (Cyprinodontiformes: Goodeidae), an endemic freshwater fish from central Mexico. Journal of Parasitology, 95(2), 315-318.

Moyle, P. B. and Leidy, R. A. (1992). Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. In Conservation biology (pp. 127-169). Springer US.

Nguyen, T. T. T. and Na-Nakorn, U. (2004). Genetic impacts of translocations on biodiversity of aquatic species with particular reference to Asian countries.AQUACULTURE ASIA, 9, 4–7.

Nico, L. G.; Loftus, W. F. and Reid, J. P. (2009). Interactions between non-native armored suckermouth catfish (Loricariidae: Pterygoplichthys) and native Florida manatee (Trichechus manatus latirostris) in artesian springs. Aquatic Invasions, 4(3), 511-519.

Page, L. M. and Burr, B. M. (1991). A field guide to freshwater fishes of North America north of Mexico. Peterson Field Guide Series, Houghton Mifflin Co., Boston.

Page, L. M. and Robins, R. H. (2006). Identification of sailfin catfishes (Teleostei: Loricariidae) in southeastern Asia. The Raffles Bulletin of Zoology, 54(2), 455-457.

Page, L. M. and Brooks M. B.A field guide to freshwater fishes: North America north of Mexico. Houghton Mifflin Harcourt, 1991.

Peh KS-H, (2002). Roosting behavior of house crow (Corvus splendens) in relation to environmental variables. Raffles Bull Zool 50:257–262.

Peh KS-H, and Sodhi, N. S. (2002). Characteristics of nocturnal roosts of house crow in Singapore. J Wildl Manag 66:1128–1133.

Peh, K. S. H. (2010). Invasive species in Southeast Asia: the knowledge so far. Biodiversity and Conservation, 19(4), 1083-1099.

Pejchar, L. and Mooney, H. A. (2009). ‘Invasive species, ecosystem services and human well-being’, Trends in Ecology and Evolution, 24 (9), 497–504.

Pimentel, D.; Lach, L.; Zuniga, R. and Morrison, D. (2000). ‘Environmental and economic costs of nonindigenous species in the United States’, Bioscience, 50 (1), 53–65.

Pimentel, D.; Zuniga, R. and Morrison, D. (2005). ‘Update on the environmental and economic costs associated with alien invasive species in the United States’, Ecological Economics, 52(3), 273–288.

Pompeu, P. S.; Agostinho, A. A. and Pellicer, F. M. (2012). Existing and future challenges: the concept of successful fish passage in South America. River Research and Applications, 28(4), 504-512.

Rahel, F. J. (2002). Homogenization of freshwater faunas. Annual Review of Ecology and Systematics, 291-315.

Reis, R. E.; Kuländer, S. O. and Ferraris, C. J. (2008). Check list of the freshwater fishes of South and Central America. Edipucrs.

Rosenzweig, M. L. 2001. The four questions: what does the introduction of exotic species do to diversity? Evol. Ecol. Res., 3: 361–367.

Sala, O. E.; Chapin, F. S.; Armesto, J. J.; Berlow, E.; Bloomfield, J.; Dirzo, R.; Huber- Sanwald, E.; Huenneke, L. F.; Jackson, R. B.; Kinzig, A.; Leemans, R.; Lodge, D. M.; Mooney, H. A.; Oesterheld, M.; Poff, N. L.; Sykes, M. T.; Walker, B. H.; Walker, M. and WALL, D. H. (2000). Biodiversity – global biodiversity scenarios for the year 2100. Science 287:1770–1774.

Simberloff, D. and Gibbons, L. (2004). Now you see them, now you don’t!–population crashes of established introduced species. Biological Invasions, 6(2), 161-172.

Vörösmarty, C. J.; McIntyre, P. B.; Gessner, M. O.; Dudgeon, D.; Prusevich, A.; Green, P. and Davies, P. M. (2010). Global threats to human water security and river biodiversity. Nature, 467(7315), 555-561.

Wooten, M. C. and Lydeard, C. (1990). Allozyme variation in a natural contact zone between Gambusia affinis and Gambusia holbrooki. Biochemical systematics and ecology, 18(2), 169-173.

Yap CA-M. (2003). A study of the changes in the range sizes of white-vented mynas in Singapore. Raffles Bull Zool 51:159–163

Yap CA-M.; Sodhi, N. S. and Brook, B. W. (2002). Roost characteristics of invasive mynas in Singapore. J Wildl Manag, 66:1118–1127.

Zedler, J. B. and Kercher, S. (2004). ‘Causes and consequences of invasive plants in wetlands: Opportunities, opportunists, and outcomes’, Critical Reviews in Plant Sciences, 23(5), 431–452.