

Case studies

Role of exotic species in aquaculture: problems and prospects in Indochina

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The participants of four national workshops recommended that the countries should be cautious of future introductions of new exotic species and their release into natural water bodies

Abstract

National workshops were held in Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam to consult local experts and users of introduced exotic aquatic organisms on the positive and negative impacts of the introduction, with a view to recommend the preparation of a regional code of conduct on the management of already introduced and new exotic species.

Exotic species have provided socio-economic benefits for a vast number of poor people in the region. There is no accurate information on their spread and negative ecological impacts as few studies have been conducted to evaluate these impacts. There is an urgent need to develop a well planned research program to assess the impacts. The governments should carefully weigh both the positive and negative impacts for each species before making any national or regional policy. After such evaluation it is necessary to develop a code of conduct for the management of alien species.

The code of conduct should address the issues of zoning, risk analysis, health certification, quarantine, development of inventory of species according to invasiveness and non-invasiveness, capacity building for monitoring and implementation of codes, and regional information exchange.

Introduction

Exotic animals are defined as “species occurring outside of its natural range”. Among numerous reasons for introduction of exotic aquatic animals into countries, aquaculture development is said to be a main motive (Welcomme, 1998 and FAO DIAS). Major concerns over the introduction of exotic fish are prolific breeding, predation or competition of the introduced species affecting indigenous biodiversity. These may lead to potential dominance of the introduced species, diseases transmission or contamination of local genetic pools.



There are two levels of aquatic animal introduction in Asia: (1) new species and (2) genetic variants or 'strains' of a particular species. Review on potential impacts of exotic species in the Mekong Basin indicates that positive impacts far outweighed any negative to date. However, there is a need for developing Codes of Conduct to limit negative consequences of future introductions and regional guidelines for quarantine and health certification. The Code of Conduct developed by European Inland Fisheries Advisory Commission (EIFAC) is usually taken as an example for such endeavours in Asia. Much of the recommendations made by various authors and organisations relate to present or future trans-boundary fish movements affecting genetic contamination and disease risk.

Many inland aquaculture species used in Asia are exotic. For example, with the exception of silver barb, striped catfish, and freshwater prawn, all cultured inland species in Thailand have been introduced within the last century. There are numerous unanswered questions regarding continuous use of exotic species in aquaculture such as:

- ▶ What are the existing guidelines for continuing the use of new and already introduced and established fish species in aquaculture?
- ▶ Have exotic fish established significant feral populations in Asia?
- ▶ Have they impacted adversely (ecologically as well as genetically) on local biodiversity?
- ▶ Have they introduced new diseases?
- ▶ What are the socio-economic benefits of these species?
- ▶ Does culturing these species benefit the rural poor?
- ▶ What is the trade-off between the environmental cost, if any, and the social benefits?
- ▶ Are there alternative indigenous species that can meet the needs of aquaculture production?
- ▶ What are the relative risks of spreading domesticated indigenous species on the genetic diversity of the same species within their natural range?

There is an urgent need to find answers to such questions. Environmental and poverty focused developmental organisations frequently question the ethics of using public funds for research and promotion of introduced exotic species.

The Asian Institute of Technology conducted National workshops in four countries: Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam in search of answers to aforementioned questions. Key informants representing all stake holders were invited to gather and present information on impacts and to air national views on introduced species. The scope of this study was to examine the environmental and socio-economic impacts of the introduction of exotic species in South East Asia with focus on Thailand, Viet Nam, Lao People's Democratic Republic and Cambodia and consequently help develop a draft Code of Conduct and Regional Guidelines on the use of new and already introduced species in aquaculture in the region. This paper presents the major findings from the four national workshops as well as recommendations for developing Regional Guidelines to reduce/eliminate potential negative impacts caused by exotic aquatic organisms.

Exotic species have provided socio-economic benefits for a vast number of poor people in the region

National workshop methodology

Workshops were convened in Thailand (24 Sept. 2002), Cambodia (3 – 4 Oct. 2002), Lao People's Democratic Republic (22–24 Nov 2002) and Viet Nam (20–21 May 2003); 30–40 key informants representing a wide range of expertise including fishermen, fish farmers, hatchery managers, extension workers, researchers, university lecturers, policy makers and environmentalists attended. Selected subject matter experts presented theme papers during the workshops. The participants were then divided into groups according to the profession e.g. producers, extension officers, academics and researchers. The major issues embodying the questions mentioned above were identified and discussed in the group sessions. Recommendations were then developed to alleviate negative impacts of exotic species introductions.

Current status on the introductions of aquatic organisms in Indochina.

A brief summary of aquatic animal introductions, their potential impacts, and the workshops' recommendations are presented below.

CAMBODIA

The participants identified 18 introduced aquatic species in Cambodia (Appendix A1) including, snails, crocodile and seaweeds. The purpose of introduction is said to be aquaculture development. *Clarias gariepinus* (African catfish) was the first fish species to be introduced from Viet Nam in 1982. Tilapia, silver carp, Indian carps (rohu, catla, mrigal) and common carp are found in natural water bodies in Kandal, Svey Rieng, Ta Kao, and Kampong Speu provinces. From the appearance in fishing lots, exotic species occupy less than 1% of the catch. Some of these species, e.g. Tilapia, Chinese and Indian carps, are said to be deliberately introduced by development projects or NGOs for aquaculture development. The rest of the species are believed to be either deliberately introduced or migrated by natural means from Viet Nam. No information about population size of exotic species in Cambodian waters is available, even though the first three species are widely used for aquaculture.

The participants identified following positive impacts of introduced species:

- ▶ easy to breed;
- ▶ small-scale farmers can produce seeds (seeds readily available);
- ▶ easy to culture (disease resistance, ability to use locally available feeds, and less attention to the culture system or less time spent for culturing fish);
- ▶ relatively higher production over indigenous species (faster growth and high survival);
- ▶ compatibility with agro-ecosystems (e.g. can integrated with rice farming or can grow in upland areas);
- ▶ source of alternative income (via sale of table fish or seeds);
- ▶ improves livelihood of people (poor people can either afford to buy exotic species due to relatively lower market price to culture them, improved nutrition of poor, improved income, employment opportunities);
- ▶ Golden snail has become a major protein source of animal/ fish feeds (poor people can collect 10 – 15 kg/day and sell to the feed companies).

Identified negative impacts were:

- ▶ over breeding of tilapia (cannot restrict to the culture system and escape to natural waters);
- ▶ water turbidity caused by common carp;
- ▶ potential negative environmental impacts;
- ▶ potential gene pool contamination (e.g. *Clarias* catfish);
- ▶ competition for habitats and natural food;
- ▶ potential loss of indigenous species (e.g. *Notopterus notopterus* is believed be decreasing in Angkor Borey district of Ta Kao province; some participant believe catch (including Notopterus) has been reduced by 20% after introduction of tilapia or other exotic species);
- ▶ potential for disease contaminations;
- ▶ low demand (low price);
- ▶ potential price drop of indigenous species due to cheaper price of introduced species;
- ▶ Golden snail damages rice paddy.

The Cambodian workshop recommended that:

- ▶ Cambodia should not import new exotic species;
- ▶ only indigenous species should be used in fish releasing ceremonies;
- ▶ hatchery and culture technologies for indigenous species should be developed;
- ▶ research should be conducted to evaluate the impacts of existing exotic species;
- ▶ the country should promote culture of exotic species away from natural water bodies;
- ▶ the Ministry of Agriculture should develop guidelines/ regulations for movement of existing/new exotic species within country;
- ▶ the regulation should delineate zones that exotic species can be cultured (rural areas away from natural waters).

LAO PEOPLE'S DEMOCRATIC REPUBLIC

Exotic species introduction has long history in Lao People's Democratic Republic. However, as fish culture is new to Lao People's Democratic Republic, most introductions (Catla, Mrigal, Rohu and common carp) were brought in 1977 from India and Thailand for aquaculture development with the assistance of international organizations. Nile tilapia was introduced from Thailand in 1965. *Clarias gariepinus* was introduced from Viet Nam in 1980 for aquaculture development. Participants of the workshop pointed out that there are about 13 alien species introduced. (Appendix A2). However, only common carp and Nile tilapia have established their population in the wild through natural reproduction.

Except for the golden apple snail, no information is available on the negative impacts of introduced species. Nile tilapia and common carp are used for cage culture. In 1995, farmers accidentally have released cage cultured fish to Nam Ngum reservoir. Participants claimed

that after this incidence, there was an increase in Nile tilapia, bighead carp and common carp population in the reservoir. The participants identified that grass carp, common carp and African catfish as high risk species

The workshop recommended that:

- ▶ introduction of new exotic species should be strictly controlled and exotics already introduced should only be used for pond culture;
- ▶ high risk species such as grass carp, common carp and African catfish should not stock in the natural water bodies;
- ▶ enhance public awareness on potential negative impacts of these species
- ▶ should develop proper quarantine procedures;
- ▶ conduct research to evaluate negative impacts of already introduced exotic species and socio-economic benefits of using native and less risk exotic species;
- ▶ develop culture techniques for indigenous species;
- ▶ should develop appropriate policies, management tools taking both positive and negative impacts into account;
- ▶ develop specific measurement for developing zones that allowed to culture exotic species and to control fish movement;
- ▶ strengthen the manpower and build the capacity for implementing policies and regulations.

VIET NAM

Participants of the workshop agreed that there have been uncontrolled introductions of 30 alien species in Viet Nam (Appendix A3). Chinese carps were introduced directly from China in 1958 by the Government of Viet Nam. Indian Major Carps were introduced from Lao People's Democratic Republic in 1984 with the help of an international organization. All these Indian and Chinese major carps are still widely used for aquaculture and have also established their population in the wild. *Oreochromis mossambicus* was brought from Africa and the Philippines by the private sector for farming in 1951 and 1955 respectively. It has established its population in the wild through its prolific reproductive nature. It is also widely cultured. Nile tilapia was imported from Taiwan, Philippines and Thailand. *Pomacea canaliculata* has been found in Viet Nam in 1988 and has most probably been introduced through the ornamental fish trade.

Alien aquatic animals are introduced to Viet Nam to diversify fish production, improve genetic materials and reduce inbreeding, improve food security, improve farmer income, creating job opportunities, use for ornamental purposes, and to use as larval/ aquarium feed e.g. Artemia. These introduced species are preferred by farmers due to well developed breeding and culture technologies, breeding potential in captivity (e.g. *P. vannamai*), high fecundity, resistance to certain diseases, higher production (fast growth and high survival), higher dress weight, ability tolerate adverse water quality, and the commercial value in both local and export markets.

There are numerous unanswered questions regarding continuous use of exotic species in aquaculture

The participants identified following benefits of introduced species:

- ▶ enhanced aquaculture production (fast growth, high survival rate, high dress weight);
- ▶ high market value;
- ▶ foreign exchange earning;
- ▶ enhanced food security of poor e.g. 35% exotic species production is used for local consumption, mainly by the poor;
- ▶ improvement in farmer income and employment opportunities;
- ▶ offer opportunity to develop hybrids that have higher growth compared to the local fish e.g. common carp and mechanism to resolve inbreeding problem of introduced species;
- ▶ can use for waste recycling/ local resources, weed control e.g. grass carp, and for mosquito control;
- ▶ some species do not breed/ survive in the natural environment e.g. introduced *Artemia*;
- ▶ use as live food e.g. *Artemia*;
- ▶ provide opportunity for in-country broodstock development;
- ▶ easy to enhance stocks;
- ▶ aesthetic and social (status) value of some ornamental species.

Since no studies have been conducted on ecological or genetic impacts, there is no scientific evidence for negative impacts. The only species that has shown clear negative impacts is the golden snail destroying rice fields. Other species that have potential for negative impacts are tilapia, grass carp, silver carp, bighead carp, *Colosoma*, *P. vannamei* and sucker catfish as they have established significant feral population in the natural environment. Gene pool contamination is common in some species e.g. between native and Chinese silver carp hybridization, and common carp (native and imported). Inbreeding problems of exotic species are common, e.g. African catfish originated from only one pair of fish.

Exotic species have introduced new parasites and diseases e.g. three new species of monogenea come with tilapia, and have reduced biodiversity by changing the species composition natural water bodies e.g. fishers in Thac Mo Reservoir in Binh Phuoc province believed that tilapia has eliminated or reduced some local fish species in the lake.

Import of exotic species is controlled by restricting species that can be imported e.g. there is a list of aquatic species which can be imported to Viet Nam. The Natural resources protection act, 1989, provides guidelines for methods of protection of indigenous aquatic resources. Decision paper, 2002, shows procedures to import new species i.e. should be disease free, for experiments, and how to receive permission to release to natural environment

The Vietnamese workshop recommended that:

- ▶ research should be conducted to evaluate positive/negative impacts;
- ▶ methods for environmental impact assessment of exotic fish species should be developed;
- ▶ strict implementation of aquatic animal inspection procedures by the custom department;

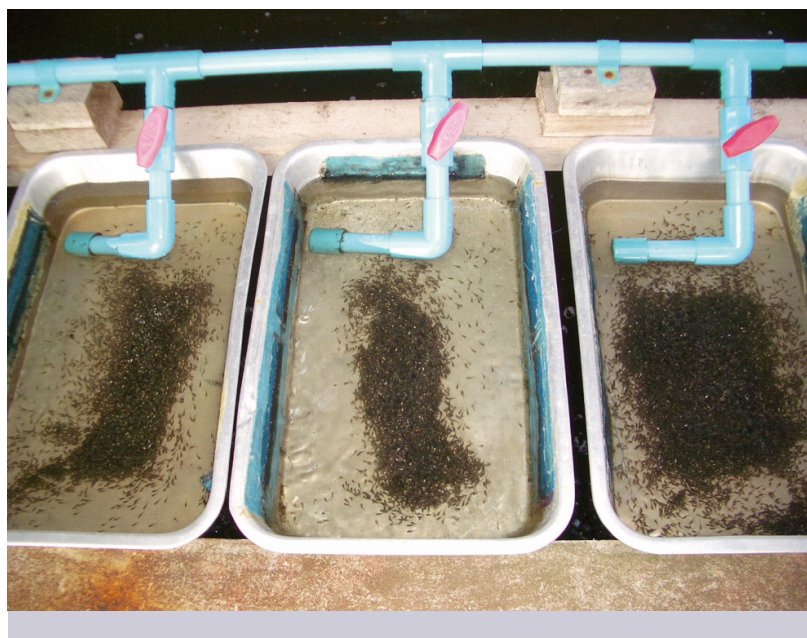
- ▶ proper quarantine system should be developed;
- ▶ control mechanisms for controlling invasive exotic species such as golden snail should be developed;
- ▶ regulation for the stocking of fish species to natural water bodies should be developed;
- ▶ trans-boundary animal movement regulations should be developed and implemented;
- ▶ code of conduct for exotic species (import and their use) should be developed;
- ▶ capacity to implement regulations (the development of manpower) should be strengthened.

THAILAND

Altogether 163 aquatic organisms including seven species of frogs, seven crocodile species, three shrimp species, over 100 species of ornamental aquatic organisms and about 20 food fishes (Appendix A4) for the aquaculture development have been introduced into Thailand during the last century. Nile tilapia (*Oreochromis niloticus*) was introduced as a gift by the Crown Prince of Japan to the HM King of Thailand in 1965 (Pullin, 1988) then distributed to the farmers through department of fisheries after successful breeding, which has been widely used for aquaculture. This species is now widely distributed in the natural ecosystem. There is some evidence that tilapia has become a main species in Ubolratana (up to 40% catch) and Lam Ta Kong reservoirs, but no information on negative impacts are available. Although other tilapia species such as *T. rendalli*, *T. zilli*, *O. aureus* and *O. mossambicus* were also introduced into Thailand, they were not cultured. Red tilapia is found in the country but they are not separate species and thought to be the hybrids of *O. niloticus* and *O. mossambicus*. Recently, new red tilapia hybrids have been introduced from various countries e.g. Taiwan, Virgin Island, Scotland, and Malaysia. This hybrid has become commercially important species to Thailand as it has higher demand due to their attractive colour. Salinity tolerance and faster growth have made red tilapia popular in coastal areas.

A few alien species have established their populations in the natural environment through natural reproduction. Out of over 30 exotic food fish species, only carps, tilapia, hybrid catfish and white shrimp have been commercially used for aquaculture. Populations of grass and silver carps have been established through continuous re-stocking into the lakes and reservoirs for their characteristic feature of controlling excessive vegetation and plankton bloom respectively. An exotic sucker fish has been found in the rivers of Thailand which has been caught by fishermen in large numbers.

Increased freshwater fish production, provision of protein



source to rural poor, income and employment generation and enhanced export income are the major positive benefits of introduced food fish species (Boonchuwong, 2002). A fish consumption survey in 1998-1999 in seven provinces of North, Northeast and central regions has shown that Thai people on average consumed 28.8 kg fish/person/year. Exotic species accounted for 12 kg fish/person/year (41.6%) of the total fish consumption. The highest consumed exotic species is Nile tilapia which account for 8.52 kg fish/person/year for the seven provinces. Nearly 46% (13.8 kg fish/person/year) of fish consumed in rural areas are exotic species (Boonchuwong, 2002). Nile tilapia accounts for 9.84 kg fish/person/year (33%) of the total fish consumption (29.88 kg fish/person/year) in the rural areas of the seven province.

Table 1. Aquaculture production including marine species (FAO 1999, 2001)

Country	Aquaculture production		Contribution of exotic species (%)
	Total	Exotic species	
Cambodia	15 500	7 650	49
Lao People's Democratic Republic	49 840	49 480	100
Thailand	724 228	191 246	26
Vietnam	545 500	390 000	73

Very limited research has been conducted in Thailand to evaluate the negative impacts of fish introductions. Na-Nakorn *et al.* (2002) showed evidence for presumed genetic introgression of *Clarias gariepinus* genes into indigenous *C. macrocephalus* and called for making proper management plans for protecting aquatic biodiversity. They also uncovered genetic differentiation between hatchery bred stock of silver barb (*Puntius gonionotus*) and their wild counterparts and cautioned that restocking programs should not use aquaculture stocks.

National laws prohibit introduction of well known invasive fish species e.g. piranha and twelve other endangered aquatic organisms. Other control measures are restricted to avoid disease outbreaks and dangers to the consumers. Other species can be imported to Thailand taking permission from competent officials. However, the main problem of controlling the introduction of exotic species is lack of proper regulation and implementation (Chinabut, 2002).

Thai national workshop recommended:

- ▶ conduct new research to evaluate ecological and socio-economic impacts,
- ▶ develop culture technologies for indigenous species,
- ▶ develop procedures for risk assessment studies,
- ▶ risk assessment studies should be conducted before allowing the introduction of new species,
- ▶ implement existing guidelines and assign a group to oversee introduction of exotic species,
- ▶ develop guidelines and manuals for each alien species and analyse the risks.

Conclusion and recommendations

A vast number of exotic species has been introduced to SE Asia. Some introduced species (e.g. tilapia, common carp) have established significant feral populations and the local communities consider them indigenous species. There is some evidence on the alteration in genetic make-up of the indigenous species (e.g. *Clarias* sp. in Thailand), and in the catch composition (e.g. 70–80% catch from Cheng Ek lake in Phnom Penh said to be tilapia).

Exotic species have made socio-economic benefits to each country covered in this study. The exotic species have played significant roles in ensuring food security. These species accounted for about 49, 100, 26 and 73% of the total aquaculture production in Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam, respectively (Table 1).

Since the culture technologies are well developed for these species, they have served as gateways of knowledge and skills for aquaculture development in the region. Hatchery and culture operation, and research into exotic species have given a large number of employment opportunities. Exotic species have served as agents for crop diversification for rural poor.

According to Dowall (1996), introduced Nile tilapia and common carp maximized the natural fertility of the paddy fields in Cambodia. Introduced trout has been reported to increase benthic phosphorous availability and stimulate the primary production (Schindler *et al.*, 2001).

There are a number of negative impacts have been attributed to exotic species. The population of *Notopterus notopterus* has been reported to be declining in Cambodia (especially in Ta Kaew) and other fish also have been reported to be declining due to exotic species such as tilapia which constitutes up to 80% of the catch in Chiang Ek Lake near Phnom Penh. In Lao People's Democratic Republic, it has been suspected that the native prawn has declined. *Hamparadisa* sp. and Pla Ka in Nam Ngum reservoir in Lao People's Democratic Republic and a local snail have disappeared most probably due to exotic fish introductions. Tilapia has also been found abundantly in the wild of all four countries studied here. In Ubonrat reservoir, tilapia can constitute up to 40% of the catch. Tilapias have also been caught in large volumes in other reservoirs of Thailand. De Iongh and Van Zon (1993) studied the impacts of the introduction of common carp, Nile tilapia, and Indian and Chinese carps into the lakes and reservoirs in northeast Thailand. According to local fishermen who caught sucker fish in large numbers from the rivers of Thailand the species might have serious impacts on indigenous species as it is a carnivorous. Participants agreed that the sucker catfish (*Hypostomus plecostomus*) has been seen in significant numbers in the natural water bodies in all the four countries, especially in the rivers.

Several diseases and parasites have been diagnosed in the exotic fish species in each of the four countries. However, it is not clear whether all these disease pathogens came with the imported fish or not. In Thailand, three fish diseases have been recorded as having entered the country along with the introduced fish (Piyakarnchana, 1989). One of the most devastating examples is white spot disease that causes virus in shrimp which was suspected to be transmitted through importation of shrimp larvae, adults, even through frozen forms and other modes (Jory *et al.*, 1999; Soto *et al.*, 2001).

There are many alternative indigenous species in the region as the Mekong River and its tributaries are rich in natural flora and fauna. There are over 1 000 indigenous species identified. However, very limited studies have been done so far in order to bring them into culture. Silver barb has been an important species among the cyprinids. Some studies

are under way on the breeding and culture of seven Mekong indigenous species. There are indications that they can be bred and cultured in captivity but are much difficult to breed and grow slower than exotic species.

Exotic species have created socio-economic benefits for a vast number of poor people in the region. More information is needed on their spread and impacts (Welcomme and Vidthayanon, 2000) There is an urgent need to develop a well planned research program to assess the impacts. The governments should carefully weigh both the positive and negative impacts for each species before making any national or regional policies. After evaluating positive and negative effects, it is necessary to develop guide lines for management of alien species.

The participants of four national workshops recommended that the countries should be cautious of future introductions of new exotic species and their release into natural water bodies. Although there are some existing regulations in these countries, there are no specific laws or implementing agencies. All four countries suggested efforts should be made to develop common agreement of regional level cooperation.

Although there are many international conventions and agreements to address the issue e.g. for example, FAO Code of Conduct for Responsible Fisheries, ICES/IFAC code, Convention on Biological Diversity (CBD), WTO agreements of Animal health and certification, OIE aquatic animal health, Bio-safety regulations, Ramsar Convention, FAO/NACA fish health guidelines, French Rural Code, none of them adequately and appropriately addresses the issue of introductions and regulations of exotic species in the region. Therefore, participants recommended developing a suitable code of conduct taking cultural and economic situation into account. The code of conduct should also address the issues of zoning, risk analysis, health certification, quarantine, development of inventory of species according to invasiveness and non invasiveness, capacity building for monitoring and implementation of codes, and regional information exchange.

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Appendix A1

Some important exotic species identified by the workshop participants in Cambodia

S.N.	Common name	Scientific name	Remarks
1	Big head carp	<i>Aristichthys nobilis</i>	Breeds in natural water bodies itself
2	Grass carp	<i>Ctenopharyngodon idella</i>	Not known
3	Common carp	<i>Cyprinus carpio</i>	Breeds in natural water bodies itself
4	Silver carp	<i>Hypophthalmichthys molitrix</i>	Breeds in natural water bodies itself
5	African catfish	<i>Clarias gariepinus</i>	Not known
6	Rohu	<i>Labeo rohita</i>	Not known
7	Mrigal	<i>Cirrhinus mrigala</i>	Not known
8	Catla	<i>Catla catla</i>	Not known
9	Java Tilapia	<i>Oreochromis mossambicus</i>	Not known
10	Nile tilapia	<i>Oreochromis niloticus</i>	Not known
11	Red tilapia	<i>O. niloticus</i> x <i>O. mossambicus</i>	Not known
12	Cuban crocodile	<i>Crocodylus rhombifer</i>	Not known
13	Australian crocodile	-	Not known
14	Turtle	-	Not known
15	Shoft shell turtle	-	Not known
16	Golden snail	<i>Pomacea canaliculata</i>	Breeds in natural water bodies itself
17	Snail from Vietnam	-	Golden apple snail
18	Sea weeds	-	Not known

Appendix A2

Major exotic species and their impacts identified the workshop participants in Lao People's Democratic Republic

Fish Species	Year	Origin	Reason	Ecological impact		Social economic impact	
				Positive	Negative	Positive	Negative
Catla catla	1977	Thailand/ India	Aquaculture	Does not destroy habitat	None	Beneficial	Cannot breed in the wild
Ctenopharyng- odon idella	1977	China	Aquaculture	Unknown	Probably yes	Unknown	Cannot breed in the wild
Cirrhinus Mrigala	1977	Thailand/ India	Aquaculture	Unknown	Probably yes	Unknown	Cannot breed in the wild
Clarias gariepinus	1980, 1986	Vietnam, Thailand	Aquaculture	Unknown	Hybridization	Beneficial & People prefer	Low price, hybrid
Cyprinus carpio	1965	Thailand	Aquaculture	Unknown	Yes	Beneficial, productive	
Laobeo Rohita	1965	Thailand	Aquaculture	Does not destroy habitat	None	Beneficial	Cannot breed in the wild
Oreochomis mossambicus	1965	Thailand/ Japan	Aquaculture	Unknown	Yes	Beneficial & People prefer	Unknown
Oreochromis niloticus	Unknown	Thailand	Aquaculture	Unknown	Yes	Beneficial & People prefer	Unknown
Pomacea canaliculata	1986	Thailand	Ornamental	Unknown	Unknown	Unknown	Unknown
Red tilapia	2002	Singapore	Cage culture	Unknown	Unknown	Unknown	Unknown
Ornamental fish	various	various	Ornamental	Unknown	Unknown	Unknown	Unknown
Freshwater prawn	NA	Thailand	Aquaculture	Unknown	Unknown	Unknown	Unknown
Fresh water ray	NA	NA	Aquaculture	Unknown	Unknown	Unknown	Unknown
Soft shell turtle	NA	NA	Aquaculture	Unknown	Unknown	Unknown	Unknown
Frogs	NA	NA	Aquaculture	Unknown	Unknown	Unknown	Unknown
Elephant ear fish	NA	NA	Aquaculture	Unknown	Unknown	Unknown	Unknown
Ice fish	NA	China	Not known	Unknown	Unknown	Unknown	Unknown

Appendix A3

Major exotic fish/shrimp species introduced to Viet Nam identified by the workshop participants

Common name	Scientific name	From	Number of introductions	Year introduced
Black Tilapia	<i>O. mossambicus</i>	Taiwan,	12	1951
Nile Tilapia	<i>O. niloticus</i>	Thailand		1973, 93, 95
Green Tilapia	<i>O. aureus</i>	Philippines	1	1996, 2001
Red Tilapia	<i>O. sp</i>	Cuba, Thailand	4	1996 1993, 96, 97
Grass carp	<i>Ctenopharyngodon idelus</i>	China	4	1958, 2000
Silver carp	<i>Hypophthalmichthys molitrix</i>	China	4	1964, 2000
Bighead carp	<i>Aristichthys mobilis</i>	China	1	1957
Hungarian common carp	<i>Cyprinus carpio L</i>	Hungary	2	1971, 1996
Indonesian common carp	<i>Cyprinus carpio L</i>	Indonesia	1	Before 1975
Indian carp				
Rohu	<i>Labeo rohita</i>	Thailand, India	3	1982, 1984, 2001
Mrigal	<i>Cirrhinus mrigala</i>	Laos, Thailand	2	1984, 1996
Catla	<i>Catla catla</i>	Laos	1	1984
	<i>Xtobus cyprinellus</i>	Cuba	1	1984
African catfish	<i>Clarias gariepinus</i>	Central African	1	1975
European eel	<i>Anguilla anguilla</i>	China	2	2000
Pacu	<i>Colossoma brachypomum</i>	China	6	1997, 1998, 2000, 2001
Oyster	<i>Crassostrea gigas</i>	China	1	2002
Triploid Murry cod		Australia	1	2003
Prawn	<i>Cherax sp</i>	Australia	2	1999, 2002
Cobia	<i>Rachycentron canadum</i>	Hongkong	12	1994-1999, 2000
Red snapper	<i>Lutianus enrythropterus</i>	Hongkong, Taiwan	4	1996-1999, 2001
Grouper	<i>Epinephelus sp.</i>	Taiwan	10	1996-1999, 2001
Seabass	<i>Lates sp.</i>	Taiwan, USA, Thailand and China	9	1996-2000, 2001
Red drum	<i>Sciaenops ocellatis</i>	China	1	1999
Sturgeon	<i>Hisodauric sp.</i>	Russia	1	1997
	<i>Setaenops ocellatus</i>	China	1	2000
Red seabream	<i>Parosomus major</i>	China, Taiwan	2	1999, 2000
Silver pomfret	<i>Pampus argentenus</i>		2	2000
Milkfish	<i>Chanos chanos</i>	Taiwan	1	1999
Black tiger shrimp	<i>Penaeus monodon</i>	Thailand, Singapore	Many times	1998-2003
White legged shrimp	<i>L. vannamei</i>	China, USA, Taiwan	Many times	2000-2003

Appendix A4

Major exotic freshwater fish/shrimp species identified by the workshop participants in Thailand

Scientific name	Common name	From	Year	Purpose	Introduced by
1. <i>Anguilla japonica</i>	Japanese eel	Japan	1973	Aquaculture	Unknown
2. <i>Carassius auratus</i>	Gold fish	China	1692-97	Ornamental	Unknown
3. <i>Carassius carassius</i>	-	Japan	1980	Aquaculture	Unknown
4. <i>Catla catla</i>	Catla	Bangladesh	1979	Aquaculture	Unknown
5. <i>Cichlosoma octofasciatum</i>		Brazil	1950s	Ornamental	Unknown
6. <i>Cirrhina mrigala</i>	Mrigal	Japan	1980	Aquaculture	-
7. <i>Clarias gariepinus</i>	African catfish	Laos	1987	Aquaculture	-
8. <i>Clarias macrocephalus</i>	-	-		Aquaculture	-
9. <i>Ctenopharyngodon idella</i>		China & Hong Kong	1932	Aquaculture	-
10. <i>Cyprinus carpio</i>	Common carp	China, Japan, Israel & Germany	1913 & onwards	Aquaculture	-
11. <i>Gambusia affinis</i>	Mosquito fish	-		Mosquito control	Government
12. <i>Gymnocorymbus ternetzi</i>	-	Paraguay & Argentina	1950s	Ornamental	
13. <i>Hypophthalmichthys molitrix</i>	Silver carp	China	1913	Aquaculture	-
14. <i>Aristichthys nobilis</i>	Big head carp	China	1932	Aquaculture	-
15. <i>Ictalurus punctatus</i>	Channel catfish	USA	1989	Aquaculture	Private sector
16. <i>Labeo rohita</i>	Rohu	India	1968	Aquaculture	-
17. <i>Mylopharyngodon piceus</i>	-	China/HKG	1913	Aquaculture	-
18. <i>Oncorhynchus mykiss</i>	Rainbow trout	Canada	1973	Fisheries	-
19. <i>Oncorhynchus rhodurus</i>	-	Japan	1981	Angling/sport	-
20. <i>Oreochromis aureus</i>	Blue tilapia	Israel	1970	Aquaculture	
21. <i>Oreochromis mossambicus</i>	Java tilapia	Malaysia	1949	Aquaculture	
22. <i>Oreochromis niloticus</i>	Nile tilapia	Japan	1965	gift to HM King	Royal family
23. <i>Osphronemus goramy</i>	Gourami	-	-	-	-
24. <i>Pomacea canaliculata</i>	Golden apple snail	Asia	1990	Aquaculture & Ornamental	-
25. <i>Pomacea gigas</i>	-	-	-	-	-
26. <i>Procambarus clarkii</i>	Red swamp crawfish	-	-	Aquaculture	-
27. <i>Rana catesbeiana</i>		-	-	Aquaculture	-
28. <i>Tilapia rendalli</i>		Zaire via Belgium	1955	Aquaculture	-
29. <i>Pampus argenteus</i>	Grey pomfret	NA	NA	Aquaculture	Unknown
30. <i>Chanos chanos</i>	Milk fish	NA	NA	Aquaculture	Unknown
31. <i>Fluta alba</i>	Albino swamp eel	NA	NA	Aquaculture	Unknown
32. <i>Epinephelus coiodes</i>	Grouper	NA	NA	Aquaculture	Unknown
33. <i>Epinephelus bleekeri</i>	Grouper	NA	NA	Aquaculture	Unknown
34. <i>Crocodilus</i> sp.	5 species	NA	NA	Aquaculture	Unknown
35. <i>Frogs</i>	7 species	NA	NA	Aquaculture	Unknown
36. <i>Lobsters</i>	3 species	NA	NA	Aquaculture	Unknown
37. <i>Turtles/tortoise</i>	5 species	NA	NA	Aquaculture	Unknown