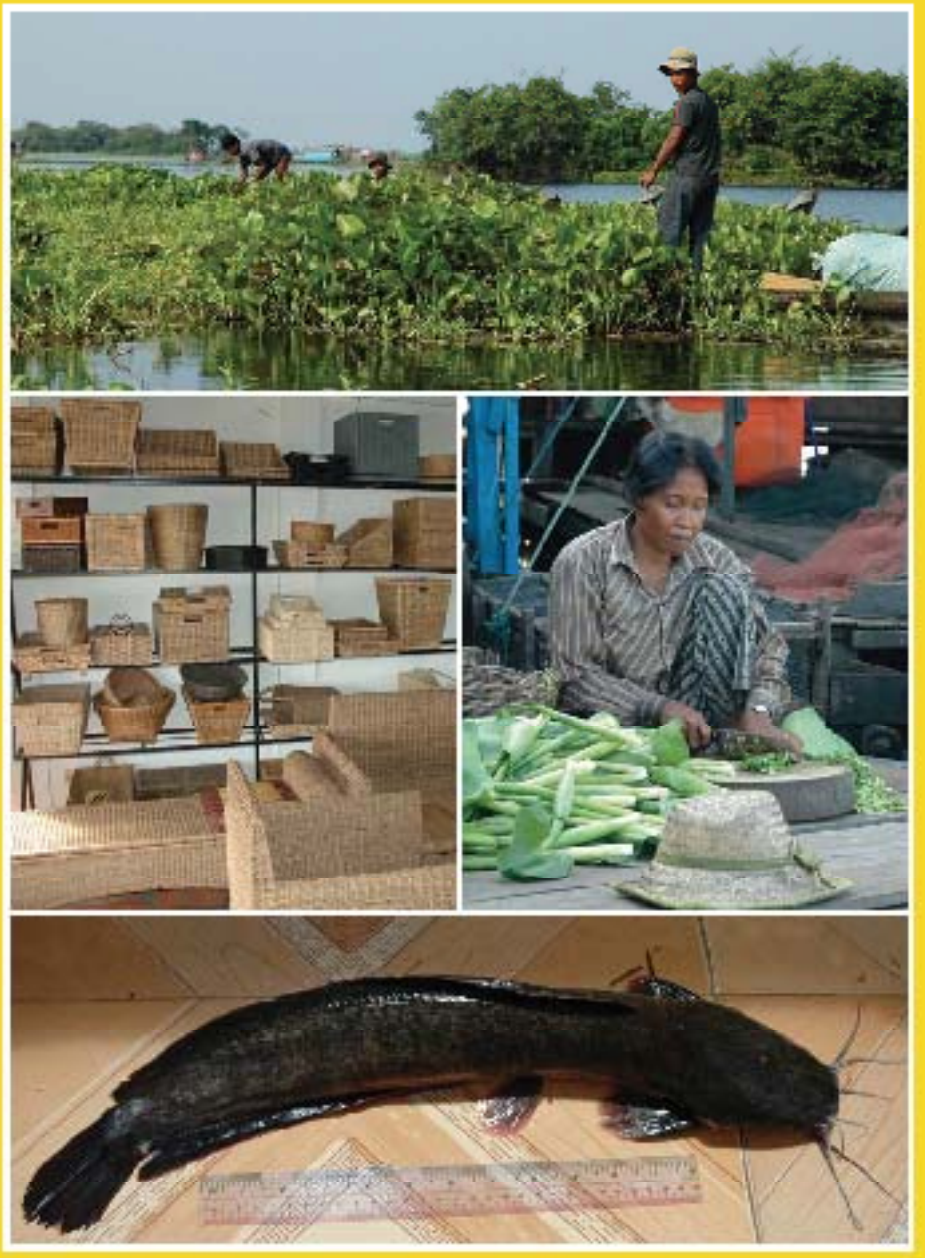
AN ASSESSMENT OF EXOTIC SPECIES IN THE TONLE SAP BIOSPHERE RESERVE



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AN ASSESSMENT OF EXOTIC SPECIES IN THE TONLE SAP BIOSPHERE RESERVE

AND ASSOCIATED THREATS TO BIODIVERSITY

A RESOURCE DOCUMENT FOR THE MANAGEMENT OF INVASIVE ALIEN SPECIES

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Executive Summary

Introduction

This report is mainly a literature review. It attempts to put together all the available information from recent biological surveys, and environmental and resource use studies in the Tonle Sap Biosphere Reserve (TSBR) in order to assess the status of exotic species and report any information on their abundance, distribution and impact. For those exotic species found in the TSBR, it is examined whether they can be termed as being an invasive alien species (IAS).

IAS are exotic species that pose a threat to native ecosystems, economies and/or human health. It is widely believed that IAS are the second most significant threat to biodiversity worldwide, following habitat destruction. In recognition of the threat posed by IAS the Convention on Biological Diversity puts forward the following strategy to all parties in Article 8h: "each contracting party shall as far as possible and as appropriate: prevent the introduction of, control, or eradicate those alien species which threaten ecosystems, habitats or species". The National Assembly of Cambodia ratified the Convention on Biological Diversity in 1995.

After reviewing the status of exotic species in the Tonle Sap from the literature, as well as the results from a survey based on questionnaires distributed among local communities, the main issues are discussed, possible strategies to combat the spread of alien species that are potentially invasive are examined, and recommendations are made to facilitate the implementation of a strategy towards reducing the impact of these species on the TSBR ecosystem.

The TSBR contains the largest continuous areas of natural wetland habitats remaining in the Mekong basin and the largest permanent freshwater body in South-East Asia, the Tonle Sap lake. The TSBR, due to the size of the annual inundation, forms the most important of the flooded areas for fish production in the Mekong river system, and the catch from the Tonle Sap area represents around 60% of Cambodia's inland fishery production. Besides the importance of the floodplain habitat for fish, it also supports the largest colonies of endangered waterbirds in South-East Asia and currently yields what is probably the world's largest snake harvest.

There are many pressures currently impacting on the lake and floodplain ecosystem, which are only likely to increase further in the short term, including habitat degradation, population growth, fishing pressure and potential hydrological changes. In the past, invasive alien species, being biological organisms themselves, have often been underestimated as a threat to biodiversity. Managers also lacked the knowledge on how to control invasive alien species and a lack of prioritization meant that there was very little funding available for any eradication efforts. The understanding of the threat invasive alien species pose to native ecosystems is increasing however and with it the recognition that due attention needs to be given to their presence and impact, especially in natural ecosystems important for conservation.

Therefore, by assessing the current status of exotic species and their impact on their environment, this study hopes to identify key issues that need to be addressed in order to negate the threat of invasive alien species in the TSBR and avoid the huge environmental and economic costs that will occur if such invasions continue to be ignored.

Results

Of the 50 or so exotic species considered in this report, there are two mammal, two mollusc, one amphibian, one crustacean, one insect, two reptile (as well as hybridized crocodiles), but 15 plant and 31 fish species. Out of all these species, the majority (which are fish with 28 species) have not been reported yet or remain unconfirmed that they have established populations in the TSBR, but they could potentially occur now or in the future as they are known to be in the Mekong basin, adjacent wetlands or are reared for aquaculture or aquaria within the basin.

These species are Siam Weed (*Chromolaena odorata*), Mission Grass (*Pennisetum polystachyon*), Peruvian Primrose (*Ludwigia peruviana*), Apple Snails (*Pomacea* spp.), North American Bullfrog (*Rana catesbiana*), Red-eared Slider (*Trachemys scripta elegans*), Chinese Softshell Turtle (*Pelodiscus sinensis*), Louisiana Crayfish (*Procambarus clarkii*), Chinese False Gudgeon (*Abottina rivularis*), *Acheilognathus barbatulus*, Chinese Bitterling (*Rhodeus sinensis*), Arapaima (*Arapaima gigas*), Goldfish (*Carassius auratus*), Mrigal (*Cirrhinus cirrhosus*), African Catfish (*Clarias gariepinus*), Pacu (*Colossoma macropomum*), Grass Carp (*Ctenopharyngodon idella*), Mosquito Fish (*Gambusia affinis*), Catla (*Catla catla*), Barbel Steed (*Hemibarbus labeo*), Spotted Steed (*Hemibarbus maculates*), Bighead Carp (*Hypopthalmichthys nobilis*), Suckermouth Catfish (*Hypostomus plecostomus*), *Metzia lineata*, Oriental Weatherfish (*Misgurnus anguillicaudatus*), Blue Tilapia (*Oreochromis aureus*), Mozambique tilapia (*Oreochromis mossambicus*), Nile Tilapia (*Oreochromis niloticus*), Red-bellied Pacu (*Piaractus brachypomus*), Guppy (*Poecilia reticulata*), Sailfin Molly (*Poecilia velifera*), Stone Moroko (*Pseudorasbora parva*), *Puntius semifasciolatus*, Redbreast Tilapia (*Tilapia rendalli*), Green Swordtail **(***Xiphophorus helleri*), and Southern Platyfish (*Xiphophorus maculatus*).

There are also captive populations of hybridized crocodile, due to the mixing of *Crocodylus siamensis* stock with *Crocodylus rhombifer* and/or *Crocodylus porosus* on crocodile farms in or near the TSBR area, especially around the town of Siem Reap. The European Honeybee (*Apis mellifera*) has also been introduced around Siem Reap in attempts at breeding and harvesting this species. These attempts have largely failed, but there may still be some people with colonies of *Apis mellifera*.

Of the remaining 18 exotic species that have been confirmed as having established populations in the TSBR from various studies, there are two domestic rat species, three species of fish and 12 plant species. The two species of rat, *Rattus rattus* and *Rattus norvegicus*, are long established and largely commensal to man, but have also been known to establish populations in natural habitats. Their impact on other fauna in the TSBR is unknown. Three species of fish, Common Carp (*Cyprinus carpio*), Silver Carp (*Hypopthalmichthys molitrix*) and Rohu (*Labeo rohita*) are regularly caught in small quantities from fishing lots on the Tonle Sap lake and river, and along the Mekong. It is likely that populations migrate between the Mekong and Tonle Sap lake, as do the majority of native fish, but this has not been confirmed. Although populations at present seem to be low, it is unknown if they are increasing and if there have been any negative impact to the environment as a result of their establishment.

A recent survey (18-19 November) of the Prey Kos area in Kampong Chhnang by a WCS/TSCP team revealed that an exotic species of fish “Trey Chaab” has been turning up regularly in fishermans' catches recently, and has been caught intermittently for around a year now. People from the area also report it as having human-like teeth, a description that fits that of a Pacu. The fish in question may be Red-bellied Pacu (*Piaractus brachypomus*), which has

been banned for aquaculture by the FiA, but fishermen report there may be two different yet similar species occurring in the Prey Kos area, also mentioning a similar species with very sharp teeth (which would indicate a Piranha). One man was reported as having been bitten by such a fish while swimming. A positive identification is required.

During this study there were a few reports of Apple Snails from individuals in Prek Loung Commune, Battambang (a villager mentioned a Japan Snail) and Sna Ansar and O Sandan Commune, Pursat. These reports need to be investigated further.

Most exotic plants seem to be long established already. The most abundant of these seem to be Water Hyacinth, Giant Mimosa (*Mimosa pigra*), Water Lettuce (*Pistia stratiotes*), Para Grass (*Brachiaria mutica*), Hippo Grass (*Echinochloa stagnina*) and Cutgrass (*Leersia hexandra*). Unfortunately at the time of preparing the questionnaire, the latter four species were not included due to a lack of a suitable Khmer name, so additional feedback on distribution, abundance and impacts from communities living in the TSBR was not gathered. Water Hyacinth can be considered a problematic species mostly due to the impact it is having on people by clogging up waterways and hindering movement. There is also likely to be an ecological impact due to its abundance, but this has not been documented and still needs to be properly assessed. However, when questioned most people would prefer to have it available for them to use, although they admitted that they would like to see it somewhat reduced in quantity. People collect it in small quantities as food for pigs and caged fish as well as themselves, and for making hammocks and string. It is also used in fisheries as a fish attractant, as it is reported that fish feed off aquatic insects attracted to the plant and use the mats as shelter.

Exotic plants are restricted in their distribution by environmental conditions. It was found that some exotic plants, namely Candlebush (*Senna alata*), Purging Nut (*Jatropha curcas*) and Mimosa spp. (*Mimosa invisa* and/or *M. pudica*) are predominantly restricted to upland areas while Water Hyacinth (*Eichhornia crassipes*) and Seedbox[*] (*Ludwigia hyssopifolia*) are limited to lowland areas. This is likely to be related to duration of flooding, to which certain species are sensitive. The extreme conditions around the Tonle Sap lake may therefore have a moderating influence on the spread of several exotic plants to some degree.

An exotic plant that is well suited to cope with conditions in most of the floodplain is the Giant Mimosa (*Mimosa pigra*). It was reported in nearly equal quantities in both upland and lowland areas, and was reported as widespread in different ecological conditions in the TSBR (*e.g.* lakes, rivers, irrigation channels, flooded forest, grassland and agricultural fields). It therefore appears that Giant Mimosa can invade all floodplain areas of the TSBR if there has been some disturbance of the natural vegetation cover, reducing competition and especially light source, and allowing seedlings to mature into established plants. Giant Mimosa plants were also reported as increasing in number by 61% of people interviewed and 83% of the people would like to see it removed from their area. It can be clearly identified as an invasive species and poses the biggest threat to biodiversity of all the exotic plants found in the TSBR. It is also a well known invasive alien species in other countries where it has occupied vast areas of productive wetland by forming dense mono-specific stands of very little to no value for wildlife and people alike. Although it is a recent introduction to Cambodia, having first been reported around the early 1980's, it is rapidly spreading along the Mekong, Bassac and Tonle Sap river systems. In the TSBR it has formed scattered populations and will quickly invade open disturbed habitats. The only way to prevent it from establishing itself is through efforts at population control and by conserving the natural vegetation cover, which prevents

[*] There is some confusion about the native range of *Ludwigia hyssopifolia* and it may actually be a native species.

the seedlings germinating.

There is very little data on the abundance of all exotic species in the TSBR and no in depth studies have been done on their impact to the ecosystem.

Recommendations

Reducing the threat of invasive alien species to biodiversity in the TSBR could become very expensive if all exotic species are targeted as potential invaders that need to be controlled. However, as some exotic species may have less of an impact on the ecosystem than others and there will be only a limited amount of funds available, prioritization is necessary. It is therefore recommended to start control programmes for those species that are clearly having, or will have, serious environmental, social and/or economic impact if allowed to spread further. At the same time surveys and ecological studies need to be conducted to better assess the status, distribution and impact of all other exotic species in the TSBR, the results of which can be used to carry out risk assessments for these species on their potential to become invasive.

Thus it is recommended to immediately start a programme aimed at the eradication of Giant Mimosa infestations and establishing a sharp reduction in the number of Water Hyacinth within the TSBR. At the same time, more information is needed about the status of all exotic species in the TSBR, as well as on the lake and floodplain ecology so that the relationship between plants and animals and the environment can be understood and the likely impact of invasive exotic species on biodiversity in the TSBR can be better assessed and predicted.

Setting up an invasive alien species control programme

In order to carry out the recommended activities a coordination unit needs to be established in accordance with the relevant government agency. The unit may consist of several teams in different provinces and a central coordination office in Phnom Penh. The teams will initiate and oversee the invasive species control programme and implementation of ecological surveys and studies. These activities may require assistance from various departments, universities, NGOs, projects and international organizations that are interested in biodiversity conservation in the TSBR. The central coordination office will monitor progress and provide direction to the overall programme.

The control of Giant Mimosa in the TSBR

In order to combat the continued spread of Giant Mimosa in the TSBR it is recommended that programmes follow a two-pronged approach:

1. Focuses on the immediate and continuous manual removal of all *Mimosa pigra* plants and seedlings from designated High Priority Areas while infestations are still scattered and manageable. For this the following approach is recommended:
    i. Conduct surveys to establish the full extent of the infestation and prioritize areas for initial control efforts.
    ii. Implement control in the priority area by first collecting all fruits and seeds from the control area and burning them, followed by the cutting and removal of mature plants and weeding of saplings. The method by which this is done will need to be adapted to the season in which the work takes place:
        a) During the rising floods (June-September), by cutting the plant as low as possible with the cut being at least 50 cm under water (the optimal depth of the cut will need to be experimented with) in order

to drown the plants.

b) In the dry season, by pulling or digging out the whole plant making sure no vegetative parts remain in the top soil, or if complete removal is not possible, by cutting the plant at least 10 cm below ground (again the optimal depth of the cut needs to be established through experimentation in the field).

iii. Community participation. Educate the community about the biological characteristics of Giant Mimosa and how to properly remove plants from their area and involve them in eradication efforts. The surveys among communities already conducted indicate they perceive this plant as a serious threat to their livelihoods and therefore it is important for them to become involved in the control programme.

2. Improving the protection of the natural floodplain habitat. Keeping the vegetation cover intact by preventing activities that cause large-scale disturbance, *e.g.* burning, within the flooding zone where the risk of the land becoming infested with Mimosa is high. Here also the communities will need to be involved. Surveys indicated that a large number of fires in the TSBR result from carelessness with burning cigarettes and cooking fires. However, it was also evident that many fires are purposefully lit, especially as a way of hunting turtles and other reptiles. Communities need to be educated on the importance of preventing the destruction of the floodplain habitat and also how fires stimulate the spread of Giant Mimosa. Awareness of the impact of burning on the ecosystem may bring about some changes to the current approaches to land use. The Planting/sowing of native fast growing grasses and shrubs in degraded areas will help the recovery process and reduce the chance of Giant Mimosa re-establishing itself.

Reducing the amount of Water Hyacinth

Water Hyacinth is not only a serious environmental weed due to its fast growth and ability to completely cover water surfaces, but also an immense economic opportunity if it can be harvested efficiently and converted into marketable products. There are many products that can be made from Water Hyacinth, including animal feed, compost, biofuel, paper, fibre boards, and furniture.

It has been suggested that an evaluation study be conducted on the feasibility of placing a number of booms at strategic locations (*e.g.* near inlets of the Sap river and other major tributaries of the lake) where a great deal of Water Hyacinth can be gathered before it enters the lake with the inflowing water and is washed out with the outgoing pulse. An industrial facility for converting the collected organic refuse into a product could be connected to such sites.

At the same time local small scale enterprises can be initiated within local communities in the TSBR. There is already one example of such an initiative in Prek Toal where local women are producing handicrafts from dried Water Hyacinth stems for sale to tourists visiting the area. There are however many more possibilities to explore including harvesting Water Hyacinth for methane gas production which can be converted using generators to supply households or villages with electricity, or the manufacturing of compost for sale to farmers in upland areas. Hydroponics, using prepared floating beds of Water Hyacinth in order to cultivate vegetables throughout the year, may be economically attractive and make a substantial contribution to the well-being of people living in the floating villages of the Tonle Sap. After the Water Hyacinth has been used in this way it can be converted to compost, further increasing its value.

Increasing the economic use of Water Hyacinth is the most realistic way at present to stimulate removal of the plant and hopefully offset its phenomenal growth rate. It is not believed that offtake will cause a shortage of Water Hyacinth so as to discontinue the production of goods, as new plants will be brought in from other areas each year in the wet season and it is known to grow and produce new plants at a very high rate. However, a serious economic enterprise will require a feasibility study on yearly plant biomass variations, influx and production to measure the amount that needs to be harvested each year in order to eventually arrive at an acceptable level of Water Hyacinth within the ecosystem (for TSBR managers) that may also ensure continued availability (for industrial use).

In other countries biocontrol has been applied, especially through the use of a pair of weevils, *Neochetina bruchi* and *N. eichhorniae* with some success, but this has mostly been efficient in stagnant to slow flowing waters where the weevils can form large colonies on the sprawling interconnected mats. In a situation such as the Mekong and Tonle Sap where many individual free floating plants are encountered or in small-medium size mats, that can also be washed away with the current towards the sea and deposited on land with the floodwaters, the build up of colonies of weevils over time, large enough to damage the majority of plants, is much less likely to occur and therefore biocontrol may be a less effective option here.

Reducing the risk of the further introduction of exotic species

Within the management unit of the TSBR there is relatively little that can be done in this regard. Most exotic species enter the TSBR via waterways. The Mekong River flows through China, Laos and Thailand before it enters Cambodia and so controlling the introduction of exotic species ultimately has to be approached in a regional context. It is always possible to set an example however, and there is no reason why Cambodia should refrain from beginning to implement certain measures.

The Cambodian government has already shown itself willing to deal with what are potentially invasive exotic species, without first waiting to see what happens, for example by imposing a ban on the cultivation of the Red-bellied Pacu (*Piaractus brachypomus*). There are many other exotic fish species that could have disastrous consequences if they were to form established populations in the entire Lower Mekong Basin and for which the risk of introduction needs to be avoided. These include many of the members of the Carp family, African and American catfish species, Tilapias and large predatory fish popular in the aquarium trade such as the Arapaima (*Arapaima gigas*).

Another option is to at least ban the use of exotic species for aquaculture within the maximum flooding zone of all major rivers, as the inundation of aquaculture ponds by floodwaters is one of the main causes of accidental introduction. This may be relatively easy to do as the availability of native fish caught from the river is preferred over exotic aquacultural species in much of Cambodia, which has resulted in exotic species being grown more in areas further from the major rivers and therefore there will be fewer enterprises affected by such a ban.

Within Cambodia there have been attempts to cultivate Apple Snails (*Pomacea* spp.) for food. The snails escape or are released by people uninterested in continuing in a market where local snails are preferred and do tremendous damage to rice crops and aquatic vegetation. Apple Snails have had a devastating impact on wetland vegetation and are listed as being one of the 100 worst invaders by the IUCN invasive species specialist group. It is recommended banning the importation and cultivation of Apple Snails and exterminate the snails and their eggs in areas where they have been found.

There have been several largely unsuccessful attempts to introduce the European Honeybee (*Apis mellifera*) in the Siem Reap area. Though the European Honeybee did not do well due to brood infections by parasites and a lack of available food sources, each attempted introduction could bring with it potential diseases that can be transmitted to local honeybees. It is recommended to stop further introductions by banning the importation and use of European Honeybees and encouraging the use of local honeybees for beekeeping instead.

Also in the Siem Reap area, some of the larger wealthier crocodile farms have been known to import exotic species such as the Cuban Crocodile (*Crocodylus rhombifer*) and use the native, but not local Estuarine Crocodile (*C. porosus*) to improve the gene pool of the local, mostly Siamese Crocodiles (*C. siamensis*) on their farms. The resultant hybridized crocodiles could threaten ongoing conservation efforts in the TSBR of the globally endangered wild Siamese Crocodiles. These crocodile farms need to be monitored to ensure that they have taken every precaution to prevent the escape of crocodiles from their farm. The use of exotic species of crocodile in the direct vicinity of the Tonle Sap lake and floodplain needs to be officially banned.

Increasing our knowledge of the ecology of the TSBR

The need for an assessment of the status of exotic species within the TSBR and the identification of potential invasive species stems mainly from the desire to conserve the TSBR ecosystem as the most important floodplain habitat for fish within the Lower Mekong Basin and its importance as a habitat for several globally threatened species of wildlife. A loss of biodiversity and productivity will have immense repercussions on the welfare of the people of Cambodia.

But how are biodiversity and productivity linked and how are they affected by invasive species or any other changes in the environment for that matter? Without a proper understanding of the ecology of the TSBR ecosystem these questions cannot be properly answered and management of the TSBR for maintaining resource productivity and ensuring the conservation of threatened species will be largely reactive in nature and always lagging behind the development of what can be major environmental and economic problems.

Ecological understanding of the Tonle Sap lake and floodplains is still in its infancy. Very few synecological or autecological studies have been conducted. There is still a lot of controversy over the relative influence of environmental vs. anthropogenic factors on vegetation formation in the floodplain. To understand the possible impacts of Water Hyacinth and other invasive species on the ecosystem, a much more detailed study of ecological relationships of the fauna and flora in the TSBR is needed. With greater availability of data on ecological relationships between species, and between species and the environment, the past, present and future impact of invasive species can be better understood.

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Finally, many thanks also to Anna-Maria Nugent for her proof-reading of the final draft.

List of Acronyms and Definitions of Biological Terms Used

AIMS	Aquaculture of Indigenous Mekong Species programme
Alien/exotic/foreign	Refers to, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem*.
Autecology	Another word for population ecology. It is the study of the dynamics of species populations and how these populations interact with the environment.
Barbels	Fleshy tentacle-like projection near mouth, chin or snout
Benthic	Dwelling on, or relating to, the bottom of a body of water.
Benthopelagic	Organisms that live and feed near the bottom of water bodies as well as in mid-waters or near the surface. Many freshwater fish are such opportunistic feeders.
Boeung	Khmer name for a lake
Carapace	The dorsal, convex part of the shell structure of turtles, consisting of an external layer of horny material, divided into large plates known as scutes, which overlie a layer of interlocking bones
CBD	Convention on Biological Diversity
CNMC	Cambodia National Mekong Committee
CITES	Convention on International Trade in Endangered Species
Demersal	Organisms that live and feed near the bottom of water bodies
Dorsal	Top or upper
EIA	Environmental Impact Assessment
Ecosystem	Refers to the complex of a specific community of organisms and its environment*
FAO	Food and Agriculture Organization
FiA	Fisheries Administration (formerly Department of Fisheries)
GISP	Global Invasive Species Programme
Herbaceous	General term for plants that do not produce woody stems
Heterotrophic	Refers to those species that must obtain their energy and other necessary organic compounds by consuming organic material. In contrast to an autotroph which is capable of synthesizing its own organic substances from inorganic compounds.

* Official U.S. definitions regarding invasive species as provided in Executive Order 13112, February 3, 1999

IAS	Invasive Alien Species
Inflorescence	The arrangement of flowers on a plant
Invasive species	Refers to an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health*
ITDG	Intermediate Technology Development Group / Practical Action
IUCN	International Union for the Conservation of Nature
JICA	Japan International Cooperation Agency
Leguminous	Refers to plant species of the family Fabaceae, of which many harbor colonies of nitrogen-fixing bacteria in their roots
Lentic	Living in swamp, pond, lake or any other standing or slow moving water, as opposed to lotic or running waters
MAFF	Ministry of Agriculture, Forestry and Fisheries
MFD	Mekong Fish Database
MoE	Ministry of Environment
MRC	Mekong River Commission
MWBP	Mekong Wetlands Biodiversity Programme or Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme
NGO	Non Governmental Organization
Pectoral	Pertaining to the breast
Pelagic	Living and feeding in open water, between the surface and middle depth
Pelvic	Related to the abdominal area or girdle
Periphyton	Refers to the mix of algae, cyanobacteria (blue-green algae), heterotrophic microbes and detritus that is found attached to underwater surfaces
Phytoplankton	Refers to those submerged floating photosynthetic organisms, excluding higher plants, whose movement is largely determined by water currents
Raceme	An inflorescence having stalked flowers arranged singly along an elongated unbranched stem
Rhizome	A horizontal, usually underground stem that will often send out roots
SL	Standard Length. A measurement referred to here as that used in fish taxonomy. The length measured from the most anterior tip of the body

* Official U.S. definitions regarding invasive species as provided in Executive Order 13112, February 3, 1999

	to the midlateral posterior edge (i.e. excluding the length of the tail fin).
Species	Refers to a group of organisms all of which have a high degree of physical and genetic similarity, generally interbreed only among themselves, and show persistent differences from members of allied groups of organisms*.
Spikelet	Type of inflorescence whereby the flowers do not have stalks but form directly on the stem
Sp.	Species (single)
Spp.	Species (plural)
Ssp.	Subspecies
Stolon	A stolon is an aerial shoot from a plant with the ability to produce adventitious roots and new offshoots of the same plant
Synecology	Another word for community ecology. It is the study of the distribution, abundance, demography and interactions of populations of coexisting species.
TL	Total length. A measurement referred to here as that used in fish taxonomy. It is the greatest length of the whole body between the most anterior point of the body and the most posterior point, measured in a straight line, not over the curve of the body.
Tonle	Khmer name for a large river
TSBR	Tonle Sap Biosphere Reserve
TSBRS	Tonle Sap Biosphere Reserve Secretariat
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States of America
WCS	Wildlife Conservation Society
Zooplankton	Refers to those floating aquatic organisms that feed on plankton and whose movement is largely determined by water currents

* Official U.S. definitions regarding invasive species as provided in Executive Order 13112, February 3, 1999

Introduction

This report is mainly a literature review. The objective of this study was to gather as much existing information as possible on the current status of foreign species of plant and animal (including fish) in the Tonle Sap Biosphere Reserve, from the literature (in English) and by interviewing key informants, and thereby also to conduct an assessment of the level of invasiveness or threat these exotic species pose to biodiversity in the reserve.

There are many native species which may be considered weeds or pests (invasive) in agricultural areas where land has been cleared and sown with the purpose of growing and reaching the full growth potential of a select few crops. Even in natural areas that are used by people, such as is found in the Tonle Sap Biosphere Reserve, depending on who is asked, native species could be termed as undesirable weeds. The difference with an exotic species, is that the growth of native species under natural conditions is affected and ultimately kept in balance by a host of parasites, predators, and diseases which have co-evolved and can be very plant specific, while exotics may find a relative absence of natural enemies. If the environmental conditions are suitable and the biological characteristics of the introduced species allow it to reproduce rapidly, and produce large quantities of offspring, their introduction can result in explosive growth. Such exotics can be described as invasive species. Invasions such as this may replace or reduce large numbers of native species and become a dominant characteristic of an altered ecosystem. The impact on biodiversity and productivity of the ecosystem as a result of the introduction of an invasive species can be severe.

What is an invasive?

In this report an invasive refers to an invasive alien species. To understand this term the words invasive and alien must be clarified.

Alien means foreign or exotic. It refers to, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, which is not native to that ecosystem.

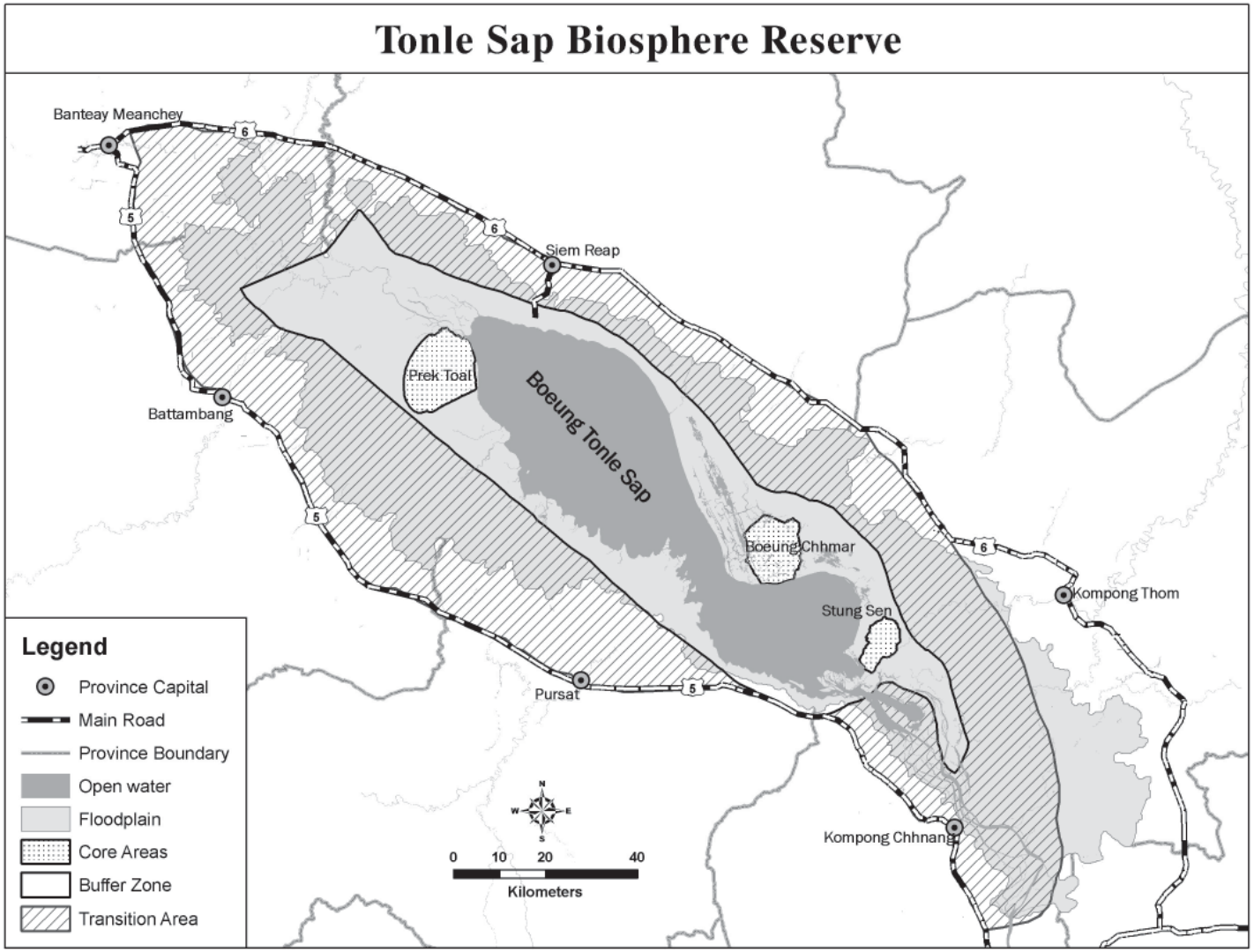
Invasive species refers to those alien species whose introduction do or are likely to cause economic or environmental harm or harm to human health.

An overview of exotic species found in the Tonle Sap Biosphere Reserve (TSBR) is presented in the main body of this report. Following the compilation of a list of exotic species reported from the TSBR, a questionnaire was developed (see Appendix B) in which community representatives were asked about the occurrence of selected species in their area, and their use. As most people are unaware about the origin of many species, as for example the Water Hyacinth which was introduced to the region over a 100 years ago (Banpot Napompeth, 1992; Tran Triet, 2000), a reference list was attached to the questionnaire to make sure at least those species were included (see Appendix C). Not all species that have been reported from the TSBR could be used in the questionnaire due to a lack of either a Khmer name or the possibility of confusion of species as sometimes a Khmer name is applicable to a range of related species. For those species that are easily identified by their appearance, a picture was included.

The questionnaire was used in order to consult the people living in the area on their impressions of the species incorporated, regarding distribution, rate of increase, as well as negative and positive aspects of their presence, which also relates to their use. The feedback confirmed the invasiveness of some species. Also the value people put on a species (usually as a resource) is a factor to take into account in determining how, and to what extent, control activities should be implemented, especially in a multiple-use area such as the TSBR.

After reviewing the status of exotic species in the Tonle Sap from the reports, interviews and questionnaires, the main issues are put forward for discussion and recommendations are made to facilitate the implementation of a strategy towards reducing the impact of invasive alien species on the TSBR ecosystem.

As an invasive species may have a large impact on the ecology and economy of the Tonle Sap Biosphere Reserve, the current situation in the Tonle Sap lake and the surrounding floodplains is described below.



Map of the Tonle Sap Biosphere Reserve

The Great Lake

The Tonle Sap lake and floodplains contain the largest continuous areas of natural wetland habitats remaining in the Mekong basin, and represent the largest permanent freshwater body in South-East Asia (Sarkkula *et al.*, 2003). The hydrology of the lake is largely determined by the Mekong. When the level of the Mekong waters rise in the flood season (June-September), the flow of the Tonle Sap river which connects the lake with the Mekong is reversed so that water is pushed into the lake. As a result the area of the lake increases dramatically, between 3-6 times, from 2,700 km^2 to 9,000-16,000 km^2 and water level is raised from around 1 m to 7-9 meters (van Zalinge, 2003b). The flooded area at its peak covers about 5-8% of Cambodia's land area (MRC, 2003 in: Hortle *et al.*, 2004).

With the flood pulse from the Mekong, sediment rich waters enter the Tonle Sap Lake and are deposited in the newly flooded areas, with only a negligible proportion settling in the actual lake itself. Around 20% of the sediment level flowing into the lake from the Mekong is swept out of the lake again when the flow reverses (Sarkkula *et al.*, 2003). Net sedimentation in the lake itself has been in the range of 0.1-0.16 mm/year since the lake was formed less than 6,000 years ago (Tsukawaki, 1997 and Penny, 2002, in: Sarkkula *et al.*, 2003). Furthermore, at present, sedimentation and erosion of soil at the bottom of the lake itself is believed to be in balance and therefore the lake proper does not appear to be filling up with sediment as was formerly thought. The soil particles deposited in the floodplain contain essential nutrients, especially nitrogen and phosphorous, the availability of which is the limiting factor for primary production at certain times of the year (Sarkkula *et al.*, 2003).

The vegetation of the floodplains and surrounding areas of the Tonle Sap lake, largely following the area now designated as the Tonle Sap Biosphere Reserve (*i.e.* the area between national roads 5 and 6) was classified, according to a 1996-7 JICA landuse survey, as mostly shrubland (34%) and wet season rice (31%). Other vegetation types that cover large areas are abandoned fields covered by grass (14.5%), grasslands (9%), abandoned fields covered by shrubs (3%), and village crop fields (3%). The actual area that is still flooded forest is around 200 km^2, which is only around 1.7% of the TSBR. Here again it has been found that the borders between forest and shrubland are difficult to mark as most shrublands will also contain relatively tall trees (Hellsten *et al.*, 2003). The vegetation structures observed at present have been influenced by over a thousand years of human use, comprising intensive fuelwood collection, past and present conversion of areas to agriculture, and slash and burn activities (McDonald and Sam Veasna, 1996).

The flooded "forest" forms a belt 7-65 km wide around the open water surface of the lake, and is estimated to cover about 3,000-3,600 km^2 at present (Neou Bonheur *et al.*, 2005; Rundel, 2000). The term flooded forest is widely applied to describe the dominant natural floodplain vegetation currently found around the lake, *i.e.* the shrubland as described above. It stems from the French "forÍt inondÈ" and refers to all seasonally inundated vegetation dominated by woody species (Campbell *et al.*, 2006). A more correct description is "seasonally flooded freshwater swamp forest" (Goes, 2005), but for ease of reading the term flooded forest is maintained in this report. It must be kept in mind that this refers to a mixed vegetation type containing both trees and shrubs.

There is some controversy over the effect extensive seasonal flooding has had on vegetation formation throughout the floodplain as opposed to anthropological influences. McDonald, besides acknowledging that a large part of the vegetation is disturbed by constant human pressure, as many authors do, also feels that as there are areas that seem to have no history of human disturbance yet also have shrubby, short tree flora. Water stress may be stunting growth of plants to such a degree that shrubs and short trees may be the climax vegetation in

much of the floodplain anyhow, even without human disturbance (McDonald *et al.*, 1997).

The natural ecosystem is adapted to withstand a seasonal water variation level of up to ten meters. Trees and shrubs are almost exclusively deciduous, but leaf fall occurs underwater when branches are submerged, and leaf regrowth takes place in the dry season as the water recedes. Flowering is also related to the dry season and the fruits that are formed are ready to be transported to new areas when the floodwaters appear (Goes, 2005). Another unique characteristic of the flooded forest is that plant species diversity decreases with proximity to the lake, where the duration of flooding is the longest, thus plant diversity here shows an unusual inverse relationship with the wettest areas of the flooded forest (McDonald *et al.*, 1997).

The rise in water levels at the beginning of the flood season triggers a migration of fish from dry season habitats, which for a large number of species is upstream in the Mekong in the deep pools area just below the Khone Falls, to the newly inundated areas in search of food. The floodwaters also carry larvae and juvenile fish into the flooded areas which will then act as a nursery, providing shelter and food, during the flood season (Poulsen *et al.*, 2002). Besides migratory fish, there are a number of species that tolerate very low oxygen levels and will remain in the shallow waters of the lake during the dry season and move into the flooded forest when water levels rise. Among those fish that depend on the flooded forest habitat are the commercially valuable Snakehead species (Troeung *et al.*, 2002 in: van Zalinge *et al.*, 2003b).

The Tonle Sap lake, due to the extent of the annual inundation, is the most important of the flooded areas for fish production in the Mekong river system (Hortle *et al.*, 2004; Hap Navy *et al.*, 2006b). The estimated fish yield from the Tonle Sap floodplains and lake ranges between 139-190 kg/ha/year (Lieng and van Zalinge 2002), with higher production being related to years with longer and more extensive flood periods. The catch from the Tonle Sap area represents around 60% of Cambodia's inland fisheries (Hap Navy *et al.*, 2006b).

Besides the importance of the floodplain habitat for fish, it also supports the largest colonies of endangered waterbirds in South-East Asia (Goes, 2005) and yields what is probably the world's largest snake harvest (Stuart *et al.*, 2000 in: Goes, 2005).

It is estimated that around 1.25 million people in 5 provinces that border on to the lake (*i.e.* Kampong Chhnang, Siem Reap, Battambang, Pursat, and Kampong Thom) are dependant on the resources that can be extracted from the lake and surrounding wetlands (Hap Navy *et al*., 2006b). Households in the Tonle Sap Biosphere Reserve engage in diverse income generating activities, including fishing, fish -processing, -culture, -marketing, farming, water snake harvesting, timber collection (both for firewood and for constructing sheds or support structures such as stilts) and gathering of other aquatic resources such as Water Hyacinth, Morning Glory/Water Spinach, Baringtonia leaves, and Water Lily among others, for household consumption and various other plants for medicine (Neou Bonheur *et al.*, 2005; Hap Navy *et al*., 2006b). Over 90% of the regional flora is of some use or economic value to the communities (McDonald and Sam Veasna, 1996; Neou Bonheur *et al.*, 2005).

The lake is often referred to as the "heart of the kingdom", reflecting both its vital importance and the annual pulse of the waters that produce its incredible richness. The Angkorian civilization flourished on the boundary of the flooded forests of the Tonle Sap or Great Lake, and later, Phnom Penh was established at the confluence of the Mekong and Tonle Sap rivers (Goes, 2005).

Recognizing the unique environmental, economical and cultural significance of the Tonle Sap lake, the Royal Government of Cambodia and UNESCO inscribed it into the world network of Biosphere Reserves in October 1997 (Goes, 2005) and in April 2001, a Royal Decree on the establishment of the Tonle Sap Biosphere Reserve was adopted culminating in the zonation of the reserve (Neou Bonheur, 2006). Biosphere Reserves are sites recognized under UNESCO's Man and the Biosphere Programme, whereby management aims to innovate and demonstrate approaches to conservation and sustainable development (UNESCO, 2006). The Tonle Sap Biosphere Reserve (14,812 km^2) consists of 3 core areas: Prek Toal (213 km^2), Boeng Chmar (145 km^2), and Stung Sen (63 km^2) where in principle only scientific research and monitoring activities are permitted, a buffer zone where human activities and settlements are allowed but activities must be in accordance with conservation objectives, and a transition zone for integrated economic development which does not cause a detrimental impact on the other zones (see the map under this section for the location of the different zones). For the Tonle Sap Biosphere Reserve some special exceptions were made by allowing both fisheries (in the form of fishing lots) and ecotourism to be undertaken in the core areas (Goes, 2005).

The lake and surrounding inundation zone are showing the impact of over-exploitation of resources which is reducing habitat quality and biodiversity value and thereby the potential to support livelihoods. Many of the pressures presently impacting on the lake and floodplain ecosystem are likely to increase greatly in the short term, including population growth, fishing pressure and hydrological changes (Campbell *et al.*, 2006). Invasive alien species can be added to this list.

How to Approach the Issue of Invasive Alien Species in the TSBR

Invasive alien species are recognised as one of the leading threats to biodiversity worldwide, second only to habitat destruction (Williams, 2002), and their presence and impact also imposes enormous costs on agriculture, forestry, fisheries, and other human enterprises, as well as human health (Wittenberg and Cock, 2001).

Rapidly accelerating human trade, tourism, transport, and travel over the past century have dramatically enhanced the spread of invasive species, allowing them to surmount natural geographic barriers. However, not all non-indigenous species are harmful. In fact the majority of species used in agriculture, forestry and fisheries are alien species. Thus, the initial step in a national programme must be to distinguish the harmful from the harmless alien species, and identify the impact of the former on native biodiversity (Wittenberg and Cock, 2001).

This report may be considered as such an initial step. By reviewing the status of exotic species in the Tonle Sap Biosphere Reserve (next chapter) it attempts to distinguish those exotics that are harmful to the environment from those that have not had any major negative impact, so that available resources can be efficiently directed towards the most threatening of the "invaders".

Due to the Rio Earth Summit in 1992, when it was recognized that biological systems are very complex and it can take a very long time to study all interactions to accurately predict an outcome, a precautionary principle has been recommended when it comes to alien species. The precautionary principle means that every alien species needs to be treated for management purposes as if it is potentially invasive unless and until convincing evidence indicates that this is not so (von Oertzen and Smith, 2001).

This is, however, an ideal. In reality the underlying understanding is likely to be that those countries that have the resources will tackle all potential invasives, while poorer countries,

although fully acknowledging any problems and seriously undertaking as much as possible to address the issue of the spread of exotics, are forced to prioritize those species that clearly pose the largest threat to the country's natural productivity.

Under the Convention on Biological Diversity, which also stems from the Rio Earth Summit, a more realistic approach (for developing countries) is advised in article 8h. Article 8h states that, "each contracting party shall as far as possible and as appropriate: prevent the introduction of, control, or eradicate those alien species which threaten ecosystems, habitats or species". Biosphere Reserves can be considered as tools to help countries implement the results of, in particular, the Convention on Biological Diversity (UNESCO, 2006). Furthermore, the Kingdom of Cambodia actively participated in the negotiations leading to the Convention, and ratified it in 1995 by National Assembly (MoE, 2002). Thus, by this reasoning, managers of the TSBR, but also national environmental departments are urged to, at the very least, make every effort to control those exotic species that may be considered as major threats to native ecosystems.

Accounts of Exotic Species Reported from the TSBR Including Species that may Potentially Occur

As the focus of this study is on exotic species that are potentially invasive within natural ecosystems, only those plants that have the ability to spread rapidly without human assistance are considered. A number of exotic plants have been introduced to the area for cropping or home gardens, or are planted near villages and along roadsides. Such introduced species reported from the TSBR include, among others: Jujube (*Zizyphus jujube*), and Tamarind (*Tamarindus indica*) for consumption purposes; Purging Nut (*Jatropha curcas*) and Candlebush (*Cassia alata*) for medicine; as well as a few long-lived tree species such as the Silkcotton Tree (*Ceiba pentandra*). Most of these plants rely on some form of human aid (at least in the environment of the TSBR), such as site selection and planting, weed removal, fertilizer and pesticides, or have long lifespans and are slow growing, or are otherwise do not spread rapidly beyond their introduced area. They have, therefore, not been included in the species account of exotics reported as occurring in the natural environment of the Tonle Sap Biosphere Reserve and which could potentially become invasive. Candlebush and Purging Nut were included in the questionnaire survey and in the species accounts below as they are quite likely to spread in drier areas of Cambodia where they have been introduced and their threat to biodiversity needs to be considered. The Silkcotton Tree was also included in the questionnaire, but was not mentioned by anyone interviewed as occurring in their area and has not been considered further.

The fish species mentioned below are species that have not necessarily been reported from the Tonle Sap lake at present, but have the potential to become established. Adults or fry of these species have been reported from the Mekong basin, or they are species that are kept in the region for aquaculture, stocking reservoirs or in aquariums whereby there is an increased risk of them entering the Mekong river system, with a potentially negative impact as a result.

Also listed in the species accounts are those exotic amphibians, mollusks, crustaceans, and mammals that have been recorded from the TSBR, as well as others that are found in the region in similar habitats and could quite easily spread to the Tonle Sap.

The species accounts use numbered referencing in the text instead of the classical approach in order to save space. Sections of text are followed by a number related to the references at the end of the report. Each species has a corresponding picture which can be found by looking up the picture number (highlighted in grey) in the species title section in the picture pages in the middle of the accounts.

Plants

Water Lettuce *Pistia stratiotes* (Araceae)

ជ័កថ័ម Châk thôm Picture #1

Place of Origin:	Africa or South America[65]
Introduced Range:	Pantropical[65,86]
Reported as invasive in other countries:	Yes[65,86]
Status reported from TSBR:	Reported as abundant[75]
Risk of species being invasive in TSBR:	Low. This is a long established species and although it is abundant local people did not report any negative impact.
Description of species:	Free-floating herb in rosettes of grey-green leaves, rosettes occurring singly or connected to others by short stolons. Leaves slightly broader than long, widest at apex, to 15 cm long. Flowers inconspicuous, clustered on small fleshy stalk nearly hidden in leaf axils, with single female flower below and whorl of male flowers above. Fruit arising from female flower as a many-seeded green berry[65]
Ecology:	It is commonly found in dams, lagoons, lakes and other still or slow-flowing waterbodies. It is also sometimes found rooting on muddy banks. Forms dense mats, which can block waterways and lead to a lower concentration of oxygen in water and sediments as well as blocking sunlight[65,86,100]
Dispersal/Propagation:	Reproduces rapidly by vegetative offshoots formed on short, brittle stolons, and then spreads by water currents and floods. Broken-off pieces or whole plants are sometimes moved on boats or fishing equipment. Reproduction also takes place by seeds. Dumping of aquarium or ornamental pond plants is often the means of spread for *P. stratiotes*[65,86,100]
Uses:	It may be used as pig feed[99]
Control methods used:	The Water Lettuce Leaf Weevil (*Neohydronomus affinis*) is a native herbivore that specifically lives and feeds on Water Lettuce and has been used with some success in Australia. Another effective biocontrol agent is the Water Lettuce Leaf Moth (*Spodoptera pectinicornis*), which is actually a native of Thailand, showing that some native species have adapted to such a degree that they are now fully reliant on this species as a resource in parts of its introduced range[86]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its abundance, distribution and impact.

Siam Weed *Chromolaena odorata* (Compositae)

ទន្ទ្រាំនខេត Tuntrien khaet Picture #2

Place of Origin:	Tropical America[100,148]
Introduced Range:	South Africa, India, China, South-East Asia[100,148]
Reported as invasive in other countries:	Yes[100,148]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low at present, but has been reported from wetlands and other habitats in the Lower Mekong[124,128]
Description of species:	Herb. Normally around 1.5-2m high, but can grow up to 6m in height if climbing on other plants. Flowers are grouped in terminal clusters of 20 to 60 heads on all stems, forming masses covering the whole surface of the bush and branches. Flowers are white, pink or pale bluish-lilac[100,148]

Ecology:	It grows in many soil types but prefers well-drained soils. It does not tolerate shade and thrives well in open areas. Forms dense tangled bushes preventing establishment of other species. Can promote bushfires when dry[100,148]
Dispersal/Propagation:	Seeds disperse with wind. Seeds can be inadvertently spread as they stick to clothing and hair and their tiny size means they can be moved unnoticed on vehicles/machinery and often occur as a contaminant in imported seed. Can propagate vegetatively from stem and root fragments[100,148]
Uses:	An ornamental plant. Has also been encouraged as a competitor for *Imperata cylindrica*, which is more difficult to control.[148] In Cambodia it is also used as a green manure[99], though this does not seem advisable given the risk of introducing seed onto the land.
Control methods used:	Grazon™ DS is a herbicide recommended by the Department of Agriculture and Food, Western Australia for control of Siam Weed[22].
Recommendation:	No action required at present, but should be included as a species to look out for. Could be included in the ongoing biodiversity surveys to reassess status.

Purging Nut *Jatropha curcas* (Euphorbiaceae)

ល្មុងខ្វាង Lhông kwâng Picture #3

Place of Origin:	Caribbean region[29]
Introduced Range:	Africa, Asia, and Australia[29]
Reported as invasive in other countries:	Yes[100]
Status reported from TSBR:	Present, but mostly planted by people. Reported as common along roadsides[11]
Risk of species being invasive in TSBR:	Low, as environmental conditions are largely unsuitable, except for the drier conditions found on raised road embankments and certain elevated areas.
Description of species:	Perennial shrub. Normally, sheds leaves in the dry season. Leaves are large, grouped alternately around stem, and are three-to five-lobed. Each inflorescence yields a bunch of approximately 10 or more ovoid fruits, containing three seeds each[100]
Ecology:	Grows on well-drained soils, with good aeration and even nutrient-poor soils. Can grow under very arid conditions[100]
Local distribution:	Has been distributed by people as an ornamental, used among others in hedges and is being promoted as a biofuel[100]
Uses:	Is promoted as a green alternative fuel source. Seeds contain 30-40% oil, kernels 50-60%[120]. All parts of the plant are used as traditional medicine to cure a whole range of mild to serious aflictions. In Cambodia, the latex from the plant is applied to wounds, leaves are used in antiparasitic remedies, scabies and rheumatism. Seeds are toxic. Ingesting 2 seeds is strongly purgative, but 4-5 seeds could lead to death[99]
Control methods used:	Metsulfuron is recommended by the Department of Agriculture and Food, Western Australia for the control of *Jatropha curcas*[23]
Recommendation:	No special management seems to be needed in the TSBR, but it may require attention in drier areas of Cambodia.

Giant Sensitive Mimosa *Mimosa invisa (diplotricha)* (Fabaceae / Leguminosae)

ព្រៃឈើ Prèah khlâb dâmréi Picture #4

Place of Origin:	South America[51]
Introduced Range:	Pacific Islands, Australia, (South-)East Asia, Mauritius & Reunion[51]
Reported as invasive in other countries:	Yes[51]
Status reported from TSBR:	Reported[75]
Risk of species being invasive in TSBR:	Uncertain. So far this species seems to be less established in the TSBR than *Mimosa pigra*[75]
Description of species:	Leguminous annual or short-lived (18-24 months) shrub or climber, 2-4 m long/tall, occasionally reaching 6 m. Stem is 4-angled and has numerous hooked prickles, 3-6 mm long. Very small pale pink flowers occur as round, fluffy balls about 12 mm across, on short stalks in the leaf joints. The numerous seedpods are clustered, clothed with small prickles, and made up of around 4-5 one-seeded pieces. Leaves are moderately sensitive to touch[51,100]
Ecology:	Grows best in tropical moist regions, and on highly fertile soils. Prefers open areas with full sunlight. May expand rapidly in pastures, roadsides and other disturbed areas. Has the ability to climb over other plants and can form a thorny mat over the natural vegetation, preventing animals from accessing the area[100]
Dispersal/Propagation:	Has been introduced to areas as a mixed crop, due to its nitrogen-fixing potential and as a control for the grass *Imperata cylindrica*. A plant produces thousands of seeds, which can lie dormant for up to 50 years. Seeds can be transported by water, people, machinery, animals, and through contaminated earth[51,100]
Uses:	In Cambodian traditional medicine the leaves, in infusion, are used to reduce fever[99]
Control methods used:	The herbicides Basta®, as well as Starane™, Tomigan®, and Flagship® are recommended by the Department of Agriculture and Food, Western Australia for controlling *Mimosa invisa*[24]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better evaluate its status.

Giant Mimosa or **Catclaw Mimosa** *Mimosa pigra* (Fabaceae / Leguminosae)

ព្រៃឈើយក្ស Prèah khlâb yiëk Picture #5

Place of Origin:	Tropical America [149]
Introduced Range:	Australia, Africa, Asia[149]
Reported as invasive in other countries:	Yes[149]
Status reported from TSBR:	The most abundant stands of Giant Mimosa were observed in the Pursat region of the TSBR, while other dense areas are in the delta of the lake and in the Siem Reap region[42]
Risk of species being invasive in TSBR:	A major threat. It is spreading rapidly and has formed dense thickets in some areas[42,61]
Description of species:	Leguminous shrub. Height up to 6 m. Stems armed with broad-based prickles up to 7 mm long. Leaves are more sensitive to touch than those of *M. invisa*. Inflorescence is a tight, ball of flowers (each head containing ca 100) 1 cm in diameter. Flowers are mauve or pink. Seedpods are clustered, brown, densely bristly all over, made up of about 21 (14-26) segments, each containing a seed[100,149]
Ecology:	Grows in wet places in the humid and sub-humid tropics, but favours climates with a distinct dry season. Would probably not be a major problem in regions with an annual rainfall of less than 750 mm or greater than 2250 mm. It is found most commonly in floodplains and riverbanks within soils ranging from black

	cracking clays to sandy clays to coarse siliceous river sand. Forms dense stands, smothering and preventing establishment of other species. Pod segments float and can be dispersed by water. Pods/seeds may also be dispersed by humans and animals in mud adhering to fur, clothing or vehicles. Seeds pass unharmed through the digestive tract of animals. It is a prolific seed producer, with seeds also being able to remain dormant for many years. Dispersal is also aided by adventitious rooting[100,149]. In the TSBR, Giant Mimosa invades fallow fields and cleared and burnt swamp forest and scrubland areas, forming dense thickets[42]
Local distribution:	It occurs in all the Lower Mekong Basin countries[126]. Probably spread into Cambodia around early 1980s[59]. It is now widespread[16,138], particularly along the Mekong, Sap and Bassac rivers[59]
Uses:	In Cambodia: limited. It is sometimes used as a green manure. It may be used as a second-rate fuel source. It is often locally called Banla Yourn (Vietnamese Thorn) [99]
Control methods used:	An integrated approach is often used involving manual removal of plants, spraying with herbicides, burning of infested areas, and introduction of biocontrol agents. Cutting can however lead to extensive resprouting and burning leads to massive seed germination. By themselves these methods have had only a limited effect on controlling Giant Mimosa in Australia[97]. Chemical control with herbicides is commonly applied to help clear persistent and large infestations. In Tram Chim N.P. in Viet Nam, a combination of cutting, burning and herbicides has been used with moderate success[89]. A major problem to the eradication programme in Tram Chim appears to be funding and political will[128]. Herbicides recommended for controlling *Mimosa pigra* are: glyphosate (*e.g.* Roundup®), a non-selective herbicide and metsulfuron methyl (*e.g.* Ally®) a selective herbicide with lower impacts on non-Mimosa vegetation, but also with a lower effectivity in reducing Mimosa[89,117] as well as Fluroxypr (*e.g.* Starane™)[97,117]. Attempts at biological control have been ongoing in Australia, Thailand, Viet Nam and Indonesia, again being most effective when part of an integrated approach together with the above mentioned control methods. An integrated approach (but not including biocontrol) has cost between A$110-250 ha^{-1} in Australia[97,117] and thus may not be affordable for all countries.
Recommendation:	Immediate removal by manual means while the infestations are still scattered and manageable. A budget needs to be worked out for this and funding secured. At the same time it is recommended to increase the protection and conservation of the original floodplain vegetation. A detailed discussion of the problem and recommended approach is given in subsequent chapters.

Sensitive Mimosa or **Touch-Me-Not** *Mimosa pudica* (Fabaceae / Leguminosae)

ត្រកួនឆាយ Prèah khlâb sâmpèah Picture #6

Place of Origin:	Tropical America[52]
Introduced Range:	Pantropical[52]
Reported as invasive in other countries:	Yes[52]
Status reported from TSBR:	Reported[75]
Risk of species being invasive in TSBR:	Uncertain. So far this species seems to be less established than *Mimosa pigra*[75]
Description of species:	Leguminous perennial creeper, which may reach 1 m in height when climbing over other vegetation and 2 m along the ground. Leaves are very sensitive, folding inward and drooping when touched or under low light conditions. The inflorescence is a ball,

	8-10 mm in diameter, of pink-purple flowers. Clusters of 2-8 pods are formed, each 1-2 cm long, consisting of 2-5 segments[52,100]
Ecology:	Grows best in slightly moist, very open areas. Disturbed areas, roadsides, cultivated areas. Forms a dense ground cover, preventing reproduction of other species[52,100]
Dispersal/Propagation:	Seedpods float and are spread by water, pods/seeds are also spread when attached to fur, clothing and mud on vehicles/equipment[52,100]
Uses:	An infusion of the twigs and leaves is used against feverish aches in Cambodia[99]
Control methods used:	The herbicides Dicamba™, as well as Starane™, Tomigan®, and Flagship® are recommended by the Department of Agriculture and Food, Western Australia for control of *Mimosa pudica* and other legumes[25]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better evaluate its status

Candlebush *Senna (Cassia) alata* (Fabaceae / Leguminosae)

ដង្កែត Dâng hët Picture #7

Place of Origin:	South America[100]
Introduced Range:	Africa, Asia, Pacific Islands, Mexico, West Indies[100]
Reported as invasive in other countries:	Yes[100]
Status reported from TSBR:	Reported, but from questionnaires distributed among local communities it appears to be exclusively planted by people
Risk of species being invasive in TSBR:	Probably low, but its occurrence away from villages should be assessed
Description of species:	Shrub, 1-2 m tall. Flowers terminal on stalk, formed in a pinnacle-shaped compound, with orange/yellow oblong sepals. Seedpods are quadrangular, flattened, and shiny[100]
Ecology:	Often forms thickets. Prefers open areas and sunlight. Grows in perennially moist areas such as along creek lines and drainage channels, and occasionally on disturbed and overgrazed areas. Particularly aggressive in areas where there is a high water table. Plant is toxic and has been known to kill cattle[100]
Dispersal/Propagation:	Introduced as an ornamental plant to places all over the world. But has been found useful as a medicinal plant. Natural propagation is by seed[100]
Uses:	Cambodian traditional medicine: crushed leaves mixed with quicklime and water treat sores and eczema. Roots are used as laxative. Pounded leaves as treatment for ringworm[99]
Control methods used:	Picloram + triclopyr, or Tordon 75 D are herbicides recommended by the Department of Agriculture and Food, Western Australia for control of other species in the genus and could be applied to *Cassia alata*[24]
Recommendation:	It is likely that this exotic plant requires no special management in the TSBR, but it could be included under biodiversity monitoring activities in the TSBR in order to better evaluate its status outside of areas where it is planted.

Seedbox *Ludwigia hyssopifolia* (Onagraceae)

ដំរី Dâmréi Picture #8

Place of Origin:	Perhaps native to Africa, Asia, and the Pacific, but the exact origins are uncertain[100]. It may actually be a native plant of Cambodia.
Introduced Range:	Pantropical[100]
Reported as invasive in other countries:	Yes[100]

Status reported from TSBR:	Reported[75] as rare from certain areas of the lake[76]. From questionnaires it seems that it is not abundant.
Risk of species being invasive in TSBR:	Probably low. Even if it is not a native to Cambodia it is at least a long established species in the region and it will likely be as susceptible to diseases and predation from local fauna as native species are. Questionnaires indicate that people living in the TSBR do not perceive it to be a major threat.
Description of species:	Annual herb, 1-3 m in height. Flowers made up of 4 yellow petals. Leaves are lanceolote, up to 9 cm long and 3 cm wide[100].
Ecology:	Wet places; swamps and stream edges, roadside ditches, ponds, rice-fields[100]. Grows on land or in water. Either free floating in water or rooted in the substrate, can be partially submerged[76]
Local distribution:	Plant seems to occur naturally in much of the region. Seeds may be water-dispersed[100]
Uses:	Stalks and leaves are used as a poultice on blisters, sores[99]
Control methods used:	Various herbicides are used to combat it as a weed in rice fields[82]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better evaluate its status

Peruvian Primrose *Ludwigia peruviana* (Onagraceae) Picture #9

Place of Origin:	Tropical America[85]
Introduced Range:	Asia, Australasia-Pacific, North America[85]
Reported as invasive in other countries:	Yes[85]
Status reported from TSBR:	Reported[11], but only one source and no information on abundance. Can be considered as unconfirmed for the time being.
Risk of species being invasive in TSBR:	Uncertain, it may be negatively affected by the extent of the floods
Description of species:	Perennial shrub that can grow up to 3-4m in height. Has small pepper-like seeds that are contained in 4-5 rows within a capsule. Leaves are alternate, 5-10 cm long, 1-3 cm wide, and hairy. Flowers are bright yellow[85]
Ecology:	Lakes, shallow, still or slow flowing streams, marshy areas, and stream banks. Forms dense monotypic stands, smothering other water and -bank vegetation, and clogging waterways[85]
Method of dispersal:	Can be spread via waterways. Often transmitted to other areas by sticking to feathers, fur, clothes, machinery. Is also introduced to new areas through contaminated seed[85]
Uses:	Ornamental. Poor wildlife value except as a possible refuge for waterbirds[85]
Control methods used:	Seedlings can be hand pulled, but larger plants will re-shoot unless the majority of the many long embedded roots are removed. Care has to be taken to first carefully remove any seed heads and bag them securely in plastic bags, so that no seeds are inadvertently dispersed through clothing, etc., and to not leave any uprooted plants behind as they may take root[85]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better evaluate its status.

Para Grass *Brachiaria (Urochloa) mutica* (Poaceae / Gramineae)

ស្មៅបារាំង Smao barang Picture #10

Place of Origin:	Africa[100]
Introduced Range:	Pantropical[100]
Reported as invasive in other countries:	Yes[100]
Status reported from TSBR:	It is reported as common in patchworks of herbaceous stands, either emergent or floating, in rivers and on the lake[75] and as

	having become a dominant species in many of the wetland margins of the TSBR[112]
Risk of species being invasive in TSBR:	Uncertain. It seems to be dominant in some areas of the floodplain while absent from others. It needs to be ascertained if it is still spreading or if the environmental characteristics of the lake are limiting its growth.
Description of species:	Stoloniferous perennial grass around 1 m tall. The lower portion of the stem is decumbent and roots at the nodes. Nodes of the stem are swollen and have dense hairs. The leaf sheath also has hairs that are often deciduous with age. Leaves are up to 30 cm long and 10 to 15 mm wide. The inflorescence is a primary axis with alternately arranged "branches" that have numerous spikelets about 3 mm long with a purple tint[100]
Ecology:	Areas of high soil moisture or nearby open water, such as flood plains, along stream banks, drainage ditches, and roadsides, as well as other disturbed sites. Terrestrially it can form dense thickets. It can also spread horizontally by floating stolons into shallow water areas of lakes, ponds, and streams and form dense, floating mats[100]
Dispersal/Propagation:	People have introduced it all over the world as a pasture grass. Natural propagation by seed and runners. Can be spread over large distances by birds and floodwaters[100]
Uses:	Good quality fodder for livestock and other ruminants[99]
Control methods used:	As with other plants, pulling or cutting the vegetation with hand tools is a possible option for small infestations. However, in many regions, hand removal alone must be performed more than once in a growing season. Best timing for hand removal of herbaceous plant species is after seedhead production but before flowering. The removal of the invasive species should be combined with the planting/seeding of suitable native species[102]
Recommendation:	This species needs to be surveyed and monitored. Impacts and benefits of this species to other organisms in the lake are also unknown and need to be studied. Therefore this species could be included under biodiversity monitoring activities in the TSBR in order to better understand its abundance, distribution and impact.

Hippo Grass or **Creeping Paddy Weed** *Echinochloa stagnina* (Poaceae / Gramineae)

ស្មៅកន្ទប Smao kandəup

Place of Origin:	Africa (Asian origins unconfirmed)[7,100]
Introduced Range:	Asia, Pacific Islands[100]
Reported as invasive in other countries:	Yes[100]
Status reported from TSBR:	Reported[11] as rare in certain areas[76], and as having widely invaded many wetland margins of the TSBR, where it is a dominant species[112]
Risk of species being invasive in TSBR:	Uncertain. As *Brachiaria mutica*, it appears to be dominant in several areas of the lake and absent from others, while its rate of spread is unknown.
Description of species:	Perennial or annual aquatic grass[7]. Floats in deep water or creeps with rhizomes and stolons, up to 2 m long (max 8 m). Readily roots and sprouts at nodes. Leaves are alternate with the leaf sheath being 15–25 cm long, glabrous or rarely hairy. Inflorescence is made up of densely flowered racemes 6–35 cm long, erect or nodding. Spikelets in pairs, narrowly ovate, 3.5–6 mm long, 1–2 mm wide[100]
Ecology:	Found in swamps, riverbanks, dams, moist disturbed sites and as a weed in rice fields[100]. Can grow in water up to 3 m deep[1]. Seeds and stem fragments are dispersed by water and by birds[100]
Local distribution:	Probably widespread. Mentioned from the TSBR and the Mekong

	Delta[125]
Uses:	Stems have a high sugar content. Highly palatable for grazers. When dried becomes a coarse, but palatable hay[1]. Stems can be used for thatching and mat-making. The ash of burnt leaves has been used in the manufacture of soap. In the Niger Delta in Mali people harvest the grain by boat and then use the stem of the plant to make sugar[7]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its abundance, distribution and impacts.

Cutgrass *Leersia hexandra* (Poaceae / Gramineae) Picture #11

Place of Origin:	Pantropical except for South-East Asia and islands[100]
Introduced Range:	South-East Asia[100]
Reported as invasive in other countries:	Yes[100]
Status reported from TSBR:	Occurs in homogenous dense mats mixed with *Oryza rufipognon* as the dominant grassland type within the inner and middle floodplain[26]
Risk of species being invasive in TSBR:	Uncertain. It appears to be a dominant species in certain areas, but its rate of spread and impacts have not been documented. The lack of a specific Khmer name has meant that it was not included in the questionnaire and no information was collected from communities about its occurrence in their area.
Description of species:	Perennial grass, 30-120cm in height. Leaf-blades are lanceolate 10-20 cm long, with tiny backward pointing spines on the back of the midrib[100]
Ecology:	Forms extensive matted carpets on the edges of swamps and floodplains. It sometimes forms floating islands[28]. Propagation is by division of shoot-/rootstocks and by seed. Water depth at the time of flowering and formation of axillary shoots by functional stolons and rhizomes is an important factor in determining stand expansion for the Giant cutgrass (*Zizaniopsis miliacea*). Also exposure to wave action and floating debris are important. As propagation of *Z. miliacea* is like that of *L. hexandra* and other aquatic grasses, it is possible that *L. hexandra* will be similarly affected[34]. In general it is tolerant of flooding, being an aquatic grass[30]
Local distribution:	It is a weed of lowland cultivated rice in Laos and Cambodia[82]
Uses:	Used as a high quality fodder crop. Preferred grazing by livestock[30]
Control methods used:	In the US a variety of specialized cutting machines are used to thin vegetation cover. Plants may be cut manually and harvested, but this is very labour intensive[102]. It has been noted in the literature that biomass of Giant Cutgrass (*Zizaniopsis miliacea*) can be reduced by cutting followed by flooding[34]. This plant was found to be susceptible to leaf yellowing, a viral disease of rice in India and to the fungus *Pyricularia* sp. in Thailand[82].
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its abundance, distribution and impact.

Mission Grass *Pennisetum polystachyon* (Poaceae / Gramineae) Picture #12

Place of Origin:	Tropical Africa to India[53,100]
Introduced Range:	Pantropical[53,100]
Reported as invasive in other countries:	Yes[53,100]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low at present, but has been reported as encroaching on wetland margins in South-East Asia[128]

Description of species:	Tufted annual or perennial grass between 1-2 m tall. Simple or few-branched. Leaf blades are 5-40 cm long and 5-18 mm wide, smooth or lightly covered with soft hairs. Spikelets are yellow-brown with a purplish tinge[53,100]
Ecology:	Inhabits disturbed areas. Mostly dry lowland regions in cultivated fields, degraded pastures and waste sites. Seeds can be dispersed by flowing water, strong winds or they may adhere to clothing, vehicle radiators, or clothing[53,100]
Local distribution:	Occurs in Thailand, Viet Nam and Cambodia[100,143]
Uses:	Originally introduced to many areas as a pasture or fodder grass for livestock[53]
Control methods used:	Trials have shown that spraying with glyphosate during the plant's maximum growth phase is effective[53]
Recommendation:	No action required at present, but should be included as a species to look out for. Could be included in the ongoing biodiversity surveys to reassess status.

Water Hyacinth *Eichhornia crassipes* (Pontederiaceae)

ក្អមផ្កា Kâmphlaôk Picture #13

Place of Origin:	Amazon Basin[49]
Introduced Range:	Pantropical[49]
Reported as invasive in other countries:	Yes[6]
Status reported from TSBR:	Abundant[11,76,112]
Risk of species being invasive in TSBR:	It is already long established, but its impacts on, for example, fish production is unclear and needs to be ascertained. The general impression of local people is that the number of Water Hyacinth is still increasing every year.
Description of species:	Perennial free-floating aquatic herb. Mother plants and daughters attached by floating stolons. Leaves rise to 1m above the water and are broadly ovate, thick and glossy. Flowers (8-15) on a single spike, have six petals, are purplish blue with the uppermost petal having a yellow central spot. The roots are 10-300 cm in length[49]
Ecology:	Grows in shallow temporary ponds, wetlands and marshes, sluggish flowing waters, lakes, reservoirs and rivers. It can tolerate extreme water level fluctuations (although the formation of large infestations may be hampered), variations in flow velocity, extremes of nutrient availability, pH, temperature and toxic substances. It thrives in nutrient rich waters, particularly those rich in nitrogen, phosphorus and potassium[49]. The plant reproduces both vegetatively and sexually. It has been reported that sexual reproduction is limited and although the plant flowers profusely, few observers have seen seeds or seedlings in the field. Water currents, winds and boat traffic readily distribute individual plants or mats. Thick mats may cover the water surface in stagnant or slow flowing water, blocking out light and reducing dissolved oxygen levels and therefore Water Hyacinth is usually considered detrimental to fish production. Can double in biomass every 6-18 days[49]. Mats of water hyacinth can block transportation along waterways, clog up irrigation systems, hinder water flow and cause flooding, and are a micro-habitat for a variety of organisms including disease vectors, *e.g.* mosquitoes (lymphatic filariasis) and snails (schistosomiasis)[49,61].
Local distribution:	Long established in the region. First introduction to a Mekong basin country may have been when it was introduced to Thailand in 1896 as an ornamental plant[3]
Uses:	Fibre from water hyacinths has been used to make paper (mixed with waste paper or jute), fibre board, yarn and rope, baskets and mats. It can be used to produce biogas and has been used for water

	purification[46]. In Cambodia there are many uses of the plant: it is used as fodder for pigs, ducks, fish (usually chopped and boiled together with other vegetable waste and rice bran); flowers and base of stems are eaten as a vegetable by people; it is also used as a mulch or as compost[99]; the plants are gathered and kept together, while still alive and floating on the water surface, in areas near villages on the lake as a fish attractant; the fibre is used for producing string and hammocks for home consumption or local markets; and stems when dried result in a soft but durable material which is woven into handicrafts and furniture for tourists by at least one NGO in Siem Reap and exported to several European countries by one factory in Phnom Penh.
Control methods used:	Small infestations of water hyacinth can be controlled by hand removal from the shore or from a boat. Harvesting systems are relatively slow compared to other control technologies. Even larger harvesting operations can harvest in the range of only 2-3 acres per day per boat. As such, this method is often used either in high-use/priority areas of lakes, to clear beaches and boat lanes or to provide fishing areas within heavy weed infestations, or for control in small areas[46]. Human and ecosystem health have to be taken in account when herbicides are applied. Also when spraying an entire heavy infestation the dead Water Hyacinth will sink and result in pollution from the rotting debris, which may deplete oxygen levels in the water, killing fish and wildlife[68]. The Mottled Water Hyacinth Weevil (*Neochetina eichhorniae*), the Chevron Water Hyacinth Weevil (*Neochetina bruchi*), and a moth, the Water Hyacinth Borer (*Sameodes albiguttalis*), are the most frequently used biocontrol agents[68]
Recommendation:	It is now extremely abundant on the lake and forms a hinderance to boat traffic. Its ecological impact has not been studied and it is difficult to say if it is invasive to the ecosystem or filling a niche and therefore largely complementary. Its impact, particularly on fish production, needs to be studied. In the mean time, (besides a high natural annual mortality when plants get stranded in vegetation as floodwaters recede), offtake can be increased by initiating various community projects that make use of Water Hyacinth and by using natural river flow and diversion booms to collect large quantities of the plant from tributary rivers. See the section on Water Hyacinth under the Important Issues chapter for more detail.

Reptiles

Hybrid Crocodiles *Crocodylus rhombifer*/*C. porosus* x *C. siamensis* (Crocodylidae)

ក្រពើគុយបា / ក្រពើអ៊ីកន់ប្រៃ Kropeau kuba / Kropeau tukprai

Place of Origin:	Cuba (*C. rhombifer*)[21], Australia and Asia, including Cambodia (*C. porosus*)[20,94]
Introduced range:	Both species have been introduced widely for farming[21]
Global Status:	Endangered in its native range (*C. rhombifer*)[21], Lower Risk (*C. porosus*)[20]
Status reported from TSBR:	At present it is believed all wild crocodiles in the Tonle Sap are *Crocodylus siamensis* although this cannot be confirmed[101]
Risk of species being invasive in TSBR:	Low, if managed properly.
Local distribution:	Cuban- (*C. rhombifer*) and Estuarine crocodiles (*C. porosus*) are occasionally used on crocodile farms in Cambodia to improve the gene pool and raise production of captive crocodiles[101]. These farms are not located on the lake, but nearer to towns yet there are still streams and rivers which provide access to the lake should any crocodiles escape. The farms on the lake itself are operated by villagers who do not have the capital to use any other stock than *C. siamensis*[43]. *C. porosus* probably used to occur naturally on the Tonle Sap as skeletal remains have been found[94]
Recommendation:	Any type of re-introduction or escape of such hybridized crocodiles from farms into the wild could pose a threat to the conservation of the remaining natural populations of *C. siamensis*[101]. Careful monitoring of crocodile farms is needed to make sure no additional wild stock is used and that holding pens are properly constructed and maintained and the risk of accidental release is minimized. Any escapes should be notified to authorities. Testing of genetics should be done to ensure that the crocodiles on the lake farms are pure *C. siamensis* and to provide researchers and managers with a baseline[43]. Wild populations of *C. siamensis* are in urgent need of increased protection and monitoring and would benefit from a reintroduction programme once protection levels are adequate[101].

Chinese Softshell Turtle *Pelodiscus sinensis* (Trionychidae)

តន្ត្រាយចិន Kontjeh tjun Picture #14

Place of Origin:	China, Taiwan, Korea, north Viet Nam[131]
Introduced Range:	Other (South-) East Asian countries, U.S.A.[131]
Global status:	Globally Threatened – Vulnerable[132]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, as natural populations of all softshell turtles are utilized heavily by people
Description of species:	Carapace normally up to 25 cm, although occasionally larger. There is a marginal ridge on the oval, slightly longer than wide, carapace. The carapace is smooth, olive to grey and in juveniles is patterned with round, light-bordered black spots. It has a bony snout which is longer than wide[131]
Ecology:	Rivers, lakes, marshes, ponds, canals, and creeks with slow currents. *P. sinensis* is predominantly carnivorous[131]
Local distribution:	The species has been introduced to the region for commercial rearing. The species now occurs naturally in Thailand and all of Viet Nam[145] and could therefore disperse throughout the Mekong basin. Past attempts at farming *P. sinensis* in the Siem Reap area have reportedly ceased[43]. There are several other species of Softshell Turtle in the Tonle Sap lake[43] and when shown pictures of the Chinese Softshell, some people called it “Kontjeh” and

	mentioned that it can reach weights of 20-30 kg. Thus it is believed that they were probably referring to the Asian Giant Softshell Turtle (*Pelochelys bibroni*)[43]
Uses:	Harvested and farmed for food. Also found in the pet trade[131]
Comment:	While this species is commercially farmed in vast numbers (several million per year) for the food trade, the wild populations continue to be exploited for food and possibly farm founder stock, resulting in a decline in abundance throughout its wide range[131]

Red-eared Slider *Trachemys scripta elegans* (Trionychidae)

អណ្តើកត្រចៀកក្រហម Andauk Tro Chiek Krohom Picture #15

Place of Origin:	U.S.A.[54]
Introduced Range:	Worldwide[54]
Reported as invasive from other countries:	Yes[54]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	There is a risk that individuals released in the Tonle Sap river may find there way to the TSBR and establish themselves.
Description of species:	Carapace up to 28 cm. Broad reddish or orange stripe behind each eye, although some red-eared sliders may not have this streak. Young hatchlings have a bright green carapace and skin with yellow green to dark green markings and stripes. Colour of carapace and skin in adults fades to a muted olive green colour[54,122]
Ecology:	Freshwater lakes, ponds, rivers, streams, swamps. Preys on invertebrates such as dragonfly- and larvae. Indirectly hampers waterbird populations by using their nests as basking areas[54]
Local distribution:	Widely distributed through the aquarium trade[54]. It has formed natural populations in Central Thailand. It is probably in the Mekong watershed because there is a tendency on the part of owners to release them when they have grown beyond an acceptable size[145]. Young Red-eared Sliders are used at the Tonle Sap river front in Phnom Penh in Buddhist release ceremonies[151]
Comments:	The published booklet, "A Photographic Guide to the Turtles of Thailand, Laos, Vietnam and Cambodia"[122] states that this species has been introduced to the Tonle Sap, but there are no records from other sources. When shown pictures of Red-eared Sliders people mention it looks like "Andauk Srei" a very similar looking turtle, but with a yellow stripe across the eye. "Andauk Srei" is believed to be the Malayan Snail-eating Turtle[43]

Amphibeans

North American Bullfrog *Rana catesbiana* (Ranidae) Picture #16

Place of Origin:	U.S.A.[19]
Introduced Range:	Worldwide except Australia and Africa[19]
Reported as invasive from other countries:	Yes[19]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Up to 500 g and 203 mm in length. Colour varies from brownish to shades of green, often with spots or blotches of a darker colour on the back[19]
Ecology:	Freshwater lakes, ponds, rivers, streams, swamps. Can cause serious predation on native frogs and snakes[19]
Local distribution:	Widely distributed through the aquarium trade and farming[19]. The bullfrog was introduced into Thailand for farming. It has become established in the wild although not in the Mekong Basin. As the species can spread overland, its eventual appearance in the basin is possible. The species is apparently already in the basin in Viet Nam

(introduced from Cuba), having been released by farmers when it was apparent that the culture of this species was not profitable[145]

Molluscs

Apple Snail *Pomacea* spp. (Pilidae) Picture #17

Place of Origin:	South America[18]
Introduced Range:	South, East and South-East Asia[18]
Reported as invasive from other countries:	Yes[18]
Status reported from TSBR:	There are as yet unconfirmed reports from Battambang and Pursat (see chapter on results from surveys among communities in the TSBR)
Risk of species being invasive in TSBR:	It is quite probable that this species will spread to the TSBR as it is already found along the Mekong in Laos[14] and Cambodia[56]
Description of species:	Can grow up to 10 cm. Shells are yellow to brown. Eggs, which are often laid on aquatic vegetation above the waterline, are orange-red to bright pink. Apple snails have both gills and lung, the mantle cavity being divided to separate the two types of respiratory structures[18,36]
Ecology:	Freshwater lakes, ponds, rivers, streams, swamps. Eggs, which are often laid on aquatic vegetation above the waterline, are bright pink[18,36]. A serious pest to rice crops, Apple snails may also cause extensive damage to other aquatic vegetation and may out compete the native *Pila* sp.[18,36]. For example, it was found in one study that densities of 2 snails per m^2 are sufficient to prevent the establishment of directly sown rice and high removal rates of aquatic plants were observed in wetlands in Laos to such a degree that Apple Snails were considered as the biggest threat to economical use of wetlands by local people[14]. Herbivory by Golden Apple Snails (*Pomacea canaliculata*) has also been found to completely alter aquatic ecosystems from an abundance of aquatic plants towards a system with few plants but high nutrient and phytoplankton levels in the water[13]. This could have different effects on different species. Some species of fish may benefit from any increase in phytoplankton, while some may be more affected by the loss of aquatic plants that provide shelter and food. Waterbirds may also be affected differently, *e.g.* snail-eating birds such as the Asian Openbill (*Anastomus oscitans*) could benefit from the presence of large numbers of Apple Snails, as has been found to be the case in Central Thailand[111]
Local distribution:	Two species occur in the region, the Giant Apple Snail (*Pomacea gigas*) and the Golden Apple Snail (*Pomacea canaliculata*). The Golden Apple Snail is the more widespread of the two. Introduced throughout South-East Asia for the aquarium trade and for farming, although often farmers could not find a market for Apple Snails as people would prefer the local snails they were used to eating[18,36]. They were first reported from lowland ricefields in Cambodia in 1995 and were subsequently reported as being cultivated for food in at least 9 provinces[138]. It has been reported from the Mekong in at least Stung Treng province from a Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme study site[60] suggesting that its spread along the Mekong and into the Tonle Sap system may follow.
Recommendation:	Managers and communities in the TSBR should be alerted about the possible occurrence of Apple Snails in or spread to their area and asked to catch and hold any specimens so that reports can be confirmed. Following a confirmed presence in an area, the rate of spread and impacts of the Snails should be monitored intensively.

Mammals

Domestic Rats *Rattus rattus* and *Rattus norvegicus* (Muridae)

Place of Origin:	Most likely Asia for both species[27]
Introduced Range:	Worldwide[74, 136]
Reported as invasive from other countries:	Yes[74, 136]
Status reported from TSBR:	Black Rats (*Rattus rattus*) and Brown Rats (*Rattus norvegicus*) have both been recorded regularly from within the TSBR. They are now long established and it is impossible to measure the effects these species have had on native fauna and flora[141]
Description of species:	*Rattus rattus*: A slender rat, it may be grey-brown on the back with either a similarly coloured or creamish-white belly, or it may be black all over. The uniformly-coloured tail is always longer than the head and body length combined. Its body weight is between 70 to 300 g. Length is typically between 35 to 40 cm head-to-tail. It is a good climber[136] *Rattus norvegicus*: A heavier, larger rat, weighing between 140 to 500 g (average 400 g) and up to 500 mm nose-to-tail (400mm on average). Hairs are coarse and brown above, sometimes with streaks of black or white hairs and usually somewhat lighter below[74]
Ecology:	Agricultural areas, coastland, disturbed areas, natural forests, planted forests, range/grasslands, riparian zones, scrub/shrublands, urban areas. Rats have caused or contributed to the extinction of wildlife through predation, especially on islands[74,136]
Local distribution:	Both species have spread all over the world, including South-East Asia, through ships, and other cargo transportation and are most common in- and in close proximity to human settlements[74,136]
Recommendation:	General pest control methods are appropriate here. Extermination is not a realistic option given the nature of the species, the scale of the lake and the ability of the species to utilize many habitats and to sustain excessive hunting pressure[141]

Crustaceans

Louisiana Crayfish *Procambarus clarkii* (Cambaridae) Picture #18

Place of Origin:	Mexico and the USA[83]
Introduced Range:	Africa, Europe, Asia and South America[83]
Reported as invasive in other countries:	Yes[83]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present, but potentially invasive
Description of species:	Usually a dark red colour. Reaching sizes in excess of 50g in 3-5 months. Adults reach about 5.5 to 12 cm in length[83]
Ecology:	Is able to tolerate dry periods of up to four months. Because of this, it is able to occupy a wide variety of habitats, including subterranean situations, wet meadows, seasonally flooded swamps and marshes, and permanent lakes and streams. May cause major changes in native plant and animal communities, by competition, predation, spread of disease, and burrowing activities which degrades river banks[83]
Local distribution:	Introduced into Thailand from an unknown source for aquaculture, this species is reported as established in the wild where it is regarded as a nuisance[145]
Uses:	Introduced for culture and harvesting, but also as a biocontrol agent for snails that host schistomiasis. Due to its ability to grow and mature rapidly, its widespread introduction has become a multi-million dollar industry[83]

Control methods:	Only the use of predatory fish has been used successfully; eels, burbot, perch and pike are predators that are all partial to crayfish[83]

Insects

European Honeybee *Apis mellifera* (Apidae)

ឃ្មុំអឺរុប Khmom Ürop

Place of Origin:	Natural range in Tropical Africa, Eurasia[146]
Introduced Range:	Worldwide[146]
Reported as invasive in other countries:	Yes, but introductions usually took place without studying the impact (see Ecology, below)
Status reported from TSBR:	Small scale introductions have occurred around the town of Siem Reap, but have largely failed. There may still be a few people making attempts at beekeeping with *A. mellifera*[58]
Risk of species being invasive in TSBR:	Low, at present, although it is unsure whether there will be more attempts at introduction in the future, by businessmen, NGOs or development projects. Any introductions may have a disastrous impact on the already vulnerable native honeybee populations.
Ecology:	Introduced and tolerant to a wide range of habitats from very dry to very wet. However, it will not find enough sources of nectar in many areas of Cambodia where the predominant landuse is the monoculture of rice[58]. There are many pathogens that rarely affect *A. mellifera* but which may be transferred and cause disastrous epidemics in Asian honeybee populations. On the other hand there are also several parasites of Asian honeybees that will seriously affect *A. mellifera*, especially *Varroa destructor* and *Tropilaelaps clarae*, are common among the local species, *A. cerana* and *A. dorsata*, respectively[92]. This species may also outcompete native bees in locating and utilizing food sources[113]
Local distribution:	It has been introduced near Siem Reap, but most of these attempts have failed due to a low availability of food sources and native parasites[58].
Uses:	Production of honey for food and medicine. In much of Asia local *A. cerana* honey is preferred and fetches a higher price than *A. mellifera* honey[92]
Comments:	In the Tonle Sap area, honey is traditionally collected from the native Giant Honey Bee, *A. dorsata* and the more abundant Dwarf Honey Bee, *A. florea*. Due to destructive harvesting measures and habitat loss, numbers of *A. dorsata* have decreased alarmingly and another valuable species of honeybee *A. cerana* has disappeared from the floodplains around the Tonle Sap, but is found in the uplands of the TSBR. There is enough potential for improving and increasing honey collection and production from native species without needing to introduce *A. mellifera*[57]
Recommendation:	Introductions of *A. mellifera* to the TSBR have failed in the past likely due to low food availability and parasitism[58]. Beekeeping efforts using *A. cerana* and sustainable harvesting of *A. dorsata* and *A. florea* should be promoted and the introduction of *A. mellifera* discouraged, as every introduction attempt brings with it the risk of transfer of pests and diseases to local honeybees[92]

Fish

Japanese Eel *Anguilla japonica* (Anguillidae) Picture #19

Place of Origin:	Pacific coasts of Japan and further south to Hainan Island and northern Philippines[31]
Introduced Range:	Europe, North and South America, South-East Asia, Pacific Islands[31]
Reported as invasive in other countries:	No, it also is not reported to have established wild populations in any of the areas of introduction[32,145]
Status reported from TSBR:	No confirmed reports. A fisherman from near the Boueng Tonle Chmar core zone reported catching single individuals of a type of eel he had not previously seen several times a year for the last 3 years. The species in question has not yet been identified.
Risk of species being invasive in TSBR:	Low, considering it has not become an invasive anywhere else
Description of species:	Maximum recorded length: 150 cm TL. Maximum recorded weight: 760 g.[31] Typical eel-like shape. Plain colouring, slightly lighter underparts[32]
Ecology:	Spawning occurs in the sea. Young eels ascend the rivers in schools and develop and mature in freshwater. After several years, upon reaching sexual maturity, they return to the sea. The extent of the migration upriver varies and some eels never leave the sea[31]. The species may crawl over land at night from one place to another. Feeds on crustaceans, insects and fish[32]
Local distribution:	Mentioned as occuring in aquaculture in Cambodia back in 1969 by JICA[32]. It was introduced into Thailand in 1973 for aquaculture, this species is rarely used for culture and there is no indication that it has entered the Mekong Basin. A few escapees from culture were found in Central Thailand in the 1980s, after which no further individuals have been found[145]
Uses:	Fisheries and aquaculture. Utilized fresh, smoked, canned and frozen. Also used in Chinese medicine[32]

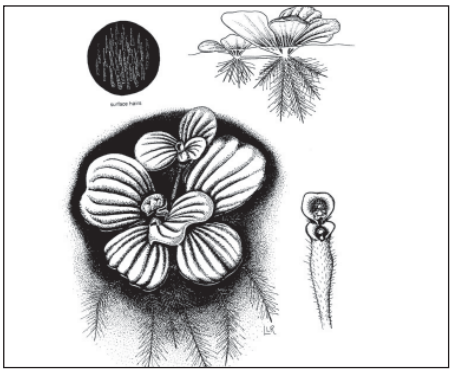
Arapaima *Arapaima gigas* (Arapaimidae) Picture #20

Place of Origin:	South America[32]
Introduced Range:	Introduced to only a few countries around the world, including Thailand[32, 145]
Reported as invasive in other countries:	No, it is also not reported to have established wild populations in any of the areas of introduction [32, 145]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Conservation status:	This species has been trade restricted since 1975. It is listed under CITES Appendix 2 with only Colombia being allowed an annual export of 5000 live specimens[132]
Description of species:	Average length: 450 cm TL. Maximum recorded weight: 200 kg[32]
Ecology:	Demersal. Freshwater[32]. The species is long-lived and grows to a very large size. It is a voracious predator and a mouth brooder. Its natural habitat in forested rivers closely resembles parts of the Mekong[145]
Local distribution:	Introduced for aquaculture, escapees have occasionally been found in natural waters in Thailand[145], but there is no evidence of wild populations having established themselves. It is a common fish in the aquarium pet trade in Cambodia[114]
Uses:	Fisheries, aquaculture, game fishing, aquaria[32]

Pacu *Colossoma macropomum* (Characidae) Picture #21

Place of Origin:	South America[32]
Introduced Range:	U.S.A. (but only a confirmed established population on Hawaii),

1a.Water Lettuce, *Pistia stratiotes* (Photo by Ann Murray, Center for Aquatic and Invasive Plants, University of Florida)



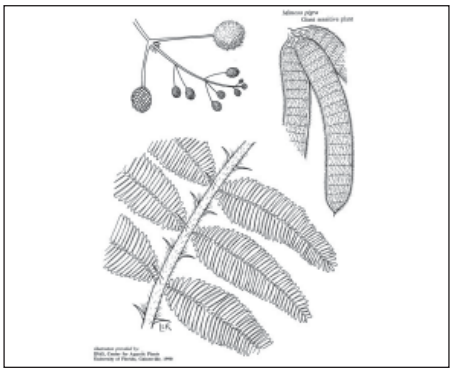
1b. Water Lettuce, *Pistia stratiotes* (Drawing by Laura Line, Center for Aquatic and Invasive Plants, University of Florida)

2. Siam Weed, *Chromolaena odorata* (Photo by Nancy van der Velde)

3. Purging Nut, *Jatropha curcas* (Photo: Technische Universitat Munchen)

4. Giant Sensitive Mimosa, *Mimosa invisa* (Photo: Department of Agriculture and Food, Government of West Australia)

5a. Giant Mimosa, *Mimosa pigra* (Photo by Robert van Zalinge, WCS)



5b. Giant Mimosa, *Mimosa pigra* (Drawing by Laura Line, Center for Aquatic and Invasive Plants, University of Florida)

6. Sensitive Mimosa, *Mimosa pudica* (Photo: Royal Forest Department of Thailand)

7. Candlebush, *Senna alata* (Photo by Robert van Zalinge, WCS)

8a. Seedbox, *Ludwigia hyssopifolia* (Photo: Nationaal Herbarium Nederland)

8b. Seedbox, *Ludwigia hyssopifolia* (Drawing: Department of Agriculture, Thailand)

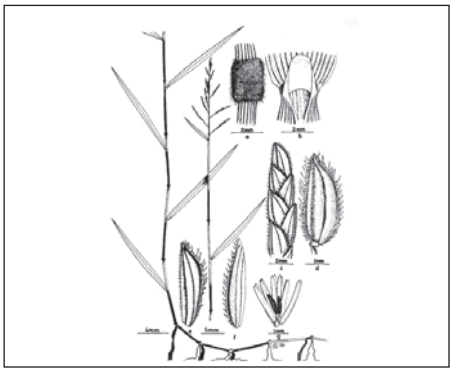
9a. Peruvian Primrose, *Ludwigia peruviana* (Photo by Ann Murray, Center for Aquatic and Invasive Plants, University of Florida)

9b. Peruvian Primrose, *Ludwigia peruviana* (Drawing by Ann Murray, Center for Aquatic and Invasive Plants, University of Florida)

10a. Para Grass, *Brachiaria mutica* (Photo by Ann Murray, Center for Aquatic and Invasive Plants, University of Florida)

10b. Para Grass, *Brachiaria mutica* (Drawing by Laura Line, Center for Aquatic and Invasive Plants, University of Florida)

11a. Cutgrass, *Leersia hexandra* (Photo by Ann Murray, Center for Aquatic and Invasive Plants, University of Florida)



11b. Cutgrass, *Leersia hexandra* (Drawing: Nationaal Herbarium Nederland)

12. Mission Grass, *Pennisetum polystachyon* (Photo: Pacific Island Ecosystem at Risk)

13a. Water Hyacinth, *Eichhornia crassipes* (Photo by Ann Murray, Center for Aquatic and Invasive Plants, University of Florida)

13b. Water Hyacinth, *Eichhornia crassipes* (Picture by Laura Line, Center for Aquatic and Invasive Plants, University of Florida)

14. Chinese Softshell Turtle, *Pelodiscus sinensis* (Photo: Asian Turtle Network)

15. Red-eared Slider, *Trachemys scripta elegans* (Picture by Al Kohutek)

16. North American Bullfrog, *Rana catesbiana* (Picture: Anonymous)

17a. Apple Snail, *Pomacea spp.* (Picture: Invasive Species Information Node)

17b. Apple Snail eggs, *Pomacea spp.* (Picture: S. Ghesquire)

18. Louisiana Crayfish, *Procambarus clarkii* (Picture: Anonymous)

19. Japanese Eel, *Anguilla japonica* (Picture: Anonymous)

20. Arapaima, *Arapaima gigas* (Picture: Anonymous)

21. Pacu, *Colossoma macropmum* (Picture: Anonymous)

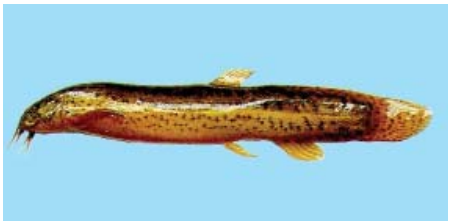
22. Red-bellied Pacu, *Piaractus brachypomus* (Picture by Chavalit Vidthayanon, MFD)

23. Mozambique Tilapia, *Oreochromis mossambicus* (Picture by Chavalit Vidthayanon, MFD)

24. Nile Tilapia, *Oreochromis nilotica* (Picture by Chavalit Vidthayanon, MFD)

25. Red-breast Tilapia, *Tilapia rendalli* (Picture by Chavalit Vidthayanon, MFD)

26. African Catfish, *Clarias gariepinus* (Picture by Chavalit Vidthayanon, MFD)



27. Oriental Weatherfish, *Misgurnus anguillicaudatus* (Picture by Shao Kwang Tsao, MFD)

28. Chinese False Gudgeon, *Abottina rivularis* (Picture by Chavalit Vidthayanon, MFD)

29. Acheilognathus barbatulus (Picture by Walter Rainboth, MFD)

30. Acheilognathus sinensis (Picture: Anonymous)

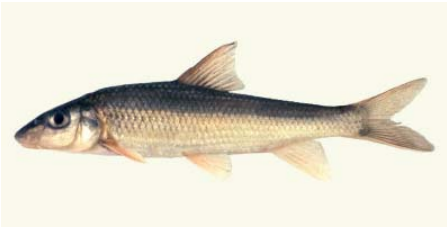
31. Goldfish, *Carassius auratus* (Picture by Walter Rainboth, MFD)

32. Mrigal, *Cirrhinus cirrhosus* (Picture by Leonard Lovshin, MFD)

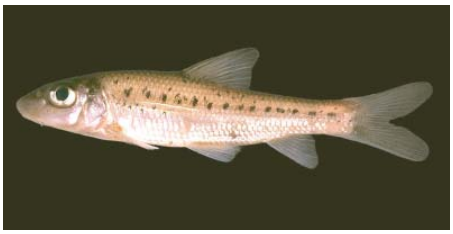
33. Grass Carp, *Ctenopharyngodon idella* (Picture by Chavalit Vidthayanon, MFD)

34. Common Carp, *Cyprinus carpio* (Picture by Chavalit Vidthayanon, MFD)

35. Catla, *Gilbelion catla* (Picture by G.C. Mair, MFD)



36. Barbel Steed, *Hemibarbus labeo* (Picture by Walter Rainboth, MFD)

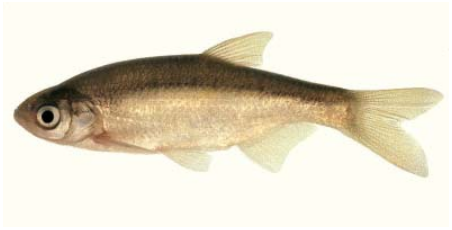


37. Spotted Steed, *Hemibarbus maculatus* (Picture by Walter Rainboth, MFD)

38. Silver Carp, *Hypophthalmichthys molitrix* (Picture by Chavalit Vidthayanon, MFD)

39. Bighead Carp, *Hypophthalmichthys nobilis* (Picture: USGS)

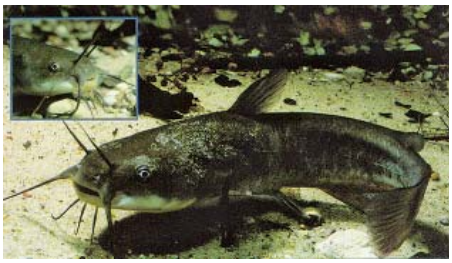
40. Rohu, *Labeo rohita* (Picture by Chavalit Vidthayanon, MFD)



41. Metzia lineata (Picture by Walter Rainboth, MFD)

42. Stone Moroko, *Pseudorasbora parva* (Picture by Chavalit Vidthayanon, MFD)

43. Puntius semifasciolatus (Picture by Calypso Photolibrary, MFD)



44. Brown Bullhead, *Ictalurus nebulosus* (Picture by Steffen Zienert, FishBase)

45. Channel Catfish, *Ictalurus punctatus* (Picture by Leonard Lovshin, USGS)

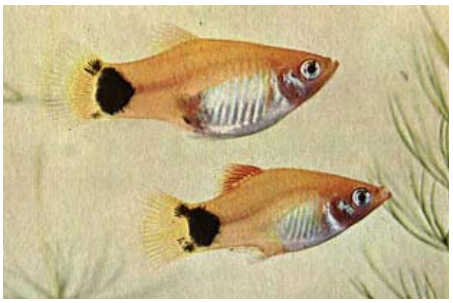
46. Suckermouth Catfish, *Hypostomus plecostomus* (Picture by Chavalit Vidthayanon, MFD)

47. Mosquito Fish, *Gambusia affinis* (Picture by Chavalit Vidthayanon, MFD)

48. Guppy, *Poecilia reticulata* (Picture by Chavalit Vidthayanon, MFD)

49. Sailfin Molly, *Poecilia velifera* (Picture by P. Marshall, FishBase)

50. Green Swordtail, *Xiphophorus helleri* (Picture by Kjell Nilsson, USGS)



51. Southern Platyfish, *Xiphophorus maculatus* (Picture by Calypso Photolibrary, FishBase)

	East, South-East Asia[32]
Reported as invasive in other countries:	No/Uncertain[32]
Status reported from TSBR:	Uncertain, the species of Pacu occurring in the TSBR is likely the Red-bellied Pacu (*Piaractus brachypomus*), but this still needs to be confirmed
Risk of species being invasive in TSBR:	Low - Uncertain. It is not confirmed from the TSBR and there are no reports of it having had a large negative impact in other countries.
Description of species:	Average length: 108 cm TL. Maximum recorded weight: 30 kg[32]
Ecology:	Benthopelagic. Freshwater. Flooded forest, rivers. Feeds on zooplankton, insects, snails and decaying plants and fruits[32]
Local distribution:	A species of growing importance for aquaculture in the region. Its use is widespread in China, Indonesia and Central Thailand. It is not a popular food in Northeast Thailand, but as it is cultured in the central region of the country, it indicates that it is potentially acceptable and may eventually be cultured in the Mekong basin[145]
Uses:	Fisheries, aquaculture, aquaria[32]

Red-bellied Pacu *Piaractus brachypomus* (Characidae)

ត្រីចាប Trey Chàb Picture #22

Place of Origin:	South America[32]
Introduced Range:	Several different countries worldwide[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	This species (Trey Chàb) has been reported from fishermen during WCS/TSCP surveys in the Prey Kos, Kampong Chhnang area (November 2006) and two fisherman mentioned it in the questionnaires from Prek Loeung, Battambang and from Kampong Loeung, Pursat. It requires further investigation to make sure that the species concerned is indeed Red-bellied Pacu.
Risk of species being invasive in TSBR:	Substantial, though now banned for aquaculture in Cambodia it seems that populations may already have become established in some areas of the TSBR.
Description of species:	Average length: 88 cm TL. Maximum recorded weight: 25 kg[32]
Ecology:	Pelagic. Freshwater. Streams, rivers, flooded forest[32]. Omnivorous. Feeds mainly on decaying plants, fruit and insects[137], but when these become scarce it has been reported to prey on other fish. There have also been (scattered) reports of attacks on people. Can cause ecological imbalance by killing local fish and wiping out eggs and fry[32]
Local distribution:	It has recently been banned in Cambodia by the Department of Fisheries[44]. However, the reports of this species being regularly caught in the last year by fishermen from Pleu Tu Commune near Prey Kos in Kampong Chhnang indicates it may already have formed natural populations. However, the size of the fish being caught at present is still small at around 5-7 cm (width of three fingers) and weighing around 100 grams each. Therefore there may still be only a few individuals capable of breeding at the moment.
Uses:	Fisheries, aquaculture, aquaria[32]
Recommendation:	It is recommended surveying the status of this species (and other exotic fish) further as soon as possible, and attempt to eradicate it. This species is mostly caught in fishing traps according to fishermen. The FiA and/or MoE could set a large number of traps in areas where it has been reported. By regularly checking the traps and removing only the Trey Chàb while releasing other fish species, eradication may be successful without impacting on other species. The eradication efforts would need to be conducted before sufficient individuals breed and the population becomes large and spreads further. Eradication efforts should only stop in an area

	when no more of this species has been caught for several months. The traps may need to be of special construction and locked so that other people cannot access them and remove all fish. Rotting fruit could be used as bait. The species will not likely be limited to the TSBR and may migrate short distances. Eradication efforts should therefore not be limited to the TSBR only.

Blue Tilapia *Oreochromis aureus* (Cichlidae)

Place of Origin:	Africa and Middle East[32]
Introduced Range:	South-East Asia, North, Central and South America[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low
Description of species:	Average length: 45.7 cm TL. Maximum recorded weight: 2 kg. Males grow remarkably larger than females and possess much more developed fins. Colouration: Juveniles, grey-brown to slightly golden; Adult males, grey-blue, with head, from upper lips to eye, greenish-brown, becoming darker towards the back. Courting males, brilliant with intense metallic blue on the head, sometimes paler blue on the body, with a reddish pink edge on the dorsal and a pink tail margin; Breeding females with paler, more orange edges of dorsal and tail fin[32]
Ecology:	Benthopelagic. Fresh and brackish water. Rivers, lakes, estuaries[32]. It is a generalized feeder with a preference for detritus and phytoplankton. It also will eat small fish and fish larvae[145]. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilization. For this reason it is vulnerable to rapid changes in water level and depends on suitable (sandy) substrates for nest building[145]
Local distribution:	Exists in reservoirs along Mekong tributaries[145]
Uses:	Fisheries, aquaculture, aquaria[32]

Mozambique Tilapia *Oreochromis mossambicus* (Cichlidae)

ត្រីឆ្តោខ្មៅ Trey tilapia khmao Picture #23

Place of Origin:	Southern Africa[32]
Introduced Range:	Pantropical[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported, but fry have been collected from the Mekong[15]
Risk of species being invasive in TSBR:	Uncertain. It is potentially invasive, but the large fluctuations in water level may limit the successful breeding of this species in the TSBR.
Description of species:	Average length: 39 cm SL. Maximum recorded weight: 1.1 kg. Has a short snout. Jaws of mature males enlarged, with mouth reaching to below back of eye. Female and non-breeding male silvery. Breeding males are black with white lower parts of head and red margins to dorsal and tail fins[32]
Ecology:	Benthopelagic. Fresh and brackish water. Estuaries, coastal lakes, pools of sluggish streams, canals, and ponds[32]. It is a generalized feeder with a preference for detritus and phytoplankton. It will also eat small fish and fish larvae[145]. It competes directly for food and nest spaces winning from less aggressive species. It is most common in brackish waters[119]. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilization. For this reason it is vulnerable to rapid changes in water level and depends on suitable substrates for nest building[145]
Local distribution:	Introduced for aquaculture to Cambodia in 1980[114]. It seems to have become established in the Mekong Delta in Viet Nam, where

	it is impacting on the shrimp fisheries through competition for food[145]
Uses:	Fisheries, aquaculture, game fishing, aquaria[32]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to assess its status

Nile Tilapia *Oreochromis niloticus* (Cichlidae)

ត្រីទីឡាបឈ្មោះ Trey tilapia chhnoht Picture #24

Place of Origin:	Africa and Middle East[32]
Introduced Range:	Pantropical[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported from the TSBR, but fry and adults have been caught from the Tonle Sap river near Phnom Penh[15,114]
Risk of species being invasive in TSBR:	Uncertain. The large fluctuations in water level may limit the successful breeding of this species in the TSBR.
Description of species:	Average length: 60 cm SL. Maximum recorded weight: 4.3 kg. Jaws of mature male not greatly enlarged (length of lower jaw 29-37 % of head length). The most distinguishing characteristic of the species is the presence of regular vertical stripes throughout the depth of the tail fin[32]
Ecology:	Benthopelagic. Fresh and brackish water. Rivers, lakes. Feeds mainly on phytoplankton or benthic algae[32]. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilization. For this reason it is vulnerable to rapid changes in water level and depends on suitable substrates for nest building[145]. In some countries small native species have disappeared once this species became established, as well as other native *Oreochromis* sp.[32]
Local distribution:	Introduced for aquaculture, it has become established in rivers and reservoirs throughout the region, although in some areas it has tended to disappear[145]. It is thought to have been introduced to Cambodia in 1980[114]. It is established in the Mekong along the Thai-Lao border[137] and adults are sometimes caught along the Mekong and Tonle Sap rivers in Cambodia[114]. There are also populations of Nile Tilapia in Cheng Ek lake[114] and several other small lakes near Phnom Penh, from where they have access to the Mekong river system during high water levels[93]
Uses:	Fisheries, aquaculture[32]
Comments:	Hybrids of *O. niloticus* and *O. mossambicus*, or from *O. niloticus* and *O. hornorum*, called Red Tilapia, are also widely used in the region for aquaculture[145], and the *O. niloticus* x *O. mossambicus* strain has been used in Cambodia since 1991[114]. Both hybrids breed true but tend to eventually revert to their parental strains through backcrossing[145]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its occurrence, distribution and impact.

Red-breast Tilapia *Tilapia rendalli* (Cichlidae) Picture #25

Place of Origin:	Africa[32]
Introduced Range:	Worldwide[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Uncertain. It is potentially invasive, but the large fluctuations in water level may limit the successful breeding of this species in the TSBR.

Description of species:	Average length: 45 cm TL. Maximum recorded weight: 2.5 kg. Head and body mid to dark olive-green dorsally, paling over the flanks. Body usually with vertical bars only and scales with a dark basal crescent. Fins olive-green. Undersides pinkish[32]
Ecology:	Benthopelagic. Fresh and brackish water. Prefers quiet, well-vegetated water along river littorals or backwaters, floodplains and swamps. Can reduce aquatic vegetation to the extent that it impacts native fish populations[32]. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilization. For this reason it is vulnerable to rapid changes in water level and depends on suitable substrates for nest building[145]
Local distribution:	Introduced into Thailand for aquaculture in 1955[145]. It is now also present in Cambodia. Populations have been known to escape into the wild throughout the region, forming dense populations of stunted fish. Regarded as a pest due to the damage it causes to aquatic vegetation, many attempts have been made to eradicate this species without success[137]
Uses:	Fisheries, aquaculture, game fishing, aquaria, weed control[32]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to assess its status.

African Catfish *Clarias gariepinus* (Clariidae)

ត្រីអណ្តែងអាហ្វ្រិក Trey andaing afrik Picture #26

Place of Origin:	Africa and Middle East[32,137]
Introduced Range:	Other parts of Africa, Europe, Asia[32]
Reported as invasive in other countries:	No/Uncertain[32]
Status reported from TSBR:	A survey has found juveniles in the Tonle Sap/Mekong river system[15] and adults occur irregularly in catch[134]. One single live adult fish in Prek Toal was photographed (this study) and identified as a possible record[15]
Risk of species being invasive in TSBR:	Uncertain. The evidence suggests that there are numbers of African catfish in the Tonle Sap/Mekong system, but they could also be hybrids (specimens used for aquaculture are commonly crossbred with *Clarias macrocephalus*, a local species[114,145]) and the ability of hybrids to sustain breeding populations over several generations in the wild is as yet undetermined[10,145]. No immediate detrimental effects have been noted[145]
Description of species:	Average length: 170 cm TL. Maximum recorded weight: 60 kg. Eyes small. Nasal barbels 1/5 - 1/2 times as long as the head in fish longer than 12 cm, and 1/2-4/5 of the head length in smaller individuals. Longest barbels on upper jaw rarely shorter than head, usually somewhat longer and reaching to a point midway between the origin of the dorsal fin and the insertion of the pelvic fins (usually longer in smaller specimens). Outer barbells on lower jaw longer than the inner pair. Pectoral fin spine serrated only on its outer side. Generally dark, greyish-black above, creamy-white below; a fairly distinct black longitudinal band on each side of the ventral surface of head[32,116]
Ecology:	A benthopelagic, freshwater species. Occurs mainly in quiet waters, lakes and pools but may also occur in fast flowing rivers and in rapids. It is tolerant of extreme environmental conditions. It is able to breath air, which it does when very active or under very dry, de-oxygenated conditions[32]. This would give them a competitive advantage over native species in the TSBR[103]
Local distribution:	Introduced to the region for aquaculture[145] and to Cambodia in 1981 from Viet Nam, together with the hybrid form of this species[114]. Has been turning up occasionally in fish catches from natural water bodies in Cambodia[134]
Uses:	Fisheries, aquaculture, game fishing[32]

Recommendation:	Although it seems to be established in the Mekong and Tonle Sap, numbers are still low. This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its abundance, distribution and impact.

Oriental weatherfish *Misgurnus anguillicaudatus* (Cobitidae) Picture #27

Place of Origin:	Myanmar and Northeastern Asia southward to Central China[32]
Introduced Range:	Several countries worldwide[32]
Reported as invasive in other countries:	Yes, in Australia[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 25 cm TL. Body is mottled with darker greenish-grey to dark brown markings, against a yellow-brown to brown colour. 10 barbels.
Ecology:	Demersal. Freshwater. Rivers, lakes and ponds, swamps and rice fields[1].
Dispersal/Propagation:	This species is spreading into Northern Laos from the Red River Basin in Viet Nam. It is unclear if this represents an extension of its natural range[2].
Uses:	Fisheries, aquaculture, aquaria[1].

Chinese False Gudgeon *Abottina rivularis* (Cyprinidae) Picture #28

Place of Origin:	North-East Asia, including Japan[32]
Introduced Range:	Mekong River and a few other basins in Asia[32,137]
Reported as invasive in other countries:	No[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 11 cm TL. No papilla on lips. One pair of short maxillary barbels. Anus closer to ventral-fin base than to anal-fin base. Body with eight rounded dusky blotches along lateral line[32]
Ecology:	A benthopelagic freshwater fish. Occurs in slow flowing waters, ponds and swamps, and in shallow water of lentic rivers and lakes with sandy or muddy bottoms[32]
Local distribution:	This species was probably introduced to the Mekong basin in Yunnan, China from where it has spread down into Laos and northern Thailand[63,145]
Uses:	Aquaculture, aquaria[32]

Acheilognathus spp. (*A. barbatulus* 29 and *A. sinensis*[145] 30) (Cyprinidae)

Place of Origin:	North-Eastern Continental Asia[32]
Introduced Range:	At least Mekong River in Laos[32,137] (both species), Japan (*A. sinensis*)[32,145]
Reported as invasive in other countries:	No (*A. barbatulus*)[32]. Yes (*A. sinensis*)[145]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	*Acheilognathus barbatulus*: Average length: 8.4 cm SL. Small maxillary barbels[32] *Acheilognathus sinensis*: Average length: 5.2 cm SL. Oval shaped body, eye diameter a bit longer than mouth. Round-shaped scale, black spot in the edge of the scales in upper part of the body. Incomplete lateral line. Dorsal fin starts from the middle of the body. Dark grey in the stomach[32]
Ecology:	Benthopelagic, freshwater fishes. Known from highland streams. The eggs of these species are deposited in bivalves, where the larvae remain protected until they can swim[32,137]. *A. sinensis* has been implicated in the decline of native species in Japan through

	competition and hybridization[145]
Local distribution:	A study on exotic fish introduced into the Mekong has mentioned these two different species of *Acheilognathus* as spreading into the Mekong basin in Laos either through aquaculture or by dispersion from China [63,145]
Uses:	Aquaculture[32]

Goldfish *Carassius auratus* (Cyprinidae)

ត្រីពណ្ណីមាស Trey Por Meas Picture #31

Place of Origin:	Central and Eastern Continental Asia[32,47,137]
Introduced Range:	Worldwide[32,47,137]
Reported as invasive in other countries:	Yes[47]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 59 cm TL. Maximum recorded weight: 3 kg. Head without scales, broadly triangular. Barbels lacking on upper jaw. Lateral line complete. Wild-caught specimens are olive brown or gold (often with black blotches) to creamy white[32,47]
Ecology:	Demersal. Freshwater[32]. Inhabits rivers, lakes, ponds and ditches with stagnant or slow-flowing water[137]. Omnivorous. Food includes plants, small crustaceans, insects, and detritus[32]. Will prey on eggs, larvae and adults of some native species as well as depleting aquatic vegetation, increasing water turbidity and stimulating algal blooms[47]. Also poses a threat to native species through competition and hybridization[145]
Local distribution:	Introduced into Thailand as an ornamental fish from China around 1300 and into Viet Nam and Cambodia at an unknown date[114,145] where it is now a common fish in aquaria. More recently, a variety of this species was recorded as diffusing into the Mekong basin from the Red River basin in Viet Nam and from Laos, and is presumed to be breeding naturally[145]
Uses:	Fisheries, aquaculture, game fishing, aquaria[32]
Recommendation:	At present the occurrence of this species in the Mekong and Tonle Sap is not well known. Therefore it may still be possible to reduce the risk of it becoming an established species. It is a potential invasive species and implementation of measures to reduce the risk of exotic species entering natural waters would be advisable.

Mrigal *Cirrhinus cirrhosus* (Cyprinidae)

ត្រីព្រាឡុង Trey Pro Long Picture #32

Place of Origin:	Indian Subcontinent[32,137]
Introduced Range:	Has been introduced to various countries in South-East Asia[32]
Reported as invasive in other countries:	No[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 100 cm SL. Maximum recorded weight: 12.7 kg. Body plain greyish. No barbels[32]
Ecology:	Benthopelagic. Fresh and brackish water; inhabits fast flowing streams and rivers[32,137]. Mrigal lay demersal eggs and feed on detritus and periphyton[145]
Local distribution:	Brought to Thailand and Laos from India and Viet Nam (from Laos) for aquaculture[145]. Introduced to Cambodia from Viet Nam in 1980[114]. The species is also used for stocking dams. It is thought to be breeding naturally within the basin, since its fry have been found in the main stream of the Mekong in Northeast Thailand[145]
Uses:	Fisheries, aquaculture, game fishing[32]

Comments:	There are two native species of *Cirrhinus* in the Mekong, which have better eating qualities, but do not respond well to culture in ponds[145]
Recommendation:	At present the occurrence of this species in the Mekong and Tonle Sap is not well known. Implementation of measures to reduce the risk of exotics entering natural waters would be advisable.

Grass Carp *Ctenopharyngodon idella* (Cyprinidae)

ត្រីការបស៊ីស្មៅ Trey Carp See Smao Picture #33

Place of Origin:	North-Eastern Continental Asia[32]
Introduced Range:	Worldwide[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low at present as there seem to be no naturalized populations in the Mekong system. However, any naturalization of populations could have a negative impact.
Description of species:	Average length: 150 cm TL. Maximum recorded weight: 45 kg. No barbels. Very short snout[32]
Ecology:	Demersal. Freshwater. Occurs in lakes, ponds, pools and backwaters of large rivers, preferring large, slow-flowing or standing water bodies with submerged vegetation on which it feeds[32,137]
Local distribution:	In manmade aquatic environments such as irrigation canals and reservoirs it is often introduced to control invasive aquatic weeds. Introduced for aquaculture to the entire South-East Asian region[32], and in Cambodia in 1981[114], but has not naturalized in any local ecosystem. It may cause serious ecological impact if it gets established in the wild due to the damage it can do to submerged vegetation[32,145]
Uses:	Fisheries, aquaculture, game fishing[32]
Recommendation:	Implementation of measures to reduce the risk of exotic species entering natural waters would be advisable

Common Carp *Cyprinus carpio* (Cyprinidae)

ត្រីការបសាមញ្ញ Trey carp samahn Picture #34

Place of Origin:	Probably Asia (Central, East Continental)[32,48]
Introduced Range:	Established populations worldwide[32,48]
Reported as invasive in other countries:	Yes[32,48,98]
Status reported from TSBR:	Apparently well established in some parts of the Mekong[137,114]. Low numbers reported in catch from fishing lots on the Tonle Sap lake, Tonle Sap river and Mekong[114]. One unconfirmed report from a fisherman in this study.
Risk of species being invasive in TSBR:	Uncertain at present, although it is not perceived as an immediate problem[145]
Description of species:	Average length: 120 cm SL. Maximum recorded weight: 37.3 kg. Robust, with crown flattened or somewhat furrowed. Scales large and thick. Wild carp is generally less stocky in build than cultivated varieties. Body grey to bronze, but can be very variable in colour and form[32,48]
Ecology:	Benthopelagic. Freshwater[32]. Hardy and tolerant of a wide variety of conditions but generally favour large water bodies with slow flowing or standing water and soft bottom sediments[137]. They seem to be capable of reproducing in cooler waters within the Mekong basin[107]. Omnivorous, feeding on aquatic insects, crustaceans, annelids, mollusks, weed and tree seeds, wild rice, aquatic plants

	and algae; mainly by grubbing in sediments[32,137]. Because of its habit of stirring up the bottom while feeding, it has the reputation of muddying the waters it occupies. This shades out macrophytes, chokes benthic invertebrates, and through the more rapid recycling of phosphate, contributes to accelerated eutrophication in some systems[98]. If such a change in conditions was to occur, the composition and abundance of the native fish fauna could be affected[98]. It may also outcompete other species with overlapping feeding habits[32]
Local distribution:	Introduced for aquaculture to Cambodia as early as 1969[114]. *C. carpio* has been introduced to over 140 countries, 18 of which have reported adverse ecological impacts[48]. It is also a common fish in the aquarium pet trade in Cambodia[114]
Uses:	Fisheries, aquaculture, game fishing, aquaria[32]
Recommendation:	Although it seems to be established in the Mekong and Tonle Sap, numbers are still low. This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its abundance, distribution and impact.

Catla *Gilbelion (Catla) catla* (Cyprinidae) Picture #35

Place of Origin:	Indian subcontinent[32]
Introduced Range:	Worldwide[1]. Has established itself in several South-East Asian countries[32,145]
Reported as invasive in other countries:	No[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 182 cm TL. Body is deep and has a large, upturned mouth, with a prominent protruding lower jaw. Pectoral fins long, extending to pelvic fins. Scales conspicuously large[32]
Ecology:	Benthopelagic. Fresh and brackish water. Occurs in rivers, lakes and culture ponds; breeds in rivers. Omnivorous[32]
Local distribution:	Introduced to the region for aquaculture[145], and to Cambodia in 1980[114]. It may be breeding naturally within the Mekong basin but no natural stocks have been clearly reported[145]. There is often some confusion with *Catlocarpio siamensis*, the Giant Barb, a local and increasingly rare endemic.
Uses:	Fisheries, aquaculture, game fishing[32]
Recommendation:	Implementation of measures to reduce the risk of exotic species entering natural waters would be advisable here.

Barbel Steed *Hemibarbus labeo* (Cyprinidae) Picture #36

Place of Origin:	Central and East Continental Asia[32,137]
Introduced Range:	Mekong basin[63]
Reported as invasive in other countries:	No[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 62 cm. Maximum recorded weight: 3kg. Body spots absent in adults. Elongated body with slightly convex dorsal profile. Long snout. Lips prominent. Barbels short and thick[32]
Ecology:	Benthopelagic. Freshwater. Rivers, streams[32]
Local distribution:	Previously occurred in Northern Viet Nam and China, without being present in the Mekong[32]. However, now it has been recorded from the Mekong basin in Laos, probably as a result of aquacultural introductions, either in Laos or, more likely, upriver in China[62]
Uses:	Fisheries, aquaculture[32]

Spotted Steed *Hemibarbus maculatus* (Cyprinidae) Picture #37

Place of Origin:	East Continental Asia[32]
Introduced Range:	Yangtze and Mekong rivers[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 34 (female)-47 cm (male) TL. Maximum recorded weight 1.7kg. Both sides of the body with 7-11 large and blackish spots. Deep body with clearly convex dorsal profile. Short snout and small lips. Barbels short and thick[32]
Ecology:	Benthopelagic. Freshwater. Rivers, streams and creeks[32]. It is potentially a serious competitor and threat to native benthic species[63]
Local distribution:	The occurrence of this species in Mekong tributaries in northern Laos are apparently the result of introductions upriver in China[63]
Uses:	Fisheries, aquaculture[32]

Silver Carp *Hypophthalmichthys molitrix* (Cyprinidae)

ត្រីកាបស Trey carp sar Picture #38

Place of Origin:	East Continental Asia[32]
Introduced Range:	Worldwide[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Low numbers have been reported in catch from fishing lots on the Tonle Sap lake[114]
Risk of species being invasive in TSBR:	Uncertain, at present. Phytoplankton levels are reportedly low in the lake, but the species can utilize available zooplankton as well[84]. It may have a substantial impact on native fish if it manages to utilize a larger proportion of the available food source.
Description of species:	Average length: 105 cm TL. Maximum recorded weight: 50kg. Body olivaceous to silvery. Barbels absent[32]
Ecology:	Benthopelagic. Freshwater. Requires standing or slow-flowing conditions such as in impoundments or the backwaters of large rivers[32,137]. The species feeds on detritus and phytoplankton (or even zooplankton[84]) and may compete with species of similar habit in the Mekong[145]. Where introduced populations of Silver Carp have become abundant, changes in the food web structure can occur[84].
Local distribution:	The species is widely used throughout the basin for aquaculture and is artificially bred for this purpose[145]. It was introduced to Cambodia as early as 1969[137]. Small numbers of adults have been caught from the Mekong and Tonle Sap[137], as well as fry[145]
Uses:	Fisheries, aquaculture, control of algal blooms in reservoirs[32]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its occurrence, distribution and impact.

Bighead Carp *Hypophthalmichthys (Aristichthys) nobilis* (Cyprinidae)

ត្រីកាបក្បាលធំ Trey carp kbal thom Picture #39

Place of Origin:	China[32]
Introduced Range:	Worldwide[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported (except for one unconfirmed report from a fisherman interviewed in this study)
Risk of species being invasive in TSBR:	Low, at present

Description of species:	Average length: 112 cm TL. Maximum recorded weight: 21.3 kg. Body with numerous scattered small black blotches. Barbels absent[32]
Ecology:	Benthopelagic. Freshwater. Rivers, lakes. Feeds mainly on zooplankton[32]
Local distribution:	Introduced for aquaculture throughout the region[145] and to Cambodia in 1981[137]. Fry has been found in the mainstream of the Mekong indicating that it has possibly established itself[145]. It was also present in Cheng Ek lake, near Phnom Penh, but these stocks have disappeared[137]. Whether because of overfishing after it changed in status from a government leased fishing lot to a community fishing ground in 2000, or if the fish had moved during a period of high water into the Mekong is unclear.
Uses:	Fisheries, aquaculture, aquaria[32]
Recommendation:	Implementation of measures to reduce the risk of exotic species entering natural waters would be advisable.

Rohu *Labeo rohita* (Cyprinidae) Picture #40

Place of Origin:	Indian Subcontinent[32]
Introduced Range:	Widely introduced in Asia, an established population has been formed in Viet Nam[32]
Reported as invasive in other countries:	No
Status reported from TSBR:	Fisheries Administration specialists mention catches of *L. rohita* from various fishing lots on the Tonle Sap lake in Siem Reap and Battambang as ranging from around 1,000-2,000 kg a year, between 1997-2001[114]
Risk of species being invasive in TSBR:	Uncertain as yet. No detrimental impact has been reported.
Description of species:	Average length: 200 cm TL. Maximum recorded weight: 45kg. Lower profile of head conspicuously arched[32]
Ecology:	Benthopelagic. Freshwater. Large rivers, lakes, reservoirs. Feeds on plants, especially periphyton and detritus[32]
Local distribution:	Introduced to the region for aquaculture[145], and to Cambodia in 1986[114]. Besides the above reported occurrence in the Tonle Sap lake, its fry are occasionally found in the main stream of the Mekong[145] and adults sometimes caught[114]
Uses:	Fisheries, game fishing[32]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its occurrence, distribution and impacts.

Metzia lineata / *Rasborinus lineatus* (Cyprinidae) Picture #41

Place of Origin:	Viet Nam, China, Taiwan[32]
Introduced Range:	Mekong basin[137]
Reported as invasive in other countries:	No[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 10 cm SL. Scales round. Black-grey above, silver-white underneath. Black spots in the base of each scale, forming several grey strips vertically[32]
Ecology:	Benthopelagic. Freshwater[32]. Known from upland streams and rivers[137]
Local distribution:	Introduced in other basins in China and has spread to northern Laos[32,137]
Uses:	Aquaculture[32]

Stone Moroko *Pseudorasbora parva* (Cyprinidae) Picture #42

Place of Origin:	Eastern Asia[32]
Introduced Range:	Europe, Asia[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 11 cm TL. Mouth facing upwards. Barbels absent.
Ecology:	Benthopelagic. Freshwater. Occurs in cool running water. Feeds on small insects, fish and fish eggs. Regarded as a pest that competes with the fry of other species due to its high reproductive rate[32]
Local distribution:	Its presence in the Mekong basin is probably due to introductions in northern Laos[32,63]. It is often accidentally introduced together with the fry of other species for aquaculture[137]
Uses:	None[32]

Puntius semifasciolatus (Cyprinidae) Picture #43

Place of Origin:	Red River basin, South-West China[32]
Introduced Range:	Widely transported around the world[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 7cm TL. Body with 4-7 narrow bars, more or less complete or dissociated into series of spots. Lateral line complete. Colouring can be variable, but generally, yellowish throughout[32]
Ecology:	Benthopelagic. Freshwater. Known from upland streams and rivers. Feeds on worms, crustaceans, insects, plant matter, and detritus [32]
Local distribution:	The presence of this species in the Mekong basin in Laos is probably due to introductions upriver in China[137]
Uses:	Aquaria[32]

Brown Bullhead *Ictalurus (Ameiurus) nebulosus* (Ictaluridae) Picture #44

Place of origin:	North America[32]
Introduced Range:	Europe, South and Central America, Asia, New Zealand[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 55 cm TL. Maximum recorded weight: 2.7 kg. Colouring: dark brown, with a green, violet or bronze luster by reflected light, often with cloudy blotches. Belly whitish to grey. Has two dorsal fins including one short adipose fin. The tail fin is only slightly notched. Four pairs of barbels around mouth[32,116]
Ecology:	Demersal. Freshwater. Occurs in pools and slow flowing rivers with soft substrate. It is a generalized nocturnal bottom feeder that can adopt predatory habits. It builds a nest for its eggs, which are later guarded by both parents. Can tolerate high carbon dioxide and low oxygen concentrations and water temperatures up to 31.6 _C. Has been observed to bury itself in mud to escape adverse environmental conditions[32]
Dispersal/Propogation:	This species was introduced into Viet Nam, probably from the USA at an unknown date and for an unknown purpose. Its fate and impact of introduction are still unclear. There are also proposals to introduce this species into Thailand for aquaculture[145]
Uses:	Fisheries, aquacuture, game fishing, aquaria[32]

Channel Catfish *Ictalurus punctatus* (Ictaluridae) Picture #45

Place of Origin:	North America[32]
Introduced Range:	Europe, Asia, Central America, Carribeans[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 132 cm TL. Maximum recorded weight: 26.3 kg. Usually bluish olive, grey or black on the upper part of the body, becoming white below. Dark spots usually scattered along the sides. Older males completely dark in colour, the head looking very broad when seen from the top. Fins are colourless, occasionally with dark edges. Long barbels surrounding the mouth and the tail is deeply forked[32,116]
Ecology:	Demersal. Freshwater. Inhabit rivers and streams and prefers clean, well oxygenated water, but is also stocked in ponds and reservoirs. This species is a generalized bottom feeder that can adopt predatory habits. It builds nests for its eggs, which are later guarded by the parents[32]
Local distribution:	This species was first introduced into Thailand in 1989 from the USA for aquaculture. It was also introduced into Central and Northern Thailand where it was cultured experimentally. All fish escaped during the great flood of 1995 and were later found in the natural habitat. However, there are no further records of the fate of this introduction[145]
Uses:	Fisheries, aquaculture, game fishing, aquaria[32]

Suckermouth Catfish *Hypostomus plecostomus* (Loricariidae) Picture #46

Place of Origin:	South America[32]
Introduced Range:	North America, Asia[32]
Reported as invasive in other countries:	Yes[32,145]
Status reported from TSBR:	Not reported (except one unconfirmed case of what may have been a single specimen caught in a fishing trap)
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 50 cm SL. Body short and robust. Upper parts of head and body encased in longitudinal rows of hardened scale plates. Lower surface of head and abdomen naked[32]
Ecology:	Demersal. Freshwater. Streams, rivers, lakes, swamps, floodplains[32]. Loricariid catfishes scrape algae off rocks and other surfaces as well as ingesting detritus. They are also implicated in attacking egg masses of fish[145]
Local distribution:	Introduced to many countries through the aquarium trade. It is a common fish in the aquarium pet trade in Cambodia. It appears to be naturalized in a number of areas and has been found in rice fields in Northeast Thailand for at least ten years. It is also particularly visible in small urban water bodies[145]. It has recently been discovered in the Mekong Delta in Viet Nam and seems to be increasing rapidly[128]
Uses:	Fisheries, aquaria[32]
Comments:	The situation regarding this species is complicated, as a number of colour varieties and body forms have been seen. In addition, at least three other Loricariid catfishes have been identified in aquaria and at aquarium rearing stations[145]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to assess its presence.

Mosquito Fish *Gambusia affinis* (Poeciliidae) Picture #47

Place of Origin:	North and Central America[32]
Introduced Range:	Worldwide[32]
Reported as invasive in other countries:	Yes[32,50]
Status reported from TSBR:	A study on exotic fish introduced into the Mekong mentions that it is now found at the margins of most water bodies including rice fields and floodplain lakes[145]
Risk of species being invasive in TSBR:	Uncertain. It is not regarded as being detrimental (in the Mekong) although its habit of eating eggs and larvae of other fish may do some damage to local fish stocks[145]
Description of species:	Average length: 4-7 cm TL. A stout little fish, the back is a little arched in front of the dorsal fin and the belly deep in front of the anal. The head is large with a flattened upper surface, the mouth is small, not reaching the front of the eyes and is slightly upturned. The eyes are very large relative to the body. The back is a greenish olive to brownish, the sides grey with a bluish sheen, and the belly a silvery white. A well-defined black spot on the upper rear abdomen is surrounded by a golden patch above and behind the vent. In mature females there is also a black patch above and somewhat forward of the vent. Fins are transparent and the dorsal fin and tail fins have small black spots[32,50]
Ecology:	Benthopelagic. Fresh and brackish water. Inhabits standing to slow-flowing water. It is most common in vegetated ponds and lakes, backwaters and quiet pools of streams[32]. Highly aggressive, they are known to attack other fish. Selective predation by Mosquito Fish has been known to alter zooplankton, insect and crustacean communities[50]
Local distribution:	*Gambusia affinis* was introduced throughout the basin at an unknown date for mosquito control. It was widely disseminated in drainage ditches from which it has been washed into the main rivers[145]
Uses:	Fisheries, aquaria, mosquito control[32]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its occurrence, distribution and impact.

Guppy *Poecilia reticulata* (Poeciliidae) Picture #48

Place of Origin:	South America[32]
Introduced Range:	Worldwide[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported, but easily overlooked
Risk of species being invasive in TSBR:	Uncertain
Description of species:	Average length: 3.5 cm (male) – 6 cm SL (female). Similar to Mosquito fish in build, but fins lack spots, are coloured and not translucent. There is a great deal of variety in colouring between populations from drab silver or brown to very vivid colour patterns[32]
Ecology:	Benthopelagic. Fresh and brackish water. Found in various habitats, ranging from highly turbid water in ponds, canals, ditches, and rice fields at low elevations to pristine mountain streams at high elevations. Feeds on zooplankton, small insects and detritus[32]
Local distribution:	Introduced to at least Thailand, for mosquito control, it has escaped and become established in the wild throughout the region in small streams and ditches, at the margins of rice fields and other shallow, still water habitats[145]. It has had rare to non-existing effects on mosquitoes, and negative to perhaps neutral effects on native fishes[32]. It is a common fish in the aquarium pet trade in Cambodia[114]
Uses:	Aquaria, mosquito control[32]

Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to better understand its occurrence, distribution and impact.

Sailfin Molly *Poecilia velifera* (Poeciliidae) Picture #49

Place of Origin:	Central America[32]
Introduced Range:	Several countries worldwide including Thailand and Vietnam[32,145]
Reported as invasive in other countries:	No[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low
Description of species:	Average length: 15 cm (male) – 18 cm TL (female). Males have an abnormally large dorsal fin relative to body size, which they can stretch out like a banner or sail[32]
Ecology:	Benthopelagic. Fresh and brackish water. Freshwater to estuaries. Feeds on worms, crustaceans, insects and plant matter[32]
Local distribution:	It was first introduced into Thailand for the aquarium fish trade around 1970 and in 1987 as a control on algal blooms in shrimp ponds in the Gulf. The species is apparently also found in the Mekong Delta in Viet Nam[145]
Uses:	Aquaria, control of algae[32]
Recommendation:	This species could be included under biodiversity monitoring activities in the TSBR in order to assess its status.

Green Swordtail *Xiphophorus helleri* (Poeciliidae) Picture #50

Place of Origin:	North and Central America[32]
Introduced Range:	Asia, Africa, Europe, Australia, NZ, Caribbean and Pacific Islands[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 14 cm (male) – 16 cm TL (female). Body elongated; head pointed. There are many colour forms due to the very extensive natural habitats, but the belly is usually white and there is a light red, dark red or brown longitudinal line on the flanks in all populations (regional forms). In a few variants, there can be one or two additional lines above and one or two below this line. In almost all populations, the dorsal fin has spots or flecks of red. This colouration can also appear in the caudal fin. The sword of males is bright yellow and edged more broadly in black below than above. Old males (3 to 4 years old) can have a totally black sword[32]
Ecology:	Benthopelagic. Freshwater. Found mainly in rapidly flowing streams and rivers, preferring heavily vegetated habitats. Also occurs in warm springs and their effluents, weedy canals and ponds. Feeds on worms, crustaceans, insects and plant matter[32]
Local distribution:	It is a common fish in the aquarium pet trade in Cambodia[114]
Uses:	Aquaria[32]

Southern Platyfish *Xiphophorus maculatus* (Poeciliidae) Picture #51

Place of Origin:	North and Central America[32]
Introduced Range:	Africa, Asia, Australia, Caribbean and Pacific Islands[32]
Reported as invasive in other countries:	Yes[32]
Status reported from TSBR:	Not reported
Risk of species being invasive in TSBR:	Low, at present
Description of species:	Average length: 6 cm TL. Distinct (gravid) spot of black pigment

	mid-ventrally at base of tail fin absent except in pregnant females. Several colour varieties possible: orange, red, grey, but usually with very conspicuous light (white/yellow) iris[32]
Ecology:	Benthopelagic. Freshwater. Occurs in warm springs, creeks, swamps, canals and ditches with typically slow-moving water, silt bottoms and weedy banks. Feeds on worms, crustaceans, insects and plant matter. Has been known to displace native fish if occurring at high densities[32]
Local distribution:	It is a common fish in the aquarium pet trade in Cambodia[114]
Uses:	Aquaria[32]

Results from Questionnaires

A total of 81 questionnaires were completed by resource users in the TSBR from Siem Reap (25), Kampong Chhnang (15), Kampong Thom (11), Pursat Province (17) and Battambang (13), between August and October 2006. Nearly all were involved in fisheries in the TSBR (72) and some mentioned also being engaged in agriculture (33), usually in the dry season only. Four respondents stated only farming as their main activities, while one was a doctor, one was a trader and three had government professions. All the people interviewed were male. Most often other people that were present such as family members (including wives) and friends would partake in answering the questions.

The distribution of questionnaires was achieved by asking commune council leaders to interview a number of people in their area. The interviewers (commune council leaders) were first trained in how to use the questionnaire. Although it was planned to obtain an even number of responses per province, eventually only a varied amount came back from the different provinces. Unfortunately no questionnaires came back from Kampong Thom at all, so any information from this area had to rely on data collected during a visit to the Boeung Tonle Chmar core zone, where people were also interviewed using the same questionnaire.

As mentioned in the introduction, not all the exotic species found in the literature review were added to the reference list used together with the questionnaires (see Appendix C), as sometimes a Khmer name was not known (some species do not even have a common English name), and for several others the name was ambiguous as it could refer to several different species. If it was felt that a physical description clearly identified a species, a colour picture of that species was included as reference.

The results of the questionnaires can only be used to get a general impression of the value people put on certain plants and their opinion on any increase or decrease in numbers in their area. The sample size was necessarily modest considering the available time and manpower. For more accuracy a higher number of people need to be interviewed. Especially for the less common plants, the low percentage of responses becomes a problem for meaningful reporting of results. A further limitation of the questionnaires is that they cannot be used to accurately describe the full range of ecological impact of the exotic species considered. The ecological impact is likely to be varied and complex and require scientific study.

Most of the responses concerned plants. Six species of exotic fish were also mentioned, though only in a few cases. Without further confirmation these records may indicate the presence of established populations, but are as yet inconclusive. The following fish species were mentioned:

1) There were five records of Common Carp (*Cyprinus carpio*), all from Pursat. Common Carp was first observed by fishermen in 2003. All mention it as occurring in rivers and not in the lake, and the majority (4/5) mention it uses the flooded forest and grassland habitats. Two respondents say they believe the numbers of Common Carp are remaining the same at present, while one believes they are decreasing. All mention it as being beneficial to them, and have not noticed any impact from its occurrence. They would be happy if there were more Common Carp.
2) There were four records of Bighead Carp (*Hypopthalmichthys nobilis*), again all from Pursat. Bighead Carp was also observed for the first time in 2003. The habitat use seems to be similar to Common Carp with all respondents mentioning it as occurring in rivers and flooded forest and two respondents also mentioning (flooded) grasslands. They consider it useful, with no impact.

3) There were two reports of Red-bellied Pacu (*Piaractus brachypomus*) from the questionnaires. It is referred to as "Trey Chaab". One was reported from Kampong Loeung in Pursat and another from Prek Loeung commune in Battambang. It was mentioned as occurring in the flooded forest and lake. Furthermore, a WCS/TSCP survey in the Prey Kos area, Kampong Chhnang found that the species is regularly caught by fishermen and there seems to be a localized population there.
4) African Catfish (*Clarias gariepinus*). One live specimen of an unknown catfish was shown to the survey team in Prek Toal, Battambang. Photographs were taken and it was tentatively identified as a possible African Catfish by a fish taxonomist from the FiA.
5) Suckermouth Catfish (*Hypostomus plecostomus*). One fisherman, from Piembang commune, Kampong Thom said he caught one single Suckermouth Catfish (identified from a photograph) in the dry season out on the Tonle Sap with a trap.
6) Unidentified eel-like fish. The fisherman, from Piembang commune, Kampong Thom described it as looking like an eel, with an elongated body and hardly any fins. He had been catching small numbers over the last three years. Always between June and late August. This year he had caught three such fish. The closest exotic, mentioned in this report that fits the description is the Japanese Eel (*Anguilla japonica*).

There were also three reports of exotic snails, presumably Apple Snails (*Pomacea* spp.). One villager from Prek Loeung commune, Battambang mentioned a "Japan Snail" as occurring in agricultural areas, lakes/ponds, and grasslands. He was not sure if it was increasing in number, but said it feeds on rice and the stalks of other plants. It can be sold or consumed as food, but he would prefer to get rid of it. There were two reports of Apple Snail from Pursat, identified from the picture supplement to the questionnaire. One was from Sna Ansar and the other from O Sandan communes. It was surprising that the dates in which they were first observed were mentioned as 1993 and 1984 respectively. These reports need to be investigated further, before confirming the presence of Apple Snails in the TSBR.

Table 1, below, is a summarized overview table of the exotic plants named by people from the distributed questionnaires. It clearly shows that Giant Mimosa is perceived as a major threat. Giant Mimosa is the only plant where the majority of respondents mention that it occurs in their area (77%), believe it is increasing in numbers (61%), and would like to see it removed (83%). The other Mimosa spp. are also perceived as a threat, 40% of people that mention this species would like to see it removed, and 31% of respondents mention it as occurring in their area, however, only 9% of all respondents mention an increase in their area, while 11% think it is decreasing, therefore it is unclear what the population trend of this species is in the TSBR.

Water Hyacinth is very abundant on the lake and 80% of respondents also mention it as occurring in their area. Besides this, 41% of respondents mention it as increasing yearly in number. However, Water Hyacinth has been described as having both a high number of positive as well as negative impacts. The relative importance of this impact was assessed in a simple way by asking if they would rather have Water Hyacinth in their area or not have it, 46% of respondents felt that it is better to have it, and a further 22% specifically mention they would like to see it reduced without being totally removed. This reflects the usefulness of the plant to people living in the TSBR. Also from respondents it was learnt that string and poles are used in village areas to keep large mats of Water Hyacinth to the sides of channels, leaving the center open for boat traffic and reducing the overall impact on boat traffic somewhat. This was still the most cited negative impact with 42% of respondents mentioning it as a problem.

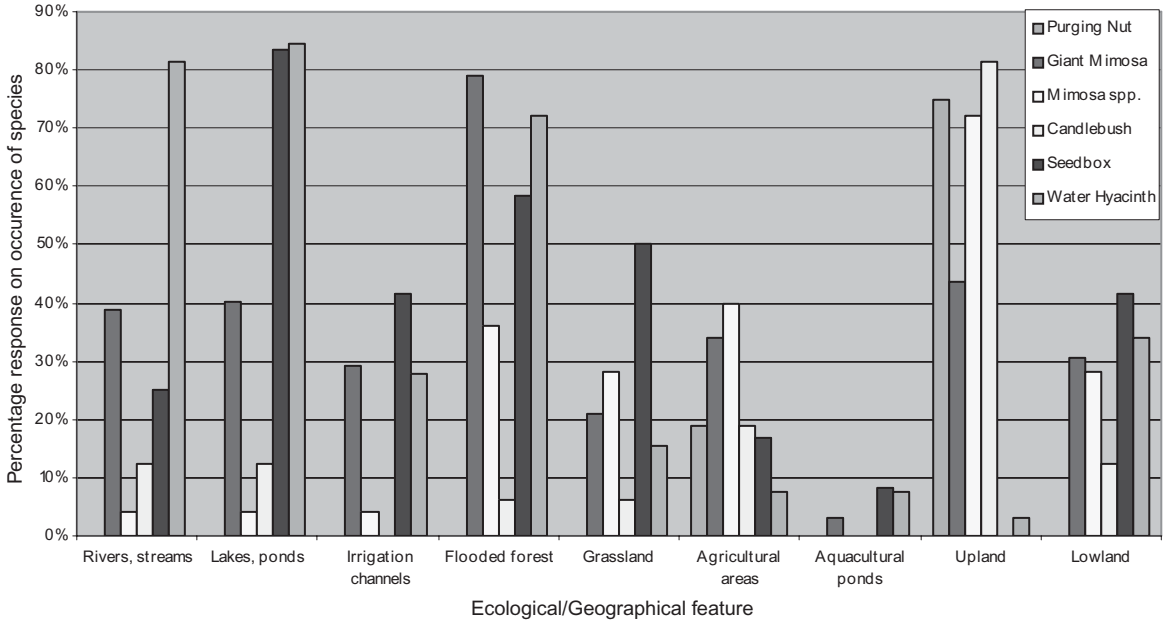


Figure 1. The relative occurrence of exotic plants in different ecological features and geographic areas

It would be logical to assume that the pattern for floating aquatic weeds such as Water Hyacinth, being especially linked in Figure 1 to lakes, natural ponds and rivers are real associations and not merely the result of the higher occurrence of these features in the TSBR. Seedbox grows well in regularly inundated areas and can even become a floating plant, this is seen from its high occurrence on lakes and it is also associated with (seasonally flooded) grasslands more than any other exotic plant studied here. The associations with inundated areas can be more clearly seen by looking at upland and lowland areas. Purging nut and Candlebush are exclusively, or almost exclusively, upland species, signifying they do not tolerate long periods of flooding. While the Mimosa spp., except for Giant Mimosa seem to occur much less in low-lying areas. Species exclusively occurring in lowland areas are Seedbox and, almost exclusively so, Water Hyacinth.

It therefore appears that elevation is a major determinant of distribution for most exotic plant species in the TSBR. The reason for this is likely to be the length of the flooding period, which is related to elevation. The only species considered here which does not show a clear preference for either upland or lowland areas is the Giant Mimosa. The ability of Giant Mimosa to withstand long periods of water stress (flooding or drought) is part of the reason why it is such a major threat to the TSBR ecosystem.

Table 1. Overview Table Showing Major Results from Questionnaires Distributed Among Resource Users in the TSBR

Species	*Percent response for species*	*Year first observed*	*Positive aspects*	*Negative aspects*	*Trend (including not reported / no presence)*	*Opinion on presence*
Purging Nut (*Jatropha curcas*)	16/81 (20%)	Always present (it is planted)	• Source of oil (31%) • Natural fertilizer (19%) • Medicine (44%) • Pesticide (6%)	• No negative impacts (63%) • Toxic (6%)	• Decrease (12%) • No change (4%) • No opinion (4%) • Not present (80%)	• Remove (6%) • Keep (63%) • No opinion (31%)
Giant Mimosa (*Mimosa pigra*)	62/81 (77%)	Range: 1979-2005 Mode: 1989 (12%)	• Firewood (27%) • No benefits (48%)	• Poor habitat for fish (78%) • Hinders animals (25%) • Replaces natural vegetation (25%) • Nuisance to people (30%)	• Increase (61%) • Decrease (5%) • No opinion (11%) • Not present (23%)	• Remove (83%) • No opinion (17%)
Mimosa (*Mimosa pudica* and/or *Mimosa invisa*)	25/81 (31%)	Always present	• Medicine (40%) • Compost (16%) • Firewood (12%)	• Impacts on other plants and crops (36%) • Fish avoid it (16%) • Hinders movement (12%) • Increases sedimentation (8%)	• Increase (9%) • Decrease (11%) • No change (5%) • No opinion (5%) • Not present (70%)	• Remove (40%) • Reduce (32%) • Keep (4%) • No opinion (24%)
Candlebush (*Senna alata*)	16/81 (20%)	Always present (it is planted)	• Medicine (82%) • Fence for house (6%) • Natural fertilizer (6%)	• No negative impacts (82%)	• Decrease (17%) • No change (3%) Not present (80%)	• Reduce (6%) • Keep (82%) • No opinion (12%)

Species	*Percent response for species*	*Year first observed*	*Positive aspects*	*Negative aspects*	*Trend (including not reported / no presence)*	*Opinion on presence*
Seedbox (*Ludwigia hyssopifolia*)	12/81 (15%)	Always present	• Habitat and food for fish (17%) • Food for cattle (17%) • No benefit (33%)	• Increases sedimentation (8%) • Impacts on agriculture (8%)	• Increase (3%) • Decrease (6%) • No change (1%) • No opinion (5%) • Not present (85%)	• Remove (25%) • Keep (17%) • No opinion (58%)
Water Hyacinth (*Eichhornia crassipes*)	65/81 (80%)	Always present	• Food for pigs (42%) • Food for fish (18%) • Food for people (37%) • Fibre for crafts (38%) • Shelter and fish habitat (51%) • Fish attraction device (8%) • Mulch or compost (20%)	• No negative impacts (28%) • Hinders boat traffic and access to fishing grounds (42%) • Increases sedimentation (18%) • Impacts on other plants (11%) • Increase in mosquitoes (3%) • Increase in rats (2%)	• Increase (41%) • Decrease (11%) • No change (15%) • No opinion (13%) • Not present (20%)	• Remove (12%) • Reduce (22%) • Keep (46%) • No opinion (20%)

Further information on the occurrence of Giant Mimosa in the TSBR

Figure 1 showed the distribution of Giant Mimosa across the TSBR landscape as reported by local people. According to this data it is most common in the flooded forest (shrublands) surrounding the lake. The lake (shore) and other permanent wetlands, including rivers and streams are also commonly mentioned as places where it can be found. This data indicates that it is less common around aquacultural ponds and in grassland areas, which are also less common features in the TSBR. If instead the reported distribution of Giant Mimosa is looked at by province, as illustrated in the figure below, it can be seen that there are some major differences between the various provinces.

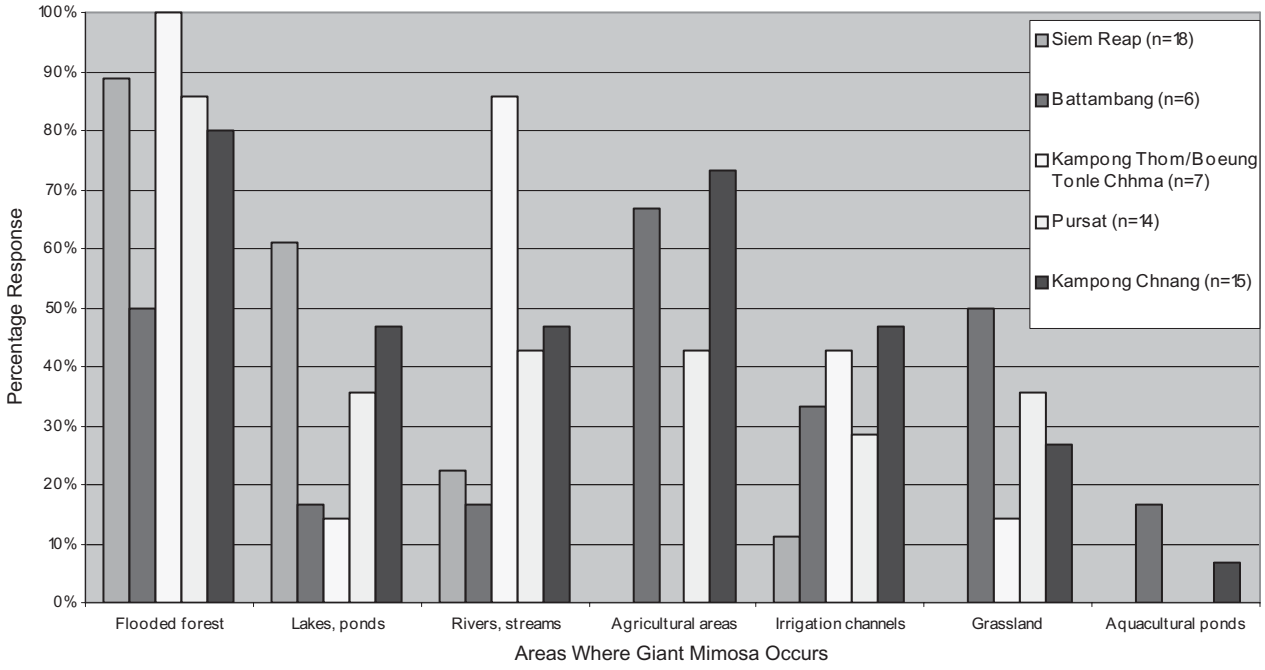


Figure 2. Main areas of occurrence of Giant Mimosa by province

It is probably the case that Giant Mimosa will be most prolific in areas of high disturbance. The most vulnerable would be agricultural fields, although not to permanent invasion if they are cleared regularly for cultivation, then flooded forest (disturbance by people through collection of firewood and other resources, fires, grazing/browsing by livestock and clearing of vegetation) and edges of rivers and lakes (being highly accessible areas and also prone to erosion) and grasslands (fires, grazing/browsing by livestock) may also be affected. The areas of occurrence described in the graph are not exclusive, there is likely to be overlap, **i.e.** edges of rivers and lakes may be flooded forest or other landuse types. Figure 2 clearly shows that only from the provinces on the western side of the TSBR is Giant Mimosa commonly reported from agriculture areas. This reflects the prevalent landuses in different provinces and a lot of the floodplain has been converted to permanent agriculture here. For all provinces except for Battambang, flooded forest ranks highest as an area where Giant Mimosa occurs, however, this is also one of the most common terrestrial features in the TSBR. It appears therefore that the results are in agreement with the idea that Giant Mimosa is probably not going to be more prevalent in relation to specific terrestrial features, but that Giant Mimosa will be found spread over all areas where seeds have been deposited by flood waters and later some disturbance has occurred that has opened up the natural vegetation cover thereby allowing the seeds to germinate, and if there is no eradication treatment, allowing seedlings to become mature plants and eventually to form into dense thickets.

Important Issues

Giant Mimosa (*Mimosa pigra*)

Reports from biological assessments and feedback from resource users confirm that at least one exotic species of plant, namely the Giant Mimosa (*Mimosa pigra*) can be declared an invasive weed in the Tonle Sap Biosphere Reserve.

Giant Mimosa (hereafter referred to simply as Mimosa), originally from South America, has become a widespread exotic of all tropical regions. Probably introduced to many sites as a green manure (being a leguminous plant), and in some countries to botanical gardens, it has eventually managed to disperse over large areas. The exact date of its appearance in Cambodia is unknown, but it is assumed to be in the late 1970s or early 80s (Lim Sovannara *et al.*, 2003) around which time the first specimen was also recorded from the Mekong Delta in Vietnam, although it had been recorded from Southern Vietnam as far back as 1960 (Tran Triet, 2006). It was first introduced to Thailand in 1947 (Lim Sovannara *et al.*, 2003). Large infestations now occur in sections of the Lower Mekong Basin in the north of Thailand (Storrs *et al.*, 2001).

Rapid proliferation started to occur in Cambodia around the early 1990s (Keo Chamroeun *et al*., 2001) and currently Mimosa occurs in at least 13 of Cambodia's 24 provinces, namely: Stung Treng, Kratie, Kampong Cham, Kandal, Kampong Chhnang, Kampong Thom, Pursat, Battambang, Siem Reap, Prey Veng, Svay Rieng, Takeo, and Kampong Speu. Over much of the Mekong, Sap, and Bassac river inundation areas, major infestations of *Mimosa pigra* can now be found (Chin Samouth, 2004) and the yearly removal of Mimosa from rice growing areas along these rivers is a costly burden to farmers (Keo Chamroeun *et al.*, 2001). Ecological surveys conducted in the TSBR have warned about the potentially disastrous impact to biodiversity that *M. pigra* may have in the TSBR (CNMC *et al*., 1998; Rundel, 2000; Smith, 2001; Hellsten *et al*., 2003), but as yet nothing has physically been done to halt its current spread to new areas of the lake, and is a growing concern to both resource managers and local communities.

Mimosa pigra is a particularly aggressive plant and widely regarded as one of the worst environmental weeds in the tropical wetlands of Africa, Asia and Australia (Walden *et al.*, 2004; Mumba and Thompson, 2005; Tran Triet, 2005). There are several features of Mimosa which allow it to become so 'successful' in wetlands:

1. The plants grow quickly, attaining rates of over 1 cm a day under the right conditions (Lonsdale, 1993) and can produce seeds in their first year (Lonsdale *et al.*, 1985)
2. Seed-rate production can be as high as 12,000 per m^2 per year (Lonsdale, 1992)
3. The seeds spread easily, they are covered in fine bristles enabling them to stick to clothes and fur, and they can float on water for extended periods (Miller *et al.*, 1981)
4. The seeds can remain viable for as long as 23 years in (sandy) soils (Lonsdale, 1992)
5. The main node will easily resprout after being cut and, following an intensive burn, up to 90% of mature plants and 50% of seedlings may regrow (Walden *et al.*, 2004)
6. It can withstand the anaerobic conditions of flooding by sprouting adventitious roots near the surface where they can take up oxygenated water (Miller *et al.*, 1981)
7. Without the level of competition and predation it finds in its native range, the plant aggressively forms large dense thickets with each plant being able to reach heights of 4-6 m compared to individual plants of often less than 2 m as found in its native range (Marambe 2004 in Tran Triet, 2006).

It is therefore of little surprise that Mimosa is able to grow well in the seasonally flooded

environment of the Tonle Sap lake. Abandoned fields, containing sparse plant cover are particularly sensitive to invasion and *Mimosa pigra* has been observed to quickly colonize such areas (Nikula, 2005). As the environment of the Tonle Sap Biosphere Reserve is regularly disturbed by human activities such as the clearing and burning of large areas in the dry season, *Mimosa pigra* is likely to spread over ever larger areas and become a dominant feature of the TSBR. Increased grazing in grasslands may also lead to an enhanced Mimosa problem, because Mimosa may benefit from the reduced vegetation cover after overgrazing. The largest infestations were observed from the south and south-western areas of the lake, as well as in Siem Reap on the eastern side in areas that had been classified earlier as abandoned fields and grasslands (Koponen *et al.*, 2003). Hellsten *et al.*. (2003) warn of a potential spread of *Mimosa pigra* infestations over 2,100 km^2 or 20% of the maximum flooding zone.

In Tram Chim N.P., located in the Mekong Delta in Vietnam, the area infested with *M. pigra* has doubled over a period of just one year (Tran Triet *et al.*, 2004a). Mimosa now occupies more than 2,000 ha of the park's 7,600 ha land area and is proving very difficult to control. Mimosa has been observed to invade using the edges of rivers, streams and canals, and across shallow water bodies such as wet grasslands, swamps and rice paddies (Tran Triet, 2006). This scenario is likely to take place in the TSBR as well, where it has been reported by local communities as rapidly increasing in numbers and areas along rivers and streams and in the floodplain surrounding the lake. Its main method of dispersal is clearly by water, and the cyclical fluctuation of water levels is aiding the plant to spread rapidly.

The impact of Mimosa on ecosystems is so severe that it completely alters the vegetation structure, changing it from a diverse assemblage of species with a wide range in vertical composition into a homogenous single species stand, whereby even the undergrowth will only be composed of *Mimosa pigra* saplings (Braithwaite *et al.*, 1989). In infested areas in Australia many animals have become scarce or have disappeared altogether. In general, stands of Mimosa support fewer birds and lizards, less herbaceous vegetation and fewer tree seedlings than native vegetation (Braithwaite *et al.*, 1989).

A study on soil insect abundance and diversity under dense *Mimosa pigra* stands compared with areas of sparse Mimosa and no Mimosa, could not find any significant differences. On the other hand, it was observed that native insects did not use Mimosa foliage as a food source (Tran Triet *et al.*, 2004b).

There are a few species that may benefit from Mimosa's presence. Certain small mammals will benefit from the shelter Mimosa provides, but only in patchy areas or along edges, from which they can make forays into the surrounding vegetation (Walden *et al.*, 2000). It may be possible that juveniles of certain species of fish using the floodplain as a nursery ground could benefit from the presence of Mimosa in this way, but this has not been documented. The use of the flowers of *Mimosa* sp. by the Giant Honeybee (*Apus dorsatus*) has also been noted from the TSBR (Jump, *pers. com*., 2006) and it may be that the presence of *Mimosa pigra* is beneficial to native bees.

Communities living in the TSBR report that the presence of Mimosa has a negative impact on fishery production and fish in general, especially those without scales, as they say fish avoid areas with Mimosa due to the dense thorns covering the plant. The view that *Mimosa pigra* is reducing the amount of suitable habitat for feeding and reproduction, especially for fish species without scales, has also been reported from fishermen and farmers in Kandal province (Keo Chamroeun, 2001). Among the species for which an increase in Mimosa would mean a loss in habitat, and decreased accessibility to certain parts of the floodplain, are the valuable Snakehead species (*Channa* spp.), of which stocks are already threatened by overexploitation (Heng Sovannara, *pers. com*., 2006). A decline in the numbers of Snakehead caught will lead to a significant decline in the value of the fish yield per ha (van Zalinge *et al.*, 2003a).

Being of very limited biological value the widespread occupation of the floodplain by *Mimosa pigra* is likely to have a corresponding negative impact on biodiversity. In total there are 25 species of wetland bird of which globally and/or regionally significant populations exist in the TSBR, 17 of which are IUCN Red-Listed. There are also 6 IUCN Red-Listed species of mammal and 8, perhaps 10, species of reptile, for which the TSBR is of special conservation value (Davidson, 2006). The coverage of wetlands by Mimosa could drastically affect waterbird populations, which rely on grassland for breeding and feeding (Walden *et al.*, 2000). The replacement of native grasslands with *Mimosa pigra* has already occurred in the Mekong Delta, reducing habitat for both the endangered Eastern Sarus Crane (*Grus antigone sharpii*) and the Globally Threatened Bengal Florican (*Houbaropsis bengalensis*) (Tran Triet, 2006), both of which also occur in the TSBR.

The continued spread of Mimosa and the formation of large monospecific stands in the Tonle Sap lake environment could represent an ecological challenge to Cambodia's natural heritage as well as an economic challenge, not only for the communities living in the TSBR, but also to the nation's freshwater fisheries, of which 60% are located in the Tonle Sap area (Hap Navy *et al.*, 2006b) with, thereby, also serious implications for the vast majority of Cambodia's people who rely on fish as their main source of protein (Hortle *et al.*, 2004). Unfortunately, it is also clear that Mimosa is unlikely to be permanently eradicated from the TSBR. New seeds are brought in with the river waters each year and there is already a well-developed seed bank after two decades of its presence in the Mekong and TSBR. However, it is imperative to assess methods of limiting its spread or otherwise see entire areas of floodplain lost to this plant.

Lessons may be learnt from U Minh Thoung N.P., Vietnam, where the population of Mimosa was nearly eradicated, while the remainder was constrained to a limited area. U Minh Thoung is very small and monthly patrols are all that is needed to prevent a recurrence of this weed (Tran Triet *et al.*, 2004a). Any efforts to control invasive species after they have already formed large populations are almost invariably extremely difficult and require a high level of commitment, coordination, funding and expertise.

The ideal scenario would be for authorities and communities to undertake a programme of eradication of *Mimosa pigra* from areas in the TSBR and to continuously monitor and hinder any spread and re-establishment of this species. This would be a major undertaking requiring substantial funding and political support. Options and methods for this programme of eradication are presented below.

Review of control methods that have been used for Giant Mimosa

Generally a choice is made from some or all of the following, depending on the level of infestation, size of the operational budget, manpower availability, availability of products and equipment, availability of technical expertise, accessibility, and ecological sensitivity of the area:

1. Manual methods: The particular advantage of manual methods of control, such as weeding of seedlings and sawing, cutting or chopping of mature shrubs, is that they can be applied by relatively unskilled labour. It is slow and hard work and thus a large labour force would need to be employed. Under dry conditions the plants can quickly regrow from any vegetative material left in the topsoil, and it is advised to cut plants at least as deep as 10 cm below ground (Miller, 2004). However, in the Mekong Delta it was observed that 75-90% of plants cut at ground level at the beginning of the flood season, when submersed in over 30 cm of water, had died off when floodwaters

receded 5 months later (Nguyen Hong Son *et al.*, 2004; Nguyen Thi Lan Thi *et al.*, 2004). Thus, this may be an effective method to apply in the TSBR although the lack of a large labour force is a major constraint.

Mimosa pigra is used as firewood by local communities around Tram Chim N.P., especially by poor and landless people who do not have access to better alternatives. However, it was observed that the method and time of harvesting (in the dry season) has done nothing to stop the spread of Mimosa (Tran Triet, 2006). In the TSBR, feedback from questionnaires show that people do not use Mimosa as a source of fuel, probably because there are many better alternatives available to them in the floodplain "forests". People should be made aware of the threat Mimosa poses to their livelihoods and be encouraged to remove the weed wherever they find it, using suitable methods, *i.e.* removal off all vegetative material from the soil or cutting of the plant well under water at the beginning of the flood season. Local people could also be employed at peak times (June-September) in the removal of *Mimosa pigra*.

2. Mechanical methods: Motor-driven cutters and chainsaws make cutting more efficient. Other mechanical methods are mainly used in areas under cultivation or infestations that are relatively accessible, and are therefore not applicable to most areas of the TSBR. Tractors and bulldozers can allow large areas to be controlled quickly by flattening and crushing the plants (Paynter and Flanagan, 2004, Walden *et al.*, 2000). Such mechanical control however rarely kills plants and is used as a preparation for more effective burning (Paynter and Flanagan, 2004, Searle, 2004).

3. Chemical control: In cases of dense, extensive infestations of *Mimosa pigra,* broad-leaf selective herbicides are often used (Paynter, 2004). Perhaps the most common herbicide used is metsulfuron methyl, available under the trade name Ally (manufactured by DuPont). It belongs to a category of herbicides that are translocated meristematic inhibitors with both foliar and soil activity that work on broadleaf weeds but have little effect on monocotyledons, *i.e.* grasses. Application rates often are less than 1.7 kilograms per km^2. They range in residual activity from very long to moderate, and have very low mammalian toxicity (Ware and Whitacre, 2004). Glyphosate has also been used in the control of Mimosa, but it is a non-selective herbicide and should not be used in environmentally sensitive areas (Nguyen Hong Son, 2004). The use of herbicides, particularly non-selective types, may actually make areas more vulnerable to reinfestation, as the general vegetation cover will be reduced, meaning there are less competitors to prevent Mimosa from re-establishing itself.

   The most effective time to apply translocated herbicides is during the period of active growth (the dry season in the TSBR), so that the chemical may be taken up by the leaves and roots and distributed throughout the plant, and before the plants have produced mature seed, in order to reduce the plant population the following year (Walden *et al.*, 2000). However, the use of chemicals not only affects *Mimosa pigra*, but is toxic to other life forms as well, and as such the use of chemicals should always be a last option when there is no other means of combating particularly large infestations. The use of herbicides increases costs and requires expertise for controlled and efficient application (Searle, 2004).

4. Burning: The use of fire as a control mechanism is widely practiced even although its effect is limited, as mature Mimosa is fire resistant and will quickly regrow any damaged parts. In addition to its use for clearing land for agriculture or increasing accessibility for further control methods such as machinery (Paynter and Flanagan,

2004), fire is also used to kill Mimosa seedlings and to encourage the germination of seeds in an effort to reduce the existing seed bank. However, the very fact that burning enhances Mimosa regeneration from the seed bank (Lonsdale and Farrell, 1998) combined with its devastating effect on competing native vegetation, will only aid the re-establishment of Mimosa in the treated area (Baratt et al., 2004). Particularly in an area such as the TSBR where new seed is brought in each year with floodwaters, it is much better to try and keep the original vegetation cover as intact as possible.

Furthermore, fires in dry vegetation are difficult to control and require expertise. Man-made fires are a major problem in the TSBR and may have already helped *Mimosa pigra* to establish in new areas. Setting fire to natural vegetation needs to be actively discouraged and thus it will not help if the authorities are seen as promoting its use.

5. Revegetation/Encouragement of competition from native species: Mimosa seedlings are susceptible to competition from grasses and other dense natural vegetation (Walden *et al.*, 2000). Studies in Australian floodplains came to the conclusion that, irrespective of Mimosa soil seed bank persistence and Mimosa seed importation rates, maintenance of non-Mimosa vegetation cover will prevent the growth of Mimosa seedlings and reduce the requirement for subsequent management (Barratt *et al.*, 2004, Paynter, 2004). Mimosa seedlings with a stunted growth due to competition with other vegetation are more likely to be inundated and drown during flooding (Paynter and Hennecke, 2001). This has implications for Mimosa infestations downstream of other infested areas that will be constantly exposed to seed importation through annual inundation, such as in the TSBR, and indicates that perhaps the most important step towards long term Mimosa control is the maintenance or encouragement of a dense cover of natural vegetation. In certain areas the recovery of the natural vegetation may have to be assisted by sowing or planting native grasses.

6. Prevention: The saying "prevention is better than cure" is very applicable to invasive species such as *Mimosa pigra*, although, to borrow another saying, this is "easier said than done". The ultimate prevention would be to have bans on the import of Mimosa plants and seeds in all countries of the Mekong basin, and tight control and restrictions on internal movement of other likely sources of seed, such as livestock and feed, vehicles, and soil coming from infested areas. Even though importation has already happened, it remains necessary to try and contain the infestation and prevent its spread. Besides stressing its importance, this report will not go further into this subject, as it is a basin-wide initiative, the implementation of which goes beyond the scope of this document.

7. Biological control: The longest established, ongoing biological control program for *Mimosa pigra* is in Australia. Since 1979 researchers have been introducing insects and pathogens from Mimosa's native range in order to reduce infestation in northern Australia to manageable levels. Of 417 species found feeding on Mimosa in its native range, 43 were brought over to Australia for further assessment and 13 have so far been released. Four of the thirteen have shown an ability to reduce the growth of Mimosa and its seed production. These four species are: *Acanthoscelides puniceus*, a seed eating beetle, *Neurostrota gunniella*, a moth, the larvae of which tunnel into the leaves of Mimosa, *Carmenta mimosa*, also a moth of which the larvae tunnel into the stems and branches, and *Coelocephalapion pigrae*, a flower-feeding beetle (Flanagan and Julien, 2004).

Clearly, the successful implementation of biological control is not a straightforward matter. There are many variables that will determine the propensity of the introduced pathogen or insect to firstly survive and secondly to thrive in its new environment. It is also likely that a whole range of biocontrol agents need to be introduced to have any real impact. Not all the species found in Mimosa's native range can be automatically released in a new environment, because of the possibility that they may affect native species as well, so a thorough assessment needs to be conducted beforehand. Nevertheless, a country wishing to introduce biocontrol agents at present can draw on the lessons learnt from past efforts. Studies carried out in Australia have shown that the incorporation of biocontrol to aid ongoing removal efforts is the most cost-effective method for clearing infestations spread over large areas (Paynter and Flanagan, 2004). Thus, when looking at control of *Mimosa pigra* in the wider Mekong basin, the implementation of a biocontrol program should get due consideration.

From the above it is also clear that the spraying of herbicides and burning of infested areas may be ineffective in areas where floodwaters continuously bring in new seed. These control methods hamper the growth of native vegetation cover that would be able to suppress the germination and establishment of Mimosa plants and would increase the risk of large-scale infestation. These treatments are therefore more applicable in areas with very large and mature infestations, where there is little risk of re-establishment if all the Mimosa in the area is treated simultaneously until the seed bank has been depleted, as there are no vectors present that will rapidly bring in new seed from other areas.

Water Hyacinth (*Eichhornia crassipes*)

Another exotic from South America, the Water Hyacinth has been introduced and spread all over the world in tropical and subtropical regions. It now occurs in at least 62 countries and is regarded globally as the most invasive and damaging floating aquatic weed (Howard and Harley, 1998). The exact date of its arrival in Cambodia is uncertain, but it is clear that it is already long established. Respondents, even those having lived over 60 years in the TSBR, mention that Water Hyacinth has been present in their area for as long as they know. It was introduced to Thailand as far back as 1896 (Banpot Napompeth, 1994).

Water Hyacinth can reproduce both sexually and asexually. It produces long-lived, viable seeds. However, it is the asexual reproduction, with a continuous production of offshoots, which then break away from the parent plant, that results in its extremely rapid growth and spread over areas of suitable habitat. Water Hyacinth can also regenerate from plant fragments provided that they include meristematic tissue. The absorption of nutrients by Water Hyacinth is extremely high, and small increases in the levels of nitrogen and phosphorous greatly increase growth rates (Howard and Harley, 1998).

On the Tonle Sap lake it is abundant, forming dense free-floating mats of clonal colonies, either in pure stands or together with other aquatic herbaceous plants (McDonald *et al.*, 1997; CNMC, 1998; Rundel, 2000). These free-floating mats are typically found as edge forming vegetation in river channels and on the lake, while during the flood season they are often broken up and pushed among the floodplain vegetation (Rundel, 2000; Hellsten *et al.*, 2003).

Like most other exotic plants it seems to be already long established. It is also not reported to be increasing to such an extent as would be expected of this extremely fast growing plant. Water Hyacinth especially thrives in slow moving to stagnant waters, where it can cover whole water surfaces. It has never been reported as causing (major) problems in lakes with (strongly) fluctuating water levels (Hellsten *et al.*, 2003). Thus the large seasonal change in water level of the lake and the strong wave action in the flood season are likely to cause high mortality. This is evident from the abundant, dessicated remains of Water Hyacinth in the

canopies of trees and in shrubs throughout the floodplain after the water recedes (McDonald *et al.*, 1997). Furthermore, there is an outflow of plants to the Mekong and to the sea in the dry season, but it is not known if this is greater, less or equal to the inflow during the wet season.

Due to its abundance it is very likely that Water Hyacinth is impacting on other species and the environment. However, what these impacts are, and to which degree they are occurring, has not been studied. There are numerous ecological impacts that large numbers of Water Hyacinth may be causing in the TSBR and the following are some possibilities.

1. An abundance of Water Hyacinth may lead to accelerated deposition of silt (Wittenberg and Cock, 2001).
2. A dense cover of Water Hyacinth can drastically reduce light penetration in water and without light, phytoplankton and submerged plants cannot photosynthesize. This decreases saturated oxygen levels in the water beneath the mats, while increasing carbon dioxide, making these waters unsuitable for aquatic life (Howard and Harley, 1998).
3. The effect that crowding by Water Hyacinth has on plant community structure and succession is little understood (Wittenberg and Cock, 2001).
4. Besides competing with other aquatic and semi-aquatic vegetation there may also be a possibility that mats of Water Hyacinth inhibit forest regeneration by hampering the development of seedlings in the floodplain (Ben Brown, *pers. com*., 2006).
5. An abundance of Water Hyacinth may also benefit certain organisms that are able to use it as a habitat, *e.g*. snails and mosquitoes (ISSG, 2006c).

The way in which aquatic plants aid the development of mosquito populations is as a result of the shelter the plants provide for larvae. Mosquito larvae are usually confined to vegetated shorelines and not the main body of water since many fish are voracious predators of mosquito larvae. Only when there is floating vegetation shielding the aquatic stages of mosquitos will populations expand (Lindsay *et al.*, 2004). At least 3 three species of mosquitoes are associated with Water Hyacinth, namely *Mansonia indiana*, *M. uniformis* and *M. annulifera*. Their larvae and pupae are found attached to the massive root system. When the plants are eradicated, there is a great reduction in the populations of the three mosquitoes (Naples, 2005). These mosquitos are among those that can transmit Lymphatic Filariasis. A few respondents in the TSBR mentioned an increase in mosquitos, but there was no strong response linking Water Hyacinth and mosquitos.

From questionnaires, Water Hyacinth was found to be having both a negative and positive impact on local communities. The impact of dense mats of Water Hyacinth on boat traffic is a minor to substantial problem in different areas of the lake. Around Prek Toal (in the province of Siem Reap) it was mentioned that the abundance of Water Hyacinth can restrict movement. This was especially apparent in the dry season when large additional quantities of Water Hyacinth are released from fishing lots, which had barricaded tributary rivers during the height of the floods to keep fish inside the lots. Some fishermen around the TSBR mentioned that fishing in the dry season has become more difficult due to the congestion of waterways with Water Hyacinth.

On the other hand, representatives of communities living in the TSBR mentioned many ways in which Water Hyacinth is beneficial to them. They mentioned that they eat the flowers and stem bases after chopping and boiling them. When boiled together with rice and mixed with rice husks, the stem bases are used as a feed for pigs and fish in cage culture. The entire stems of larger specimens are sliced lengthways, dried and woven into hammocks and mats or simply used as short pieces of string. An NGO, based in Siem Reap, Osmose, has initiated

a project with a group of women from Prek Toal village to make a variety of handicrafts and furniture from Water Hyacinth. Entire plants are also used as mulch in agricultural areas and they are valued for their water retention properties. Dense mats of Water Hyacinth are likely to be a good habitat for water snakes, the annual harvest of which is a lucrative seasonal activity for communities in the TSBR. When asked if they would rather keep the plant or remove it, the majority of people (61%) said they preferred to keep it.

It is also widely believed by local communities that Water Hyacinth is beneficial to fish production. They mention that all sizes of fish will use it as a habitat. Small fish use it as shelter and larger predatory fish are attracted to the concentrations of fish found there. Some species will attach their eggs to the long trailing roots. Water Hyacinth is therefore also used as a fish attractant, whereby people gather Water Hyacinth in a convenient place, *i.e.* near the village and keep the plants together by tying a string around the mat perimeter. After a few months (towards the end of the flood season), they will surround the Water Hyacinth with nets and trap all the fish inside. However, this is in contrast to the general belief by scientists that Water Hyacinth negatively impacts on fish populations through the changes it makes to the environment (see the potential impacts listed above). The impact of Water Hyacinth on dissolved oxygen concentrations, particularly at low water levels during the dry season, and with specific reference to the impact on fish production, is an important topic that has yet to be formally investigated in the Tonle Sap.

Review of control methods that have been used for Water Hyacinth

Due to its prolific spread throughout tropical and subtropical areas, there are many different control strategies that have been adopted in efforts to eradicate or reduce infestations. The main choices are to apply physical, chemical and/or biological control methods. It is also recommended to try and reduce the nutrient input into the aquatic system, by treatment of sewage and reducing runoff and erosion along waterways.

> Physical control: includes both manual and mechanical removal. Manual removal using knives or ropes to cut mats into manageable pieces and drag them to the bank or boat is extremely labour intensive, and even where manpower is plentiful and cheap, it would only be effective for small areas (Howard and Harley, 1998). This is due to the weight of the plants, whereby only small quantities can be removed by manual labour, and the very high growth rate. There are a lot of potentially rewarding ways to use Water Hyacinth so the encouragement of utilization by communities may enhance their welfare, but manual removal cannot be seen as a serious method of controlling Water Hyacinth throughout the TSBR.
>
> In order to try and turn a problem into something positive, many people have been trying to find useful ways to utilize Water Hyacinth. It has been used to make paper by mixing the fibre together with waste paper or jute fibre; fibre boards have been made that are of sufficient quality to use as indoor partition walls and ceilings; baskets, mats, furniture and other domestic products are woven from the dried stems; charcoal briquettes can be made together with other combustable waste material; biogas or methane gas can be produced by the anaerobic breakdown of organic matter (*i.e.* Water Hyacinth) together with smaller quantities of animal or human excrement which provide the micro-organisms needed, inside an air tight container (digester); the stem bases may be used as animal feed; the whole plant is used as mulch to make compost or as ash fertilizer; or through hydroponics, by using beds containing layers of compacted Water Hyacinth whereupon vegetables can be grown (Haq *et al.*, 2004; ITDG, 1997; Lindsey and Hirt, 1999).

Mechanical methods of removal can harvest larger amounts and may be best combined with an industrial type of use of Water Hyacinth. Mechanical harvesting by boats is costly and only suitable for establishing control in relatively small areas. A fleet of water and land-based vehicles would be needed to transport the large quantities of Water Hyacinth. Mats of Water Hyacinth can be enormous and due to its high water content, can reach up to 600 tons per ha. To be effective the rate of removal needs to be equal or higher than the rate of growth and invasion by mobile mats (Howard and Harley, 1998; Gutierrez *et al.*, 2001). However, along rivers, booms can be placed to divert Water Hyacinth to a collection area for removal and possibly further processing. As they have no moving parts, booms can be very cost-effective. However, they must be cleared at frequent intervals to prevent breakage from the weight of accumulated plants (Howard and Harley, 1998).

Chemical control: is rapid and effective in the short term, but Water Hyacinth will reinfest from seeds and invasion by new plants. Common herbicides are 2,4-D Diquat and Glyphosate (ITDG, 1997; Howard and Harley, 1998; Lindsey and Hirt, 1999). The use of chemicals over wetlands is a very controversial issue as all chemicals will not only affect Water Hyacinth, but also other organisms, and may contaminate water supplies. For such a large area as the TSBR, which is also extremely important for the nation's fisheries and biodiversity conservation and contains sizeable populations of people, the application of herbicides is not really an option. Furthermore, the simultaneous decay of large quantities of Water Hyacinth may reduce the oxygen content in the water body to such a degree that fish would not be able to survive even if the chemicals have not harmed them (Lindsey and Hirt, 1999).

Biological control: is the release of host specific natural enemies in areas of proliferation. Several insects and fungi have been identified as control agents. These include a variety of weevils, a moth and fungi. Particularly the weevils, *Neochetina bruchi* and *N. eichhorniae* and the moth, *Sameodes albiguttalis* have been widely established and are contributing to the control of Water Hyacinth (Howard and Harley, 1998). For Water Hyacinth, biological control is often considered the most cost effective approach now that suitable agents have been found, and said to be environmentally benign, as the control agents tend to be self-regulating (ITDG, 1997). However, control has generally been less successful in fast-flowing rivers where plants with weevil larvae are continually washed downstream (Center, 1994 in: Howard and Harley, 1998). It is therefore uncertain if it would be effective in the TSBR where a lot of Water Hyacinth is deposited on land or floats towards the Mekong Delta when the water recedes from the lake.

Other Exotic Plants

Besides Giant Mimosa and Water Hyacinth, several other exotic plants have been named by local communities, such as Seedbox (*Ludwigia hyssopifolia*) and Mimosa (of which it is yet unsure if the people refer to *Mimosa pudica* or *Mimosa invisa* or both). They have sometimes been described as locally problematic, but at least from the results of the questionnaires, no other plants are reported in such large numbers and as increasing to such an extent that it looks like they have become serious invasive species.

However, there is insufficient data to say with certainty that these other exotics are not impacting on the ecosystem. Most studies have looked at vegetation or habitat type patterns in the TSBR and briefly mention common associations of species and usually attach a checklist of plant species observed as an annex, but which does not mention abundance (*e.g.* CNMC *et al.*, 1998; Rundel, 2000; Hellsten *et al.*, 2003). There is only information on

abundance on a few exotic species from sites surveyed by McDonald and others in 1996 and 1997 (McDonald and Veasna, 1996; McDonald *et al.*, 1997).

The above mentioned survey mentions Para Grass (*Brachiaria mutica*) and Hippo Grass (*Echinochloa stagnina*) as being abundant in some areas while rare or absent from others, so they clearly have restrictions to their occurrence, possibly being hindered by the degree of change in water level and perhaps therefore also being seasonally more abundant.

Initially, from questionnaire surveys conducted in this study it appears that *Jatropha curcas* is planted by people in home gardens, does not seem to be spreading naturally, and is becoming less common. *Ludwigia hyssopifolia* appears to be fairly widespread, but not abundant and is not perceived by communities around the lake as having any major impact. One name was used in the questionnaire ("Preah khlob sampeah") to describe *Mimosa invisa* and *Mimosa pudica*. *Mimosa* sp. were reported from only a few areas, but they were described as impacting on other plants. Even though it was thought to be affecting other species, more people described it as declining in abundance than increasing. However, after the questionnaire was made it appears that "Preah khlob sampeah" refers to *Mimosa pudica* and *M. invisa* is generally called "Preah khlob damrei". The accuracy of this, especially for the TSBR area, has not yet been confirmed and the best way to assess the status of these species is through a botanical survey.

The lack of understanding about the synecology of the Tonle Sap lake and the surrounding floodplains, as well as more detail on the autecology of exotic plants within this context, makes it difficult to evaluate the impact exotic species are having and the threat they pose to biodiversity. It could well be that the extreme environment, as a result of the extensive flooding (and subsequent "drought"), is not suitable for most exotic plants that are not especially adapted to such conditions. However, as mentioned already, these relationships need to be studied further.

Exotic species that are not thriving at present could still do so in future as human influence alters the environment. The burning of forests, either accidental or not, the conversion of forest to agriculture and nutrient input (directly in the TSBR and through runoffs upstream) into the ecosystem are some of the factors which are likely to increase in the future. These may spur a proliferation of exotic plant species as many of the exotic plants in the TSBR will have formed extensive seed banks over the years and any major changes in the environment can lead to rapid spread. Reduced flooding through the damming of the Mekong would also lead to major environmental changes.

Aquaculture, Aquaria and Introduced Fish Species

There are also several species of exotic fish, which are being found, although irregularly, in the Tonle Sap lake. Fish are mobile so they are better able to cope with the "peculiar" environment of the TSBR and such species as the African Catfish (*Clarias gariepinus*) could do very well in the Tonle Sap lake, even at very low water levels, and the near anaerobic conditions that prevail at this time. It is too early to tell if any of the introduced fish species that are finding their way into the river ecosystem, or have already done so, are impacting on the status of native species and –biodiversity in the TSBR.

The situation regarding the establishment of populations of exotic fish species in Mekong waters is, as mentioned earlier, quite unclear. The Mekong Fish Database (MFD), produced in 2003 by the Mekong River Commission (MRC) as a reference work on the biology and distribution of native and exotic fish occurring in the wild and in culture within the Mekong Basin, only names the Common Carp (*Cyprinus carpio*) and Nile Tilapia (*Oreochromis*

niloticus) as alien species that are now established in parts of the Mekong River (Visser *et al.*, 2003).

Another study, conducted in 2003 for the MRC, reports that 8 different species seem to have become established (Welcomme and Chavalit Vidthyanon, 2003). Besides the 2 species mentioned in the MFD, also: Mrigal (*Cirrhinus cirrhosus*), African Catfish hybrids (*Clarias gariepinus*), Mosquito Fish (*Gambusia affinis*), Rohu (*Labeo rohita*), Mozambique Tilapia (*Oreochromis mossambicus*), and Guppy (*Poecilia reticulata*) were believed to have become established. While for still 2 other species, the status is as yet uncertain, but the existence of established populations is possible: Grass Carp (*Ctenopharyngodon idella*) and Bighead Carp (*Aristichthys nobilis*). Any species occurring in the Lower Mekong is also quite likely to be found (at least seasonally) in the Tonle Sap river and lake, or is likely to spread.

This report identifies four different categories of potential impact:

1. Severe effects causing economic or environmental damage
2. Establishment of species leading to local extinction of native species
3. Establishment of species leading to genetic mixing and the production of viable hybrids between introduced and native species
4. Establishment of species with no noticeable impact

The authors believe that all introductions of exotic fish seem to fall into the last category so far, *i.e.* they are not having any noticeable impact, except for the detrimental effect *Oreochromis mossambicus* is having on shrimp farms in the Mekong Delta, making it a level 1 impact and for *Clarias gariepinus*, which may be hybridizing with local catfish species (level 3 impact) and perhaps *Labeo rohita* which may have an impact on native labeos, but for which there is no evidence (Welcomme and Chavalit Vidthyanon, 2003).

A third paper written in 2003 by Fisheries Department specialists mentions 4 species as being caught regularly in the fisheries along the Mekong and 3 species from the Tonle Sap and other tributary rivers. These are Silver Carp (*Hypopthalmichthys molitrix*), Rohu (*Labeo rohita*), Common Carp (*Cyprinus carpio*), and Nile Tilapia (*Oreochromis niloticus*). Tilapia were only reported from the Mekong (Sam Nuov *et al.*, 2003).

However, the fishermen in the TSBR that were interviewed rarely mention catching unknown or uncommon alien fish species. Three exotic species were named (Common Carp (Trey samahn), Bighead Carp (Trey carp kbal thom), and Red-bellied Pacu (Trey Chàb). One was identified from a photograph (Suckermouth Catfish), One could not be identified, but was described as a eel-like fish, and another was photographed by the author and tentatively identified by a fish taxonomist of the FiA as an African Catfish. Except for Trey Chàb, these were all single to uncommon incidents and without more confirmed reports these records by themselves are far too few to be able to say anything about the presence of breeding populations in the TSBR. Trey Chàb was later also recorded during a survey of the area around Prey Kos, Kampong Chhnang as being caught regularly and the people even reported at least one incident of a man being bitten while swimming by what they believe to have been Trey Chàb. The fish that were being caught were small at 5-7 cm and weighing less than 100 grams.

With fish it is very difficult to estimate how many there are, and the bigger the ecosystem, the more difficult this becomes. The main stream of the Mekong can be considered to be nearly 4,200 km long, stretching from Tibet to Viet Nam and as such it may take a long time before populations of any introduced species build up to such a degree that they become noticeably invasive. Therefore, it is difficult to predict accurately, even for those species that have clearly established breeding populations, whether that species has or will build up its

population to such an extent that it may start to have an impact on other species.

It will always be very difficult to manage or control populations of specific fish species. Fishing gear can be made more selective by increasing the mesh size (fisheries targeting large bodied fish) or by using attractants such as lights (*e.g.* squid fisheries), or by using specific bait together with fishing line put out at specific depths (*e.g.* crab fisheries), or if targeting a fish that will form large single-species schools (*e.g.* herring). However, fishing methods are largely non-selective and targeting any one species for population control is in most cases impossible.

It is therefore extra important to prevent exotic species from entering the natural watershed of the Mekong. On National Fish Day the Fisheries Administration (FiA) tries to raise awareness among the population, so that when releasing fish back into natural waters, as is the custom on this day, they will release only native species.

The FiA has placed a ban on the importation and farming of the Red-bellied Pacu, *Piaractus brachypomus* in an effort to prevent further accidental introductions of this species into natural waters. Yet perhaps more species than just the Pacu need to be considered for regulation of import and cultivation. For example, the Mozambique Tilapia, *Oreochromis mossambicus*, could be considered, as it is potentially invasive and not a preferred fish for eating anyway. Also a number of large and small aquarium fish are imported which could be harmful to the ecosystem if released, *e.g.* Giant Arapaima, *Arapaima gigas*, a voracious predator. There needs to be more attention given to the importation and use of exotic species in general. Any future trade and movement restrictions on certain exotic species should take place throughout all the Mekong basin countries to be most effective.

The Aquaculture of Indigenous Mekong Fish Species (AIMS) Cambodian component programme realizes the threat to biodiversity posed by the widescale and uncontrolled use of exotic fish in Cambodia's steadily increasing aquaculture sector. It is now testing certain native species for their suitability in aquaculture to the degree that they may complement or replace the use of imported exotics in the Mekong basin.

Typically, Cambodians prefer indigenous fish and the culture of exotic species is more a reflection on the introduction of pre-established culture systems than by popular demand due to taste (Funge-Smith, 2001). However, it still remains to be seen how many indigenous species can grow well in aquacultural systems. Some indigenous species are kept in cages lined with nets (cage culture) under house boats on rivers and lakes. Snakehead and (Pangasiid) Catfish are some of the commercially important indigenous species found in these systems (van Zalinge *et al.*, 2003a). Cage culture within natural waters clearly carries an increased risk of escape and accidental introduction. Fortunately, most cage culture is with indigenous species as they are valued more than exotic species, hence it is only in pond culture where the use of exotic species becomes prevalent, as these are species that have been selected for their strong growth rate under these type of conditions, where phytoplankton is the main food source (Funge-Smith, 2001; Ouk Vibol, *pers. com*., 2006).

Recommendations

Control of Giant Mimosa

It is recommended that a programme to reduce the extent of Giant Mimosa in the TSBR and prevent its spread, be set up under the direction of the relevant authorities, focusing on two things:

1. The immediate and continuous manual removal of all *Mimosa pigra* plants and seedlings from designated High Priority Areas while infestations are still scattered and manageable (the determination of these areas is not within the scope of this work but might include any TSBR core affected areas).
2. Improving the protection of the natural floodplain habitat. Keeping the vegetation cover intact by preventing activities that cause large-scale disturbance within the flooding zone, *e.g.* burning, where the risk of the land becoming infested with Mimosa is high. Planting/sowing of native fast growing grasses and shrubs will also help this process, although it will be expensive.

The programme should at least contain the following basic elements, adapted from the advised approach for control of *Mimosa pigra* in Tram Chim N.P. (Walden *et al.*, 2000):

Surveys: Surveys should be conducted to establish the full extent of the Mimosa infestation. An assessment can then be done on which areas should be prioritized. Prioritization could be based on a number of factors, including: the low level of current infestation; the potential of the site to become (further) infested; the particular biodiversity conservation value of the area; the location and the potential for the infestation to spread to other sites. Interview surveys have already started as part of this work.

Control measures: Recommended control methods are:

1. The cutting and removal of plants by first collecting all seed pods and burning them immediately (in a mobile furnace by eradication teams, the ash should be deposited in a deep pit), and then weeding out saplings and removing mature plants, either:
    i. during the rising floods (June-September) by cutting the plant as low as possible with the cut being at least 50 cm under water (the optimal depth for cuts will need to be experimented with)
    ii. in the dry season, by pulling or digging out the whole plant, or if that is not possible by cutting the plant at least 10 cm below ground;
2. Where ground cover is sparse either due to Mimosa clearing activities or for other reasons, native fast growing grasses or shrubs could be sown or planted to encourage a competitive vegetation cover, reducing the risk of Mimosa establishing itself in the area.

Community participation: Mimosa poses an indirect threat to the livelihoods of local communities in the TSBR. The TSBR inhabitants surveyed mentioned that they remove Mimosa plants from areas near or in the village, but that they always grow back. They need to be made aware of proper methods of removal so that the likelihood of the regrowth is decreased and in order to minimize the risk of accidentally aiding the plant in its spread. People living in places where there is no Mimosa as yet, should be trained to recognize the plant and what to do if they find it in their area. Perhaps, most importantly, people should be made aware of how current

land use, *i.e.* the burning of vast tracts of land will allow Mimosa to spread rapidly. As the popular sentiment towards Mimosa is very negative, it is quite likely that communities will be willing to learn of the ways in which they can help reduce the extent of its spread.

On the whole, people in the TSBR do not seem to use *Mimosa pigra* much as firewood, even believing in some cases that the fumes are toxic. However in other areas of Cambodia and in Vietnam and Thailand, the use of Mimosa as firewood has been reported, although only as a second-rate fuel source (Tran Triet, 2006; Lim Sovannara *et al.*, 2003; Keo Chamroeun et al., 2001; Robert, 1982, in Miller, 2004). Making charcoal briquettes from Mimosa wood chips and possibly other combustible sources could increase the energy produced from burning (Presnell, 2004). Young stems have also been used as fertilizer after cutting them into small pieces (Keo Chamroeun *et al.*, 2001). And in Vietnam it has been shown that mushrooms can be grown on cultures of chopped and sterilized Mimosa stems (Tran Triet, 2006). A study tested the leaves of Mimosa for antimicrobial activity and found it to be effective against four different common bacteria, but not *Escherichia coli*. It was concluded that the use of Mimosa could not be justified for treating diarrhea, but could be supported for the treatment of infected wounds, and skin and eye infections (Rosaldo-Vallado *et al.*, 2000, in Miller, 2004). Furthermore, all types of livestock have been documented as being able to feed off Mimosa leaves and shoots, and experiments have shown that goats can even live on a diet of only Mimosa (Miller, 2004). Mimosa has a high protein content and the leaves and shoots can be used as a high-protein additional feed component (Miller, 2004).

The use of Mimosa however carries a substantial risk in that it can facilitate further spread, and it is not recommended to promote Mimosa as being useful. Livestock should not be encouraged to feed on live plants. If involving communities in eradication programmes, whereby the use of the harvested Mimosa is permitted, the people will need to be trained how to do so properly. They will need to take care with the seeds and collect and destroy them before using the rest of the plant as firewood (if they want to use it for this purpose). The main purpose of harvesting Mimosa should still be to reduce the amount of plants in the area.

Fostering the utilization of Mimosa among communities in a vast, sparsely populated area such as the TSBR will not likely contribute substantially to the overall decrease of Mimosa infestations, and carries the risk that people may inadvertently increase its spread. However, if communities can be educated and mobilized, then the spread of Mimosa may be contained in areas around villages by the communities themselves. Hopefully, the increased awareness of the risk a spread of Mimosa over large areas of the Tonle Sap would pose to the availability of many of the resources they rely upon, will bring about a more cautious approach to land-use in the floodplain. For all other areas of the TSBR that require treatment, government coordinated removal efforts are the only possible means of controlling Mimosa.

Research, review and reassessment: In order to make control methods more effective, their application should be studied and reviewed. For example, in a particular treated area, information on the number of plants cut, the depth of water at time of cutting, the period of inundation that followed, and the number of plants that survived the flooding, gives an indication of the effectiveness of the treatment. Other studies could look at Mimosa seed production, growth, and rate of spread and compare this with the rate of removal by the programme to evaluate the programme's effectiveness as a whole. It still needs to be determined which native species are efficient competitors so

that they may be used under the revegetation component. The effect *Mimosa pigra* is having on fish production and biodiversity is also an important question that needs to be answered through research. Additionally, land-use practices in the TSBR that may have an effect on ground cover (*e.g.* burning, grazing, cultivation) or opening of canopy cover (firewood and timber collection) need to be studied for the contribution they have to the spread of Mimosa. Finally, the participation of communities needs to be monitored and reassessed to see what works, what does not, and how it could be improved.

Control of Water Hyacinth

In a large area, such as the TSBR where there is also continuous inflow of Water Hyacinth from tributary rivers, it is likely that, as with *Mimosa pigra*, total removal is impossible. Therefore it is recommended to implement the most cost-effective and suitable methods that can at least match the rate of growth and influx of Water Hyacinth in the TSBR.

It is suggested that an evaluation study be conducted on the feasibility of placing a number of booms at strategic locations (*e.g.* near inlets of the Sap river and other major tributaries of the lake) where a great deal of Water Hyacinth can be gathered before it enters the lake with the inflowing water and as it is washed out with the outgoing pulse. A facility for converting the collected organic refuse into biogas, animal feed, fertilizer or other products could be coupled to such sites. If such a harvesting system is feasible and depending on the proportion of Water Hyacinth intercepted, this may cause a substantial reduction in the number of plants on the lake over a short time period, as within the lake system there is already a substantial mortality from "beached" plants in the dry season. However, there will always be regrowth so it will remain an available resource to be exploited by local communities.

The case in Prek Toal whereby fishing lot owners release a great deal of Water Hyacinth as waters recede could also be avoided if they can be convinced of the income that can be made from collecting the plants and converting them into fertilizer or using them as mulch.

The benefits gained from Water Hyacinth by local communities should be explored further. The idea of manufacturing handicrafts and souveniers to sell to tourists, as first initiated by Osmose, may be expanded so that instead of only in Prek Toal, other villages are incorporated and the items brought to Siem Reap where there is a much larger (tourist) market. Another idea which Osmose has been considering and which is a strongly recommended approach to increase the benefit communities can get from this plant, is the development of hydroponic vegetable gardens on a prepared bed of Water Hyacinth substrate. In the flood season there is only water, and such vegetable gardens would vastly improve the health and well being of the communities living in the floating villages of the Tonle Sap. It is possible that fish would still use the garden mats as shelter, so that people could use them for fisheries and in the dry season they could harvest the used Water Hyacinth and convert it into compost, which, as with vegetables, they could potentially sell.

Currently the villagers rely on car batteries or, in some cases, generators to have access to electricity. Small household or larger village biofuel digesters coupled to electricity generators could be a solution to the expensive and environmentally unfriendly use of car batteries, and gas could replace the use of firewood for cooking.

Investigation of the Occurence of Red-bellied Pacu in the TSBR

The establishment of Red-bellied Pacu in the TSBR has a potentially severe environmental impact. It is an aggressive species that will not only directly compete with native species that feed on fruit and detritus, it will turn to insects and other fish when other food sources are low.

Red-bellied Pacu or Trey chàb (*Piaractus brachypomus*) was reported as being caught regularly by fishermen in the Prey Kos area, Pleu Too Commune, Kampong Chhnang during a recent WCS/TSCP survey (November 2006). The team was unable to see any specimens themselves and so these reports still need to be verified. Through questionnaires it was learnt that one fisherman from Prek Loeung, Battambang believes to have caught a Trey chàb and one fisherman from a village in Boeung Tonle Chhma reported a Trey chàb being brought to Kampong Loeung to be sold.

The occurrence of Red-bellied Pacu (*Piaractus brachypomus*) in the TSBR needs to be investigated further. As people have reported that it is often caught in fishing traps, it may be possible to set up an eradication campaign using traps once areas of occurrence have been identified. These traps would need to be regularly monitored and all native species of fish released back into the water. Besides regular supervision, the traps may need to be modified so that they can be locked and not broken into easily by other people.

Surveying the TSBR for Exotic Species

As very little is known about the exact status of exotic species in the TSBR, it would be useful to incorporate a survey of exotic species under the ongoing biodiversity monitoring activities in the TSBR to collect more data on their distribution, abundance and population trends, as well as uses.

Plant species to include in surveys would be: *Brachiaria mutica*, *Chromolaena odorata*, *Echinochloa stagnina*, *Eichhornia crassipes*, *Pennisetum polystachyon*, *Pistia stratiotes*, *Jatropha curcas*, *Leersia hexandra*, *Ludwigia hyssopifolia*, *Ludwigia peruviana*, *Mimosa invisa*, *Mimosa pigra*, *Mimosa pudica* and *Senna alata*.

For fish, it is recommended to first focus on those species, which are reported as the most likely to have established populations in the Mekong and Tonle Sap. Thus the following could be included in biodiversity surveys: *Aristichthys nobilis*, *Cirrhinus cirrhosus*, *Clarias gariepinus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Gambusia affinis*, *Hypopthalmichthys molitrix*, *Labeo rohita*, *Oreochromis mossambicus*, *Oreochromis niloticus*, *Piaractus brachypomus* and *Poecilia reticulata*.

The above can be included in species surveys conducted in various places around the TSBR, but likely concentrating on the Core Zones as main areas for biodiversity conservation. Besides direct methods of investigation the use of questionnaires can form a basis for conducting a rapid initial assessment as well as for periodic monitoring. Questionnaires can also provide information on rare or new species that are likely to be missed by surveys. Direct observation, through counts and sampling, can be used for most flora and fauna. For fish, the usual method involves examining the catch of fishermen. As this requires a great deal of extra time and skills it may be chosen to rely on the FiA for these data.

TSBR managers should continuously look out for invasion by new species from other areas in the future, *i.e.* for Apple Snails, which are found in the upper reaches of the Mekong in Cambodia down to Phnom Penh and could quite easily spread to the TSBR.

Without quantitative data over time from the whole of the TSBR through regular monitoring of distribution and numbers, it will only become clear that there is a real problem when an invasive species is in its explosive stage and it becomes increasingly difficult to eradicate, as is happening now with Giant Mimosa. A lot of the otherwise occuring ecological damage and economic costs will be mitigated by eradicating or containing the spread of invasive species when the population levels are still low and confined to a limited area. Also the most effective way to deal with invasives along waterways is at basin level. So ideally a programme is needed that will look exclusively at alien species in the Mekong basin and implement projects to control those that are invasive, as well as looking at implementing cross border cooperation in restricting their movement and spread.

Research Studies

Ecological understanding of the Tonle Sap lake and floodplains is still in its infancy. Very few synecological or autecological studies have been conducted. There is still a lot of controversy over the relative influence of environmental vs. anthropogenic factors on vegetation formation in the floodplain. To understand the possible impact of Water Hyacinth and other invasive species on the ecosystem, a much more detailed understanding of ecological relationships of the fauna and flora in the TSBR is needed. With the availability of data on ecological relationships between species and between species and the environment, the past, present and future impact of the various exotic species occurring can be better understood. Risk assessments can then be made for the species mentioned in this report and others if there have been any further introductions so that invasive species control can be more thorough and efficient. Until then, invasive species control will be largely reactive in nature and always lagging behind the development of what can be major environmental and economical problems.

Establishing an Alien Invasive Species Task Force

The management of invasive species in the TSBR will be a large task and will require a team of individuals to coordinate the necessary activities. A number of biologists/ecologists will be needed to work from several locations around the TSBR in teams with several community participation/extension officers. They would logically be directed by an overall coordinator. Especially for the removal of Giant Mimosa, a large labour force will be needed, which, if possible, can be drawn from local communities.

If an Alien Invasive Species Task Force or Control Team can be formed to coordinate the control programmes for invasive species in the TSBR, there will be a central authority to which communities can turn when they encounter new species in their area and thus the team can, while raising awareness about invasive species, also encourage communities to report any new species encountered in their area. This may be an effective approximation of an "early-warning system", which is essential in preventing the spread of invasives.

Reducing the Risk of Further Introductions

<u>Aquaculture</u>

With fish there are a number of problems that make control of invasive species very difficult. Firstly, it is inherently problematic to monitor populations of organisms that live underwater

and only surface when caught in a fisherman's net, an incident that usually goes unreported. So it may well be that it is only obvious that a species is established in an ecosystem once it has already become quite numerous. This also means that if control action is taken, it is very difficult to say when a species is completely eradicated. It is also near impossible to reduce the numbers of the target species without affecting other fish as well. Because of all these issues any control programme would be a vast undertaking requiring a substantial amount of money and would run a high risk of not succeeding. All of these factors make it difficult to find financial and political backing for such an undertaking.

Clearly with fish, it is especially important to minimize the risk of further introductions of exotic species into the Mekong ecosystem. Considering the already existing preference for the growth of indigenous fish over exotic fish in natural waters, together with the continuous ongoing work of AIMS in finding local species suitable for pond cultivation, it may be relatively easy to implement restrictions on the raising of exotic species in aquacultural ponds within the maximum flooding zone of rivers, in order to reduce the risk of accidental introductions occurring. Thus pond culture with exotic species would only be allowed outside of the flooding risk zones.

To increase the control and management of the number of exotic fish in the natural river system a number of steps could be taken, although not all are applicable to managers of the TSBR, *i.e.*:

1) Find out more about the extent of "contamination" by exotic species. Besides integration into ongoing biodiversity surveys, a simple way to achieve this could be by spreading the word that any new or unknown species caught should be kept alive and a MoE ranger/ FiA officer notified. The rangers/officers could then go to the fisherman with a prepared form to take certain measurements and record further details and photograph the specimen (including one together with the finder if possible). The specimen should not be released back into water (as often people do if they consider it special). Also, media coverage every now and then keeps people interested in reporting their finds.
2) Increase awareness among all Cambodians about exotic species and their potential impact when released into the ecosystem.
3) Establish zones where only the cultivation of indigenous species is allowed, related to the area of historical maximum flooding in very wet years, but actually following some governmental/political boundary, *i.e.* commune boundary, for ease of application. Aquacultural ponds containing exotic species would thus only be permitted outside of these zones.
4) Carry out a risk assessment for all exotic fish in the aquarium and aquaculture trade on their possible impact on the Mekong River System. Use this risk assessment as a decision making tool for imposing restrictions on import and use of certain potentially harmful species.

Crocodile Farming

The importation of crocodile species such as the Cuban crocodile (*Crocodylus rhombifer*) and the Estuarine crocodile (*Crocodylus porosus*) in order to improve the gene pool in the larger crocodile farms should be strongly regulated. Importation should only allowed to farms that comply with the minimum safety requirements of holding pens in respect to the likelihood of crocodiles escaping. Even though it is likely that crocodile farmers in floating villages on the lake do not keep any other type of crocodile than *Crocodylus siamensis* (as this requires a capital investment not available to them), a ban on the use of any other species than C. *siamensis* in farms on the lake should be put in place and people should be made aware of this development.

Bee Keeping

The importation of the European Honeybee (*Apis mellifera*) is another example of an introduced species which the government should consider banning. There is enough potential for beekeeping with the native species *Apis cerana*, the honey of which is also sold at higher prices in local markets in most of South-East Asia (Gard Otis, *pers. com.* 2006).

Incorporation of Invasive Alien Species Issues and Policy Formation in Regional Mekong Basin Management

Although this report particularly looks at issues concerning invasive species within the Tonle Sap Biosphere Reserve, ultimately, efforts at invasive species control in the TSBR cannot be effective without concerted action throughout the Mekong Basin. More attention not only needs to be given to alien species in the Tonle Sap Biosphere Reserve, in Cambodia, but also for the entire Mekong Basin. The TSBR is a very important part of the basin due to its significant value as a habitat for rare and threatened species, as well as its function as a wet season nursery and habitat for many species of fish. It is a major contributor to inland fishery production in Cambodia. Thus, it is of special conservation importance.

To start with, as the threat of *Mimosa pigra* on this most important of floodplain habitats for Cambodia's inland fisheries is substantial, the spread may first be attempted to be contained at a local level. After a control programme has been underway for some time in the TSBR, it may result in the threat of *Mimosa pigra* and other invasive species receiving more attention and convincing more people of the need to manage the introduction and spread of alien species, so that strategies can begin to be developed on a larger, regional scale, *i.e.* an integrated strategy on alien and invasive species control for all Mekong basin countries.

At a regional level, as the assessment of the status and distribution of exotic species and their impact becomes more meaningful, more efficient initiatives to halt the spread of invasive species throughout the Mekong basin can be initiated. For *Mimosa pigra*, which is already clearly a regional threat, a programme of biocontrol throughout the basin could be initiated.

Not only must plans be developed to deal with the invasives causing problems at present, but strategies must be implemented to reduce the risk of future introductions of a particularly aggressive invasive species. To this end, risk assessments need to be carried out, as a type of obligatory environmental impact assessment, for any proposed introduction of an exotic species. Often business or development plans (even eco-initiatives, such as those stimulating production of biofuel crops) select fast growing, extremely tough species that can grow under nearly all conditions and have very few biological enemies, *i.e.* species that are also likely to be very troublesome invasives. The placement of restrictions in the form of bans on trade and translocation of certain potentially invasive species of animals, plants and fish is something which requires attention, once the political environment is favourable to seriously implement policy, legislature and enforcement regarding the control of invasive species.

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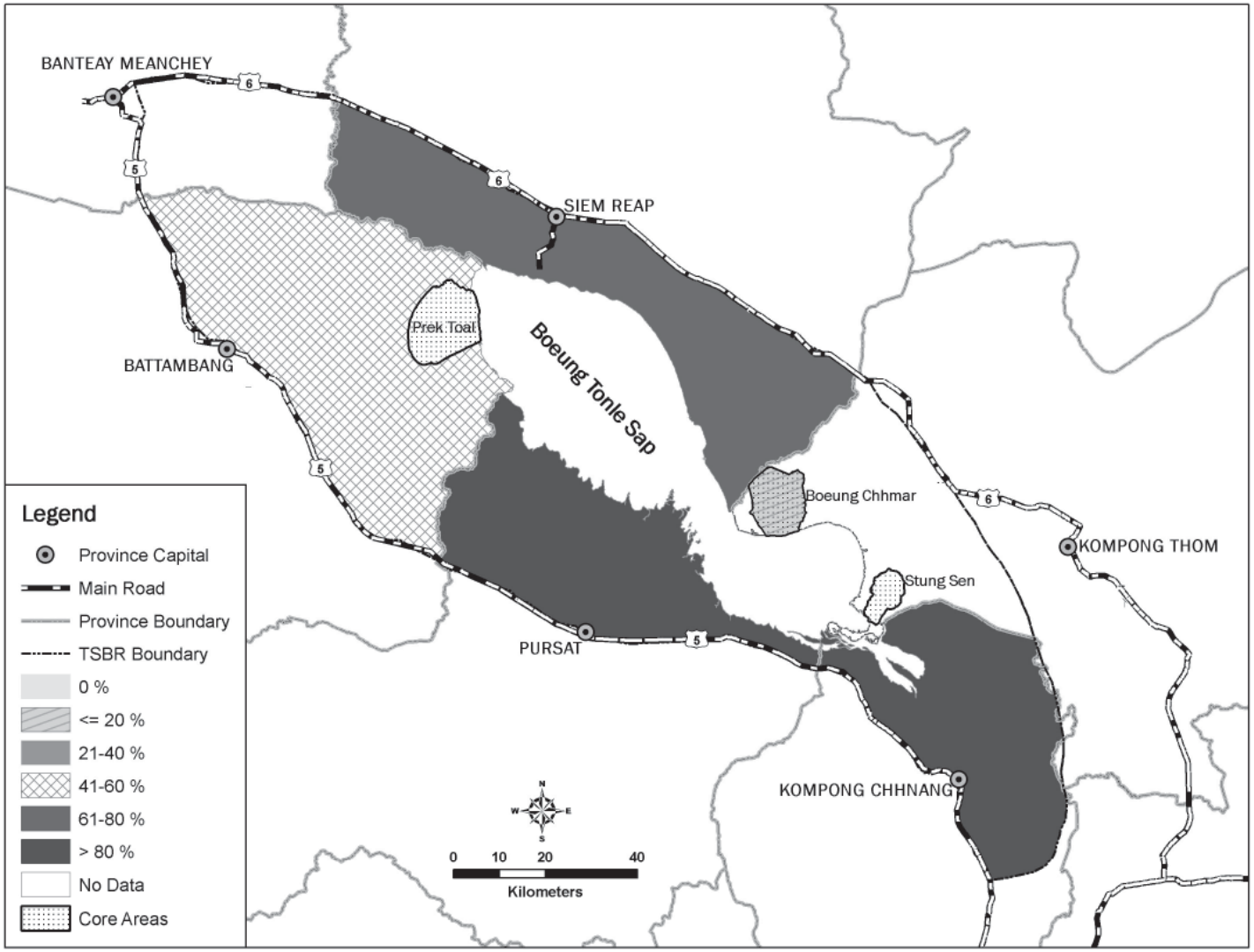
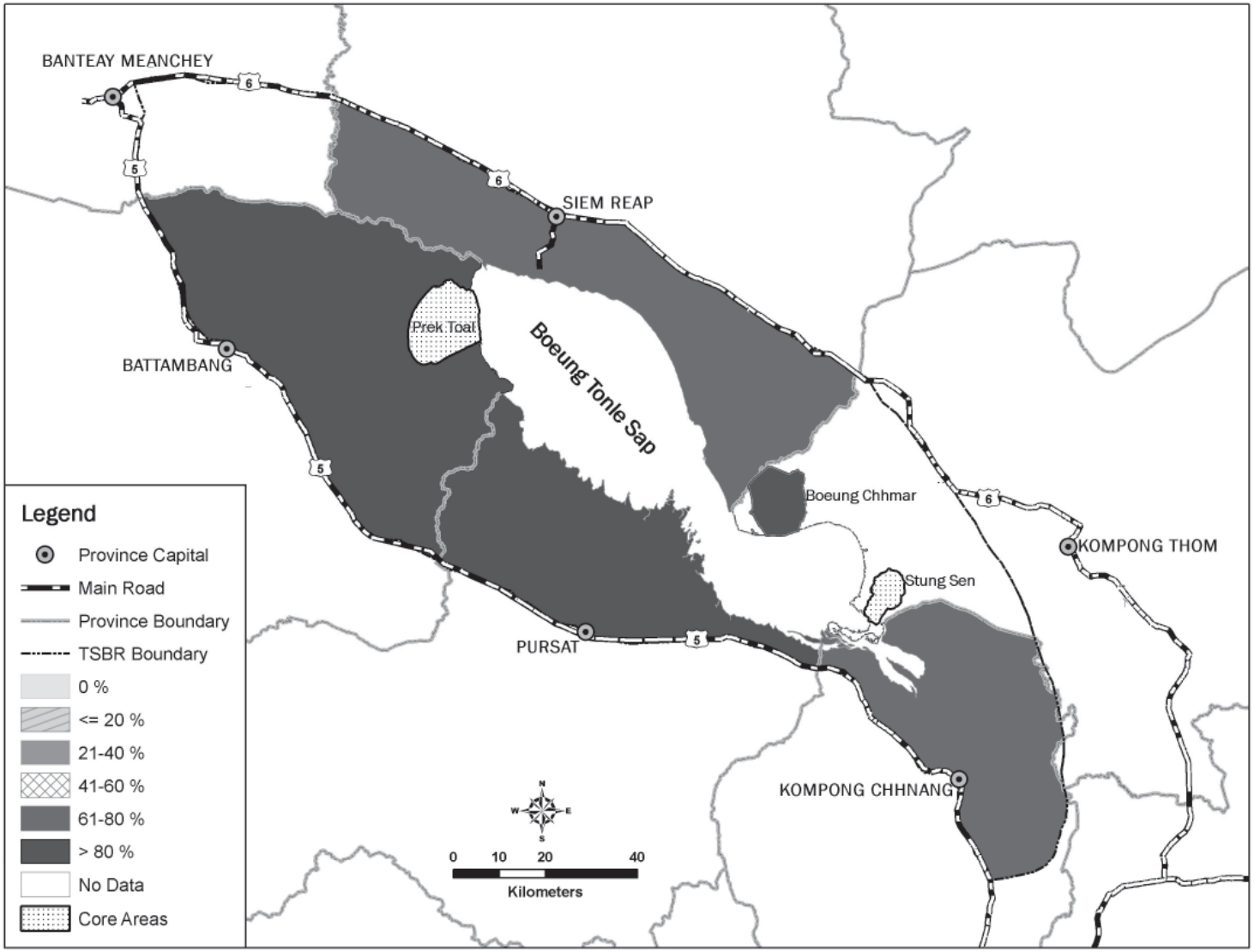
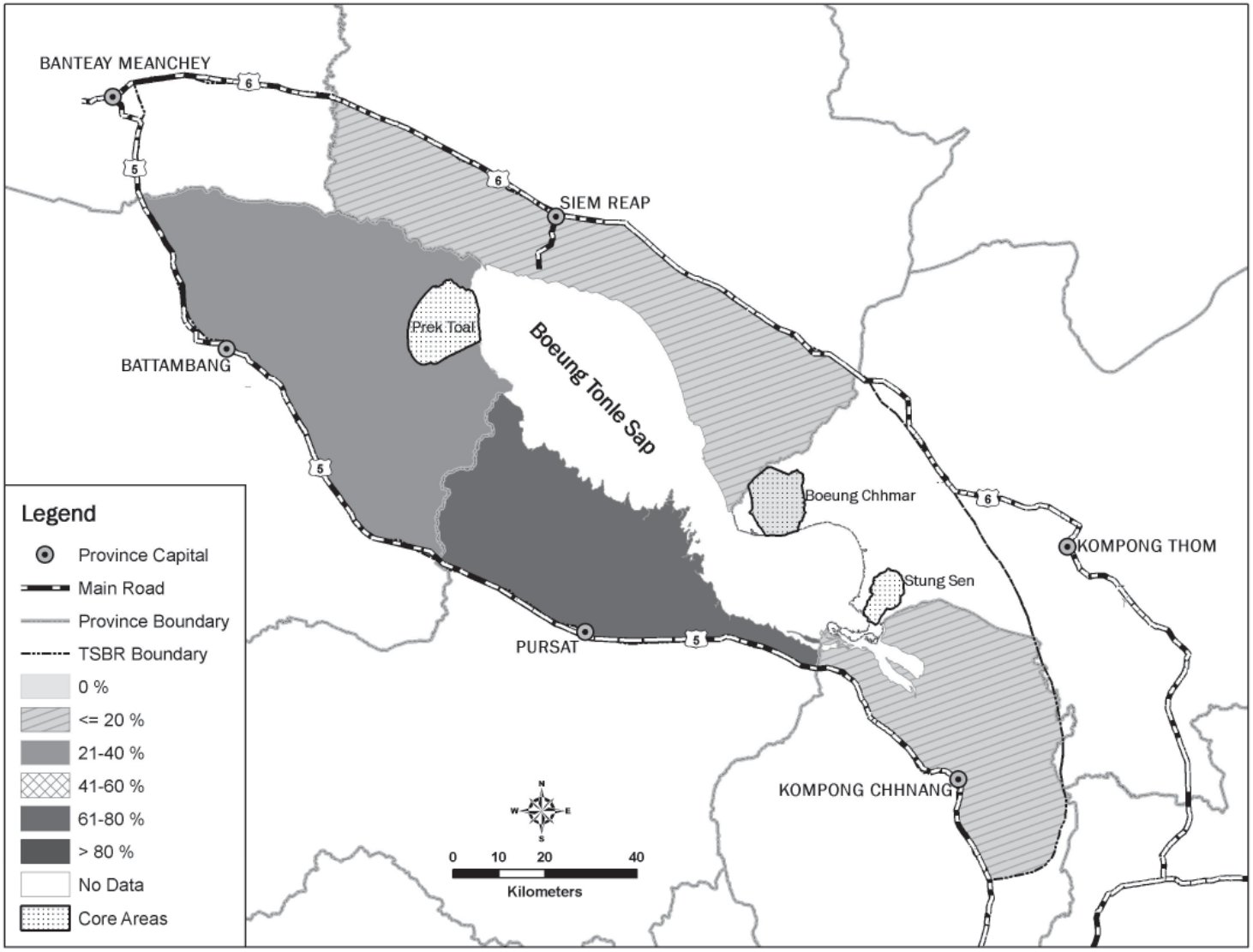
Appendix A: Maps of Species Abundance Measured as Percentage Response per Species in Questionnaires by Province or Area Surveyed



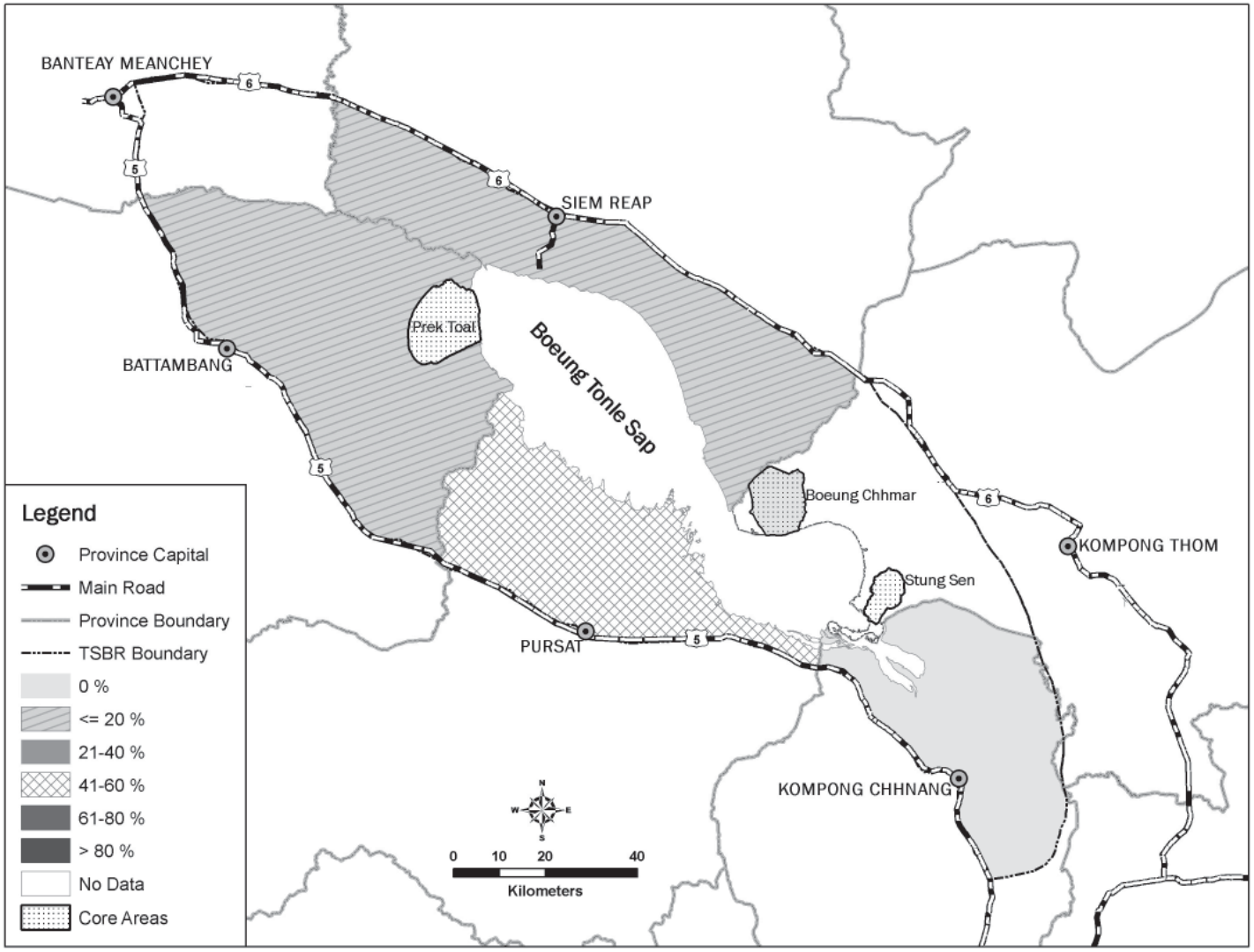
Map showing percentage of respondents mentioning **Giant Mimosa (*Mimosa pigra*)** as occurring in their area, aggregated by province



Map showing percentage of respondents mentioning **Water Hyacinth (*Eichhornia crassipes*)** as occurring in their area, aggregated by province



Map showing percentage of respondents mentioning **Mimosa spp. (*Mimosa pudica* or *Mimosa invisa*)** as occurring in their area, aggregated by province



Map showing percentage of respondents mentioning **Seedbox (*Ludwigia hyssopifolia*)** as occurring in their area, aggregated by province

Appendix B: Exotic Species Questionnaire

បញ្ជីសំណួរ

សំរាប់ប្រមូលទិន្នន័យ និងពត៌មានប្រភេទចំណូលស្រុក

<u>សូមថ្លែងអំណរគុណចំពោះការបំពេញបញ្ជីសំណួរនេះ</u>

អង្គការសមាគមអភិរក្សសត្វព្រៃថ្មីៗនេះកំពុងធ្វើការសិក្សាស្រាវជ្រាវអំពីប្រភេទចម្លែក និងប្រភេទចំណូលស្រុក នៅក្នុងនិងជុំវិញបឹងទន្លេសាប។ ប្រភេទចម្លែក គឺមានន័យថា ពពួកសត្វនិងរុក្ខជាតិចម្លែក ដែលបានចូលមកប្រទេសកម្ពុជា នា ពេលថ្មីៗនេះ រឺកើតមានដោយខ្លួនឯង ។ ប្រភេទទន្ទ្រានជាប្រភេទចម្លែក ដែលប្រកួតប្រជែងដោយផ្ទាល់ រឺទន្ទ្រានដើម្បីបំផ្លាញ រឺជំនួសប្រភេទដែលជាប្រភេទដើម។ តាមរយៈសំនួរនេះយើងសង្ឃឹមថានឹងអាចស្វែងយល់បន្ថែមទៀតអំពីស្ថានភាពប្រភេទចម្លែក ដែលកើតមានរឺអាចមានសក្តានុពល កើតមានជុំវិញតំបន់បឹងទន្លេសាប ហើយថាតើវាអាចជាប្រភេទទន្ទ្រាន រឺជាកត្តាចម្លែក រឺអត់ ហើយ ថាតើចាំបាច់ត្រូវមានវិធានការ គ្រប់គ្រងបែបណា។

សូមមើលក្រដាស់អត្តសញ្ញាណប្រភេទ ហើយបំពេញនៅក្នុងបញ្ជីសំនួរនេះ ចំពោះប្រភេទដែលអ្នកស្គាល់នៅក្នុងបឹង ទន្លេសាប បើអ្នកត្រូវការសរសេរលំអិតបន្ថែមសូមបន្តទៅទំព័រចុងក្រោយ។ ប្រសិនបើអ្នកបំពេញសំណួរនេះ ដោយមានការជួយ ពីអ្នកផ្សេងទៀត ត្រូវបំពេញឈ្មោះអ្នកទាំងនោះ ហើយកត់ត្រាចម្លើយលំអិតអំពីពត៌មានផ្ទាល់ខ្លួន ក្នុងទំព័រទី ១ ។ ប្រសិនបើអ្នកស្គាល់ប្រភេទចម្លែក ដែលកើតមាននៅក្នុងតំបន់បឹងទន្លេសាប ប៉ុន្តែមិនមាននៅក្នុងតារាង សូមបំពេញបន្ថែមនៅក្នុងតារាងបញ្ជីនេះ ។
យើងខ្ញុំសូមថ្លែងអំណរគុណយ៉ាងជ្រៅលជ្រៅចំពោះ ការឆ្លើយសំនួររបស់លោកអ្នក ក្នុងការស្រាវជ្រាវនេះ ពត៌មានដែលទទួលបាន

ពីបញ្ជីសំណួរនេះ នឹងប្រើប្រាស់ដើម្បីទទួលបាននូវបញ្ជីប្រភេទចម្លែក និងប្រភេទដែលទន្ទ្រាន ក្នុងបឹងទន្លេសាប ហើយនឹងការពិពត៌នា អំពីការប្រើប្រាស់របស់វា ប្រសិនបើមាន ។

កាលបច្ឆេទចុះសម្ភាសន៏: ថ្ងៃទី.....ខែ.....ឆ្នាំ: 200....., ម៉ោង: .....
ឈ្មោះអ្នកចុះសម្ភាសន៏: ....., ☐ ប្រុស ☐ ស្រី
តួនាទី :..... អង្គការ.ស្ថាបន៏:.....
លេខទូរស័ព្ទ : .....

អ្នកផ្តល់ពត៌មាន: .....☐ ប្រុស ☐ ស្រី មុខរបរ.....
.....☐ ប្រុស ☐ ស្រី មុខរបរ .....
.....☐ ប្រុស ☐ ស្រី មុខរបរ .....

១- តើអ្នករស់នៅ នៅតំបន់បឹងទន្លេសាបអស់រយៈពេលប៉ុន្មានឆ្នាំហើយ ? How long have you been in the Tonle Sap Biosphere Reserve?
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២- តើតំបន់មួយណា នៃបឹងទន្លេសាបដែលអ្នកតែងតែចុះទៅកាន់ទីនោះ? Which areas of the lake do you regularly visit?

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៣-តើសកម្មភាពអ្វីខ្លះដែលអ្នកអនុវត្តនៅក្នុងតំបន់បឹងទន្លេសាប? What kind of activities do you undertake inside the Tonle Sap Biosphere Reserve?

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ឈ្មោះប្រភេទ Species Name	តើអ្នកឃើញប្រភេទចំណូលស្រុកនេះ នៅឆ្នាំណា នៅតំបន់របស់អ្នក? When did you first observe it in your area?	តើប្រភេទនេះមាននៅក្នុងតំបន់មួយណា នៃបឹងទន្លេសាប? សូមគូសប្រអប់ខាងក្រោម ។ In which areas is it found?									តើចំនួន ឬទំហំរបស់វាកំពុង កើនឡើង ថយចុះ នៅដដែល ? គូសលើណាមួយប្រអប់ខាងក្រោម How have numbers changed in time?		
		ស្ទឹង-ទន្លេ River	បឹង-ត្រពាំង Lake	ប្រឡាយ Channel	តំបន់ដីគោក Upland	តំបន់ទំនាប Lowland	តំបន់ព្រៃលិចទឹក Flooded Forest	តំបន់វាលស្មៅ Grassland	តំបន់កសិកម្ម Agricultural Area	តំបន់វារីវប្បកម្ម Aquaculture ponds	ចំនួន ឬទំហំ កើនឡើង Increase	ចំនួន ឬទំហំ ថយចុះ Decrease	ចំនួន ឬទំហំគ្មានប្រែប្រួល No change

ឈ្មោះប្រភេទ Species Name	តើប្រភេទនេះមានប្រយោជន៍អ្វីខ្លះ ដល់អ្នក ឬអ្នកជង់ខែ ឬ រុក្ខជាតិ សត្វ និងត្រី ? What are the positives of having this species in the area for people as well as for other plants, animals, fish?	តើប្រភេទនេះមានផលប៉ះពាល់អ្វីខ្លះ ដល់អ្នក ឬអ្នកជង់ខែ ឬ រុក្ខជាតិ សត្វ និងត្រី ? What are the negatives of having this species in the area for people as well as for other plants, animals, fish?	តើអ្នកយល់យ៉ាងណា បើប្រភេទនេះត្រូវគេបំផ្លាញពីតំបន់អ្នក? If you had a choice would you keep this species or remove it?

ពត៌មានបន្ថែមស្តីពីការប្រែប្រួលនៃប្រភេទសំខាន់ៗ នៅក្នុងតំបន់បឹងទន្លេសាប

(សូមធ្វើការពត៌នាលំអិតនៅការផ្លាស់ប្តូរ ដែលអ្នកបានសង្កេតឃើញ ដោយលើកឡើងនូវឈ្មោះប្រភេទទាំងនោះ)

Additional information on major species changes in the Tonle Sap Lake
(please describe in detail the change that you have observed, stating the species involved)

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Appendix C. Exotic Species Reference List for Use with Questionnaire

	វក្ខជាតិ	Transliteration	English Name	Scientific Name	Picture
	Plants				
1	ដង្កិត	Dâng hët	Candlebush	*Cassia alata*	
2	កំពោក	Kâmphlaôk	Water hyacinth	*Eichhornia crassipes*	
3	ល្មុងខ្វង	Lhông kwâng	Purging nut	*Jatropha curcas*	
4	ស្មៅស្វាច់ទឹក	Smao smach tük	Seedbox	*Ludwigia hyssopifolia*	
5	ព្រៃកួបយក្ស , បន្ទាយួន	Prèah khlâb yiëk / Bânla yourn	Giant mimosa	*Mimosa pigra*	
6	ព្រៃកួបសំពៈ បន្ទាស្ទិត	Prèah khlâb sâmpèah	Mimosa	*Mimosa pudica or M. invisa*	
	Reptiles				
7	ក្រពើគុយបា	Kropeau kuba	Cuban crocodile	*Crocodylus rhombifer*	
8	គន្ធាយចិន	Kontjeh tjun	Chinese softshell turtle	*Pelodiscus sinensis*	yes
9	អណ្តើកអាមេរិច		American painted turtle	*Pseudemys scriptac*	yes
	Molluscs				
10	ខ្យងមាស		Apple snail	*Pomacea sp.*	yes
	Fish				
11	ត្រីអណ្តែងអាហ្វ្រិក	Trey andaing afrik	African catfish	*Clarias gariepinus*	
12	ត្រីកាបសាមញ្ញ	Trey carp samahn	Common carp	*Cyprinus carpio*	
13	ត្រីពណ្តើកាបប្រាក់	Trey carp sar	Silver carp	*Hypothalmichthys molitrix*	

14	ត្រីកាបក្បាលធំ	Trey carp kbal thom	Bighead carp	*Hypothalmichthys nobilis*	
15			Suckermouth catfish	*Hypostomus plecostomus*	yes
16	ត្រីទីឡាបព្យាឆ្នូត	Trey tilapia chhnoht	Nile tilapia	*Oreochromis niloticus*	
17	ត្រីទីឡាបព្យាខ្មៅ	Trey tilapia khmao	Mozambique tilapia	*Oreochromis mossambicus*	
	Crustaeceans				
18			Louisiana crayfish	*Procambarus clarkii*	yes
	Insects				
19	ឃ្មុំអឺរុប	Khmom Ürop	European honeybee	*Apis mellifera*	

Appendix D. Full list of exotic species (potential invasives) treated in this report

Common Species Name	Scientific Name	Presence in TSBR
Plants		
Candlebush	*Cassia alata*	Planted near villages
Silkcotton Tree	*Ceiba petandra*	Reported
Siam Weed	*Chromolaena odorata*	Not reported
Water Hyacinth	*Eichhornia crassipes*	Abundant
Purging Nut	*Jatropha curcas*	Planted near villages
Peruvian Primrose	*Ludwigia peruviana*	Reported
Seedbox	*Ludwigia hyssopifolia*	Reported
Giant Mimosa	*Mimosa pigra*	Common in some areas
Giant Sensitive Mimosa	*Mimosa invisa*	Reported
Sensitive Mimosa	*Mimosa pudica*	Reported
Water Lettuce	*Pistia stratiotes*	Common
Para Grass	*Brachiaria mutica*	Common in some areas
Hippo Grass	*Echinochloa stagnina*	Common in some areas
Cutgrass	*Leersia hexandra*	Reported
Mission Grass	*Pennisetum polystachion*	Not reported
Reptiles		
Hybrid Crocodiles	*Crocodylus rhombifer / Crocodylus porosus* x *Crocodylus siamensis*	In vicinity (*e.g.* Siem Reap)
Chinese Softshell Turtle	*Pelodiscus sinensis*	Not reported
Red-eared Slider	*Trachemys scripta elegans*	Not reported
Molluscs and Amphibeans		
Apple Snail	*Pomacea* spp.	In vicinity (Mekong) and unconfirmed reports from Pursat and Battambang
North American Bullfrog	*Rana catesbiana*	Not reported
Crustaceans and Insects		
Louisiana crayfish	*Procambarus clarkii*	Not reported
European honeybee	*Apis mellifera*	Not reported
Mammals		
Black Rat	*Rattus rattus*	Reported
Fish		
Chinese False Gudgeon	*Abottina rivularis*	Not reported
	Acheilognathus barbatulus	Not reported
Chinese Bitterling	*Acheilognathus sinensis*	Not reported
Arapaima	*Arapaima gigas*	Not reported
Japanese Eel	*Anguilla japonica*	Not reported
Goldfish	*Carassius auratus*	Not reported
Mrigal	*Cirrhinus cirrhosus*	Not reported
African Catfish	*Clarias gariepinus*	Individual fish reported; Juveniles have been found in the Mekong, indicating there may be breeding populations
Pacu	*Colossoma macropomum*	Not reported
Grass Carp	*Ctenopharyngodon idella*	Not reported
Common Carp	*Cyprinus carpio*	Reported
Mosquito Fish	*Gambusia affinis*	Not reported
Catla	*Catla catla*	Not reported

Barbel Steed	*Hemibarbus labeo*	Not reported
Spotted Steed	*Hemibarbus maculatus*	Not reported
Silver Carp	*Hypopthalmichthys molitrix*	Reported
Bighead Carp	*Hypopthalmichthys nobilis*	Unconfirmed reports from fishermen
Suckermouth Catfish	*Hypostomus plecostomus*	Unconfirmed report from a fisherman
Rohu	*Labeo rohita*	Reported
Brown Bullhead	*Ictalurus nebulosus*	Not reported
Channel Catfish	*Ictalurus punctatus*	Not reported
	Metzia lineata	Not reported
Oriental Weatherfish	*Misgurnus anguillicaudatus*	Not reported
Blue Tilapia	*Oreochromis aureus*	Not reported
Mozambique Tilapia	*Oreochromis mossambicus*	In vicinity (Mekong around Phnom Penh)
Nile Tilapia	*Oreochromis niloticus*	In vicinity (Tonle Sap and Mekong River)
Red-bellied Pacu	*Piaractus brachypomus*	Unconfirmed reports from fishermen
Guppy	*Poecilia reticulata*	Not reported
Sailfin Molly	*Poecilia velifera*	Not reported
Stone Moroko	*Pseudorasbora parva*	Not reported
	Puntius semifasciolatus	Not reported
Redbreast Tilapia	*Tilapia rendalli*	Not reported
Green Swordtail	*Xiphophorus helleri*	Not reported
Southern Platyfish	*Xiphophorus maculatus*	Not reported

Appendix E. Useful Addresses and Contacts for Follow-up Projects

Internet Links to Information on Invasive Species Relevant to the Tonle Sap Biosphere Reserve

Databases:

http://www.issg.org/database/welcome/
Database on the most serious global **invasive species** known. Produced by experts of the IUCN Invasive Species Specialist Group under the Global Invasive Species Programme (GISP).

http://filaman.ifm-geomar.de/search.php
A global information system on **fish**, with details on country-wise introductions for fish used in aquaculture, their establishment in the wild and ecological effects. Developed and maintained by WorldFish Center and the Food and Agriculture Organization (FAO), among others.

http://www.hear.org/pier/
Website detailing the results of a risk assessment carried out for many of the worlds invasive and potentially invasive **plants** that pose a threat to Pacific Island ecosystems. Describes the origin and biological characteristics of all the plants treated and lists previous introductions and cases of invasiveness.

Conventions:

http://www.biodiv.org/
Website of the Convention on Biological Diversity. Treaty signed by 150 governments, including Cambodia, at the 1992 Rio Earth Summit. It stipulates the need to prevent the introduction of, control or eradicate alien species that threaten ecosystems. It provides guidelines and recommendations for participating countries in order to manage their invasive species problems.

Ongoing Programmes and Projects Addressing the Issue of Invasive Species in Cambodia

Aquaculture of Indigenous Mekong Fish Species (AIMS) Component: has been created in order to carry out research on economically feasible and attractive aquaculture systems using indigenous Mekong fish species that may complement or replace the use of exotic species for culture purpose in the Mekong basin.
Contact: Mr. Ouk Vibol
National Component Director, MRC-AIMS
IFRIDI, Fisheries Department, #186 Norodom Boulevard

Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme: Through partnership, the MWBP will be developing and facilitating the implementation of a strategy to combat Invasive Alien Species affecting wetlands in the Lower Mekong Basin.
http://www.mekongwetlands.org

Tonle Sap Environmental Management Project: was initiated in 2003 in order to develop the capacity for natural resource management coordination and planning, community based natural resource management and biodiversity conservation.
http://www.tsbr-ed.org/en/

Government Agencies Working on Biodiversity Issues in the TSBR

Tonle Sap Biosphere Reserve Secretariat: formed under the Cambodia National Mekong Committee (CNMC) at the time of the official establishment of the Tonle Sap Biosphere Reserve in 2001. The role of the TSBR Secretariat is to facilitate the ongoing process of coordination, or mutual compromise and benefit, among stakeholders.

Department of Nature Conservation and Protection: under the Ministry of Environment (MoE) conducts surveys, implements environmental projects, and is responsible for the site management of the TSBR.

Fisheries Administration: under the Ministry of Agriculture, Forestry and Fisheries (MAFF). Overseas fishing activities on the Lake.

Non-Governmental Organizations Working on Biodiversity Issues in the TSBR

Wildlife Conservation Society (WCS): started support of waterbird conservation activities in Prek Toal in 2000 and has over the years been building on this conservation programme.
Cambodia@wcs.org

Osmose: started work on waterbird conservation in Prek Toal in 1997 and has implemented an ecotourism project around the large waterbird colonies and a handicrafts project in Prek Toal village.
Contact: Francoise Bricout
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osmose@online.com.kh

WCS

WILDLIFE CONSERVATION SOCIETY

CAMBODIA PROGRAM