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USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin

Fisheries Report

February 2014


"A variety of fish species are caught by people in Thuan Hoa commune, Vietnam, for both their household consumption and commercial value." by Ienkate S./DAI

USAID Mekong ARCC
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The USAID Mekong ARCC project is a five-year program (2011-2016) funded by the USAID Regional Development Mission for Asia (RDMA) in Bangkok. The larger project focuses on identifying the environmental, economic, and social effects of climate change in the Lower Mekong Basin (LMB), and on assisting highly exposed and vulnerable rural populations in ecologically sensitive areas adapt to climate change impacts on agricultural, fisheries, livestock, ecosystems, and livelihood options.

This phase of the project was led and implemented by ICEM, and focuses specifically on predicting the responses of the key livelihood sectors—agriculture, livestock, fisheries, rural infrastructure and health, and natural systems—to the impacts associated with climate change, and offering broad-ranging adaptation strategies to the predicted responses.

This volume is part of the USAID Mekong ARCC study set of reports:

1. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Summary
2. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Main Report
3. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Agriculture
4. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Livestock
5. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Fisheries
6. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Non-Timber Forest Products and Crop Wild Relatives
7. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Protected Areas
8. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Socio-economic Assessment

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ABBREVIATIONS AND ACRONYMS

3S River Basins	Sekong, Sesan and Srepok River Basins
ACIAR	Australian Centre for International Agricultural Research
CAM	Climate Change Adaptation and Mitigation Methodology
CC	Climate Change
FAO	Food and Agriculture Organization of the United Nations
g/L	Grams per liter
ha	Hectare
ICEM	International Centre for Environmental Management
km	Kilometer
Lao PDR	Lao People's Democratic Republic
LMB	Lower Mekong Basin
m^3/s	Cubic Meter per Second
Mekong ARCC	USAID Mekong Adaptation and Resilience to Climate Change Project
mm	Millimeter
MRC	Mekong River Commission
MT/yr	Million Tonnes per year
NTFPs	Non-Timber Forest Products
PAs	Protected Areas
SLR	Sea Level Rise
sq km / km^2	Square Kilometer
USAID	United States Agency for International Development
VA	Vulnerability Assessment
WFP	United Nations World Food Programme
WWF	World Wide Fund for Nature

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"In addition to the key families of fish harvested commercially in the Mekong Vietnamese delta, families of shrimps, crabs, and mollusks are economically important in this ecozone." *by Ienkate S./DAI*

INTRODUCTION

USAID MEKONG ARCC PROJECT

The USAID Mekong ARCC project is a five-year program (2011-2016) funded by the USAID Regional Development Mission for Asia (RDMA) in Bangkok and implemented by Development Alternatives Inc. (DAI) in partnership with International Centre for Environmental Management (ICEM), and World Resources Institute (WRI). The project focuses on identifying the environmental, economic, and social effects of climate change in the Lower Mekong Basin (LMB), and on assisting highly exposed and vulnerable rural populations in ecologically sensitive areas increase their ability to adapt to climate change impacts on water resources, agricultural and aquatic systems, livestock, ecosystems, and livelihood options.

USAID Mekong ARCC includes five major technical tasks in addition to overarching program management. These are:

1. Regional Platform Partner and Knowledge Center;
2. Climate Change Impact and Adaptation Study;
3. Ecosystem and Community-based Adaptation Initiatives;
4. Valuing Ecosystem Services in Economic Planning for the Lower Mekong River Basin; and
5. Scaling-Up Successful Approaches.

CLIMATE CHANGE IMPACT AND ADAPTATION STUDY

The aim of the Climate Change Impact and Adaptation Study is to undertake a climate change vulnerability and adaptation study on the water resources, food security, livelihoods, and biodiversity of the Lower Mekong Basin (LMB). The study is led by ICEM and the study team is made up of 21 international and regional specialists.

The Climate Change Impact and Adaptation Study lays the foundation for the whole USAID Mekong ARCC project by providing the scientific evidence base for identifying highly vulnerable and valuable agricultural and natural systems assets in the LMB, defining adaptation options and priorities, and guiding the selection of focal areas for enhancing existing adaptation strategies and demonstrating and testing new approaches. The study focuses on five themes: i) agriculture; ii) capture fisheries and aquaculture; iii) livestock; iv) natural systems; and v) socio-economics.

The objectives of the Climate Change Impact and Adaptation Study are to take an ecosystems approach in:

1. **Identifying climate change impact and vulnerabilities** of the rural poor and their environment—water resources, food security, livelihoods, and biodiversity (fisheries and wildlife);
2. **Identifying hot spots in the LMB** to provide a scientific evidence base to guide the selection of pilot project sites;
3. **Defining adaptation strategies for the main threats** to inform and guide community- and ecosystem-based adaptation pilot projects; and
4. **Communicating the results** of the vulnerability assessment and adaptation planning.

The study has an LMB-wide perspective. It starts by analyzing basin-wide climate changes and vulnerabilities according to ecological and administrative boundaries. It takes the vulnerability and adaptation responses to the species and habitat level but still from a basin-wide view. Necessarily the adaptation strategies proposed provide broad guidance—the site-specific adaptation plans under subsequent project phases need to be developed with local communities and government with the benefit of local knowledge and tailored specifically to suit local conditions drawing from the tool box set out in the results of this study.

FISHERIES THEME

This report presents the results of the fisheries component of the USAID Mekong ARCC Climate Change Impact and Adaptation Study. It first provides an overview of the current state of the important capture fisheries and aquaculture systems in the LMB, focusing on those elements that are threatened by climate change. This report then presents a methodology and results for vulnerability assessments, carried out using a CAM approach, for six climate change hotspots (Chiang Rai, Khammoun, Gia Lai, Mondulkiri, Kien Giang, and Stung Treng). Having assessed these areas for capture fisheries and aquaculture vulnerability, adaptation approaches are discussed.

SECTION 1
FISHERIES AND AQUACULTURE BASELINE

Fisheries & aquaculture are vitally important for food and for the livelihoods of people of the LMB. Virtually all rural families in the Lower Mekong Basin are involved in fishing at some time of the year and small-scale capture fisheries remains a 'livelihood of last resort' for many rural families. Climate change will threaten the viability of these traditional and contemporary livelihoods.

This section presents an overview of the current state of the important capture fisheries and aquaculture systems in the Lower Mekong Basin, focusing on those elements that are threatened by climate change. This section of the report adopts an ecozone-approach perspective, describing each of these zones in terms of important fishing/aquaculture areas, species, systems used, tolerances and life cycles conditions, and trends, threats, and opportunities in each of the zones.

1 CAPTURE FISHERIES OVERVIEW

About 20 million hectares of wetlands (200,000 sq km) occur in the LMB (including all seasonally-inundated land and rice fields), 30% within the zone that is inundated by major floods (Hortle and Bamrungrach 2012). In Cambodia and the Vietnamese Delta, most of the wetland area is within the productive major flood zone, whereas in Thailand and Lao PDR most of the wetland area is classed as rainfed.

The biodiversity and productivity of the fishery is linked inextricably to the annual flood pulse and to the diverse range of natural habitats as well as some artificial habitats (such as rice fields and reservoirs). The flood pulse inundates terrestrial foods and liberates nutrients from sediment, supporting high primary productivity and in turn the food chains that fish depend upon. Most fish and other aquatic species migrate between feeding, spawning, and resting habitats.

The total LMB catch is thought to come mainly from the major flooded zone and rainfed habitats (primarily rice fields) in about equal quantities. Large waterbodies contribute a smaller but significant proportion of the total yield. Capture fisheries contributed about 1.9 million tonnes (Mt)/year out of a total inland fisheries yield of 2.6 Mt/year. This estimate is conservative as it does not take into account wastage and use in fish and animal feed, but still has a market value of US$3.9–7 billion. This is around 2% of the World's total marine & freshwater capture fishery. Despite a series of recent revisions, capture fisheries are still probably under reported in the statistics. For example, some countries do not include fish production from rice fields and seasonal wetlands in their inland fisheries statistics.

The number of fish species in the Mekong Basin is estimated to be between 500 and 1,200, and a high degree of within-species diversity exists. Some reports suggest that the number of fish species in the LMB may actually exceed 2,000 (Zalinge et al. 2003). The present estimates include known species while there are thought to be several hundred species that have yet to be discovered, particularly in the upper catchment areas. Additionally, some of the well-known lowland species may in fact comprise assemblages of several species (Kottelat et al. 2012). The fish fauna in the upper catchments areas is generally less diverse than in the lowlands. To some degree, this can be explained by the fewer habitat types found in these upland areas.

The fishes of the LMB can be grouped according to their ecology and migration behavior. The 'Black Fish' group includes those species with limited lateral migrations from the river onto the floodplains and limited longitudinal migrations upstream or downstream. They tend to not leave the floodplains and wetlands, and spend the dry season in pools in the rivers or floodplains. This group includes the Chanidae (snakeheads), Clariidae and Bagridae (catfishes), and Anabantidae (including the climbing perch). Most Black Fish species are able to survive poor water quality conditions (low DO, low pH, high turbidity, and high ammonia) and are able to withstand harsh dry season environments, including high temperatures and anoxic conditions. Their limited migratory habits make them less vulnerable to wetlands fragmentation.

The 'White Fish' group undertakes long-distance migrations, in particular between lower floodplains and the Mekong mainstream. This group includes many cyprinids (e.g., *Henicorhynchus* spp. and *Cirrhinus* spp.) and also many Pangasiidae catfishes. A large proportion of the total fish catch in the Mekong Basin is from this group of fishes. Some of these species are known to migrate long distances, e.g., *Pangasius krempfi,* which migrates many hundreds of kilometers from the South China Sea to Northern Lao PDR where it spawns (Kottelat et al. 2012).

Most White Fish species require higher water quality conditions in terms of DO and alkalinity. They are more vulnerable to increased temperatures, especially at maturation and fry stages. Many of these species are highly migratory some crossing international borders, thereby constituting trans-boundary resources. According to Baran & Mith (2007), around 87% of Mekong fish species are migratory and 50% of the total catch is made up of long-distance migratory species.

Broad classification can include three other groups: 'Grey Fish', 'Estuarine Fish' and 'Exotic Fish'. Grey Fish do not spend the dry season in floodplain pools nor do they undertake long distance migrations. When the flood recedes they tend to leave the floodplain and spend the dry season in local tributaries. This group includes the *Mystus* catfishes. Estuarine Fish are found in the lower reaches of the river system. The sea bass (*Lates calcarifer*) is an example of this group of fish. As a result of accidental introductions a number of exotic fish species, such as the common carp (*Cyprinus carpio*) and rohu (*Labeo rohita*), have become established and now form feral populations in parts of the LMB. In addition to the fish groups describe above, there are a large number of aquatic animals that are important for consumption and income generation, particularly among the poorer people of the LMB. These include crustaceans, amphibians, mollusks, and edible aquatic insects.

Virtually all fish species caught from the fishery have commercial value**.** The Siamese mud carp**,** *Henicorhyncus siamensis,* can be singled out due to its high importance for fish paste production in several LMB countries. Other commercially important species/genera include: *Channa sp., Puntius sp., Leptobarbus hoevenii, Pangasias sp., Wallago attu, Kryptopterus aponogon, Notopterus sp., Anabas testidudineus, Oxyeloetris marmorata, Mystus sp., Clarias sp., Trichogaster sp*., *Clupea thibaudeaui, Thynnichthus thinnoides, Labeo sp., Cirrhinis microlepis, Hilsa sp., Osteochilus melanopleura,* and *Sciaenidae sp.* Even poisonous fish species such as *Tetronodon* spp. can be consumed and have a market value.

The regional demand for wild, high-value fish is high. In many markets, wild fish are now more valuable than cultured fish. Capture of low-value fish for fish and animal feed remains an important driver of intensive aquaculture but one that may limit further growth of the industry. Table 1 below highlights the importance of fish for consumption from capture fisheries in the LMB and extrapolates these figures using population levels to arrive at an estimate of annual capture fisheries production.

Table 1: Fish consumption rates in the LMB countries

	Cambodia	Lao PDR	Thailand	Vietnam	Average / Total
Fish consumption (kg) /capita/year	36.8	28.6	29.1	39.0	33.6
Extrapolated fish production (tonnes/year)	587,004	208,503	911,485	852,823	2,559,815

The Mekong fishery is dominated by the use of small-scale gears operated by individuals. At least 80 categories of gear have been identified in Cambodia alone. Women are actively engaged in fisheries-related activities throughout the LMB, particularly on the post-harvest side. Children are also involved in fishing, mainly for homestead food security. Catches tend to show seasonal trends related to water level and flow and with fish migrations. The highest catches are made at the beginning of the wet season (June–July) when many fish are migrating to breeding grounds and at the end of the wet season (November–December) when fish are migrating off flooded areas and moving towards dry-season refuges. Processed fish products such as fish paste, etc. are important during low fish production periods.

Major changes in annual catches are largely the result of variation in the available biomass of fish, which is heavily influenced by the extent of annual flooding and by the condition of the environment. The overall trend is not clear. MRC fish catch data collected from 15 sites over a number of years showed that seven had a declining trend, six an increasing trend, and two were stable during early months of the study when catches are typically low.

The Cambodian Fisheries Administration monitoring of the Dai fishery on the Tonle Sap (now in its 8th year) is a useful proxy for the general health of the Tonle Sap/Mekong system. The study shows a fairly strong correlation between water levels, flood durations, and fish yields. The available data do not support the view that there is a decline in the total production from the fishery. However, there are clearly serious declines in the stocks of certain species, including some of the giant fish species such as *Catlocarpio siamensis*. In addition, the average size of some species is reducing suggesting stocks are being over fished.

1.1 CLIMATE CHANGE THREATS TO CAPTURE FISHERIES

1.1.1 INCREASED TEMPERATURES

Increased temperatures are likely to affect fisheries in the following ways. Virtually all fish species as well as other aquatic animals are poikilothermic and their behavior is determined largely by the temperature of their environment. Any changes to habitat temperature will influence metabolism, growth rate, production, reproduction (seasonality and efficacy), recruitment, and susceptibility to toxins and diseases (FAO 2008). Little is known about the vast majority of the Mekong's fish species preferred temperature ranges and tolerances. Increasing temperatures could affect the natural ranges of some species resulting in changes in biodiversity abundance in some areas. Some species may extend their natural range northwards while other species ranges may retreat to upland areas. Disease ranges may also be extended. Higher temperatures could allow invasive species to compete more effectively with indigenous species and become established in waterbodies. Lower dissolved oxygen levels in water as temperatures rise may favor some Black Fish species over White Fish species, resulting in a shift in the balance of some fisheries. Increased phytoplankton populations could stimulate productivity of some fisheries but harmful algal blooms affecting fish survival or production could also result. The melting of glaciers is not likely to result in major changes to river flows in the LMB and so may have limited effects on the region's fisheries.

1.1.2 CHANGES IN RAINFALL

Changes in rainfall patterns are likely to affect fisheries in a number of ways. Erratic rainfall could affect the flood pulse cycle of the Mekong River, affecting the hydrology of the Tonle Sap Great Lake and corresponding fish migrations, reproductive success, and fish production. Shifting rainfall patterns including longer dry periods could affect the survival of fish through the dry season, particularly in upper floodplain areas, which are already under pressure from hydropower development, over fishing, and agriculture intensification. Increased erosion in catchments could affect river floodplain water quality reducing fish reproductive success and productivity. Increased runoff from inland areas could result in the flooding of coastal lowlands, altering salinities, and increasing fluvial deposition.

1.1.3 INCREASED CO_2 LEVELS

Increased CO_2 levels are likely to affect fisheries through the acidification of some waterbodies. This may affect the abundance of some White Fish species but many Black Fish species are already well adapted to survive low pH conditions. In the Mekong Delta area, the capacity of mollusks to form shells may be compromised.

1.1.4 INCREASED SEA LEVELS

Sea level rise (SLR) is likely to affect coastal fisheries through the migration of coastal mangrove areas northwards. This will allow the establishment of brackish water species further inland than is presently the case. However, the loss of coastal brackish water and wetland areas will occur in the lowest areas. The loss of some freshwater/brackish water coastal lagoons may also result.

1.1.5 STORM INTENSITY AND FREQUENCY

Storm intensity and frequency could result in saline inundation of freshwater areas farther inland, the increased erosion of some areas such as sand bars and islands, and changes in delta erosion and accretion patterns.

1.1.6 OTHER THREATS TO CAPTURE FISHERIES

A number of other factors not directly related to climate change threaten the future of the fisheries of the LMB. The largest threats to the diversity and productivity of the fishery are considered to be the alteration of river morphology caused by hydropower projects, or the excavation of channels to aid navigation and the extraction of ground and surface waters for irrigation (Kottelat et al. 2012). Plans for cascades of dams, as planned for the Nam Ngum, could be catastrophic for tributaries' fisheries diversity and productivity.

Periodically there are news reports of plans to divert water from tributaries in Lao PDR, under the Mekong, or from the mainstream Mekong to the drier northeastern part of Thailand for irrigation purposes[1]. If such projects come to fruition then their impact on fisheries could be considerable. Other threats include the following:

- Physical barriers constraining the migration of fish species
- Overfishing, resulting from increased numbers of fishers and size of gears
- Loss of productivity through habitat destruction/change
- Aggressive fishing methods, e.g. explosives
- Radical changes in landuse patterns that change runoff patterns from upland areas. The increase in the number of land concessions and vast rubber plantations is a concern
- Establishment of exotic fish populations from aquaculture escapees
- Water pollution from urban centers, industry, and intensive aquaculture
- Fragmentation of the river and floodplain fisheries. Loss of connectivity
- Climate change mitigation for other sectors could have adverse effects on the LMB fisheries

[1] http://www.newsmekong.org/thailand_water_diversion_plans_lead_to_trouble_-_activists

2 AQUACULTURE OVERVIEW

Aquaculture has been a long established activity in parts of the LMB, particularly on the Tonle Sap and the Delta. However, over the past 30 years, the aquaculture sector has boomed. The latest production estimates of around 1.9 Mt are now similar to the production levels from the capture fisheries and look set to surpass it over the next few years. Much of this production (1.6 Mt) is from intensive catfish culture (particularly *Pangasius* spp.) and shrimp farms, and is destined for export. Large areas of the Mekong Delta are now under *Pangasius* culture[2].

Traditionally, many aquaculture systems have been dependent upon the capture fisheries for wild-caught juveniles for culture and low-value fish for feed. However, the development of hatcheries and the availability of commercial fish feeds throughout the LMB have reduced this dependence on wild resources. Semi-intensive and extensive aquaculture systems often include a significant proportion of wild fish in the harvests.

Current trends in aquaculture include: a reduction in use of low-value fish for fish feed; an increase in the use of hatchery-reared juveniles; and the culture of 'new' fish species/strains, e.g., 'Tub Tim' fish (*Oreochromis* spp.). Effective networks of fish seed producers and distribution have emerged in Thailand and Vietnam and are emerging in Cambodia and Lao PDR. And a wide variety of indigenous and exotic species are now available for culture. Indigenous species include *Pangasius sp., Barbodes gonionotus, Clarias sp., Channa sp., Anabas testudineus, Trichogaster pectoralis, Oxyeleotris marmorata, Macrobrachium rosenbergii, Osphrenemus goramy.* A large number of exotic species are also cultured, often in polycultures with indigenous fish, and these include the Chinese carps, Indian carps, *Oreochromis spp., and Colossoma sp.* In the Thai part of the LMB, tilapia is the most commonly cultured fish (41%), followed by clarias catfish, (26%), barbs (11%), snakeskin gourami (7%), and giant freshwater prawns (6%). In the Delta, aquaculture production is dominated by Pangasids followed by tiger shrimp (*Penaeus monodon*) although in recent years there has been some diversification.

The aquaculture sector can be expected to continue to grow rapidly. As LMB countries become wealthier, the demand for diverse and inexpensive fresh fish is increasing and it seems unlikely that the region's capture fisheries, no matter how well managed, would be able to keep pace with this demand. The disappearance of some fish species from the capture fishery (e.g., *Oxyeleotris marmorata*) and the growing market acceptance of exotic fish such as tilapia are creating new opportunities for aquaculture. There is also a growing demand for the restocking of depleted fisheries such as *Macrobrachium rosenbergii* juveniles, which have been released in floodplains in Cambodia. Strong promotion by governments, which includes the training of manpower, is technically supporting this development. The sector therefore should continue to grow, generating wealth and creating new livelihood opportunities for rural people.

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[2] In 2011, total *Pangasius* culture area and production was estimated around 5,430 ha and 1,195,344 tonnes in the Mekong Delta (Directorate of Fisheries 2012).

Much of the aquaculture expansion in the past has resulted in new areas being utilized for aquaculture. This is certainly true of the coastal region where large areas of mangrove forest and/or rice fields have been converted to shrimp farms. Large freshwater wetland areas considered suitable for the expansion of inland aquaculture also exist. However, environmental constraints are starting to affect aquaculture production and diseases and water quality issues are increasingly affecting production in intensive culture systems. Projected climate change is likely to place additional stress on these culture systems, although in some areas new aquaculture opportunities may be created.

The inevitable escapes from aquaculture farms have resulted in several feral non-native species populations becoming established in the LMB. At least 17 exotic species are known to have established wild populations in the basin (Welcomme and Vidthayanon 2003) and this is of some concern. These exotic species potentially compete with, prey upon, or transmit diseases to valuable native fish. Cage farms are particularly likely to have fish escape from them. The Cambodia Fisheries Administration has prohibited aquaculture of one exotic species, the red-bellied pacu (*Piaractus brachypomus*), but without similar action in other countries this ban is unlikely to limit its spread in the wild.

2.1 CLIMATE CHANGE THREATS TO AQUACULTURE

2.1.1 INCREASED TEMPERATURES

Increased temperatures will likely affect aquaculture in the LMB in several ways. The concentration of dissolved oxygen in water falls as temperatures rise adding to the high stresses of some species in intensive systems, and as a result, some diseases are likely to become more prevalent. Some aquaculture species may not be able to tolerate elevated temperatures (e.g., *Penaeus monodon*) or will have difficulty in breeding at higher temperatures (e.g., *Cyprinus carpio*). Increased temperatures will result in increased decomposition rates and eutrophication, leading to increased fouling of structures such as nets and reduced dissolved oxygen levels. Additional costs associated with aeration and other water treatment will incur.

However, to a point, increased temperatures will also result in the eutrophication of some waterbodies that will suit some planktophageous species (such as carps and tilapias). Increased metabolic rates and therefore feeding activity may also result in positive effects such as faster growth of some species. The water temperature ranges and optimums for the commonly cultured fish have been well studied in the past and are presented below (Table 2).

Table 2: Optimum water temperature ranges for commonly cultured fish in the LMB[3]

Temperature ©	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46
Species																						
Oreochromis niloticus														OP	OP							
Cyprinus carpio													OP	OP								
Pangasius sp.												OP	OP									
Clarias sp.													OP	OP								
Penaeus mondon										OP	OP											

2.1.2 CHANGES IN RAINFALL PATTERNS

Changes in rainfall patterns are likely to affect aquaculture in a number of ways. Increased flash flooding will result in increased loss of stock. Longer dry seasons may affect freshwater availability and constrain fish production; and changes in water quality caused by increased erosion (wet season) or increased pollutants (dry season) may also limit production. Irregular and changeable weather patterns, particularly in the level of sunshine and rain in the periods between the dry and rainy seasons, may cause stress and appetite loss, resulting in slower growth.

2.1.3 STORM INTENSITY AND FREQUENCY

Storm intensity and frequency could affect coastal aquaculture infrastructure and inland aquaculture farm flood security, resulting in impacts such as increased erosion of pond embankments.

2.1.4 INCREASED CARBON DIOXIDE

Increased carbon dioxide levels will result in the acidification of waterbodies reducing their primary productivity and potential for enhanced fisheries. In coastal areas, the culture of mollusks could be affected if their ability to form shells is compromised.

2.1.5 INCREASED SEA LEVELS

SLR will likely affect aquaculture in the LMB by reducing the area available for aquaculture. Increased inland flooding may result through higher tides restricting runoff to the sea. Freshwater and brackish water species most tolerant of salinity, such as *Oreochromis,* will be favored; freshwater aquaculture will likely move inland, while new areas for brackish water aquaculture may emerge. In the Delta's *Pangasius* growing areas, saline water intrusion may force some farmers to relocate to fresher sites. Clam culture may be reduced as the farming ground becomes unmanageable due to higher water level. For intensive

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[3] Notes:
Pangasius optimal temperature (OP): 27°C to 30°C. Lower temperatures lead to less feeding and slower growth rate. Penaeus monodon optimal temperature is from 28°C to 30°C and is optimal for growth rate. Less than 27°C will lead to disease outbreak (white spot).

shrimp farms, SLR (and corresponding higher water levels in river channels and canals) may lead to shrimp escapes and lost yield.

Overall, while climate change threats to aquaculture must be taken seriously, the diversity of aquaculture in the region in terms of species and systems suggests that farmers have a number of tools and strategies with which they can adapt and modify their production systems.

3 THE LOWER MEKONG BASIN ECOZONES

This section of the report attempts to describe capture fisheries and aquaculture characteristics in each of the ecozones being used by the USAID Mekong ARCC project in the LMB (Figure 1). The classification of the LMB fisheries by ecological zone is complicated by the lack of aggregated data relating to each zone, the wide range of different aquatic environments in the same zone, and the migratory tendency of many of the fish species.

River catchments have been overlaid on the ecozone image and the larger river systems identified for each ecozone (Figure 2). As most of the data available are from catchment or river-based studies, this allows for fisheries species and aquaculture systems to be linked to the ecozones used by the USAID Mekong ARCC project. Where the river systems include large wetland areas, a note has been made. The fisheries and aquaculture systems of these larger river systems have then been described.

In this study, indicator species representing a range of fish types can be used as proxies to visualize what specific climate change threats might mean for the wider group. The database currently holds information on 30 aquatic species from a range of Mekong environments consisting of upland, migratory, black, estuarine, and exotic/invasive species.

3.1 HIGH-ELEVATION MOIST BROADLEAF FOREST (ANNAMITES)

This is the only ecozone that does not contain significant wetlands areas, although the headwaters of the Sesan and Sekong Rivers originate in this zone. Fisheries activities where they do exist will be very small scale in nature and focused on the harvesting of fish and other aquatic animals (e.g., crabs, snails, and shrimp, etc.) from the headwaters of small streams or small seasonal pockets of water. The ecozone's steep gradients, rapid water level fluctuations, lack of floodplains, and low overnight temperatures will limit fisheries productivity. Of the project's 30 indicator species, three are found or likely to be found, in this zone. These are *Channa striatus, Clarias batrachus, and Tor tambroides.*

It is unlikely that there is or could be any significant aquaculture in this ecozone. Neither is their much potential for development due to the limited water availability and relatively low temperatures (27°C mean daily maximum).

Figure 1: Ecozones in the Lower Mekong Basin

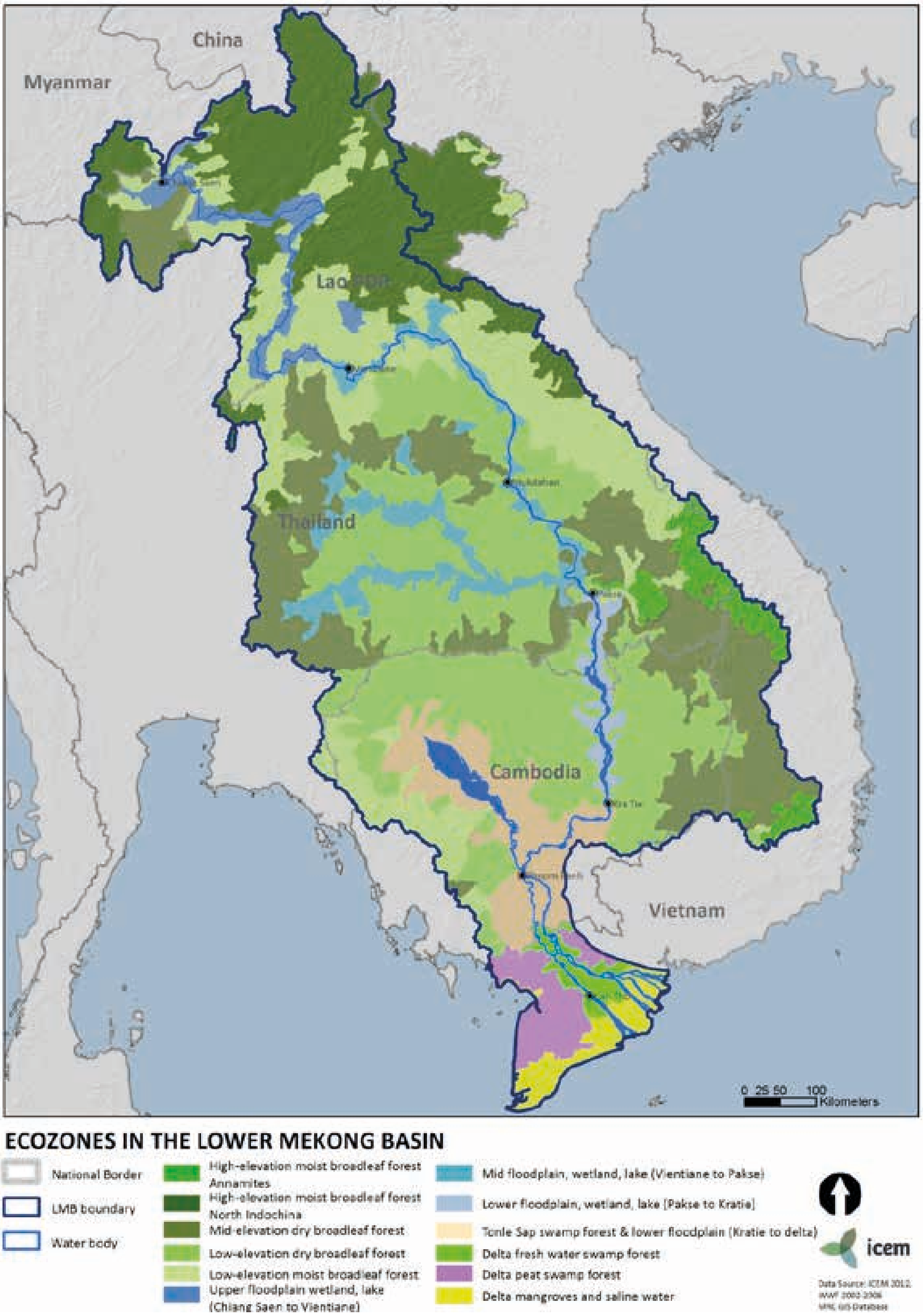
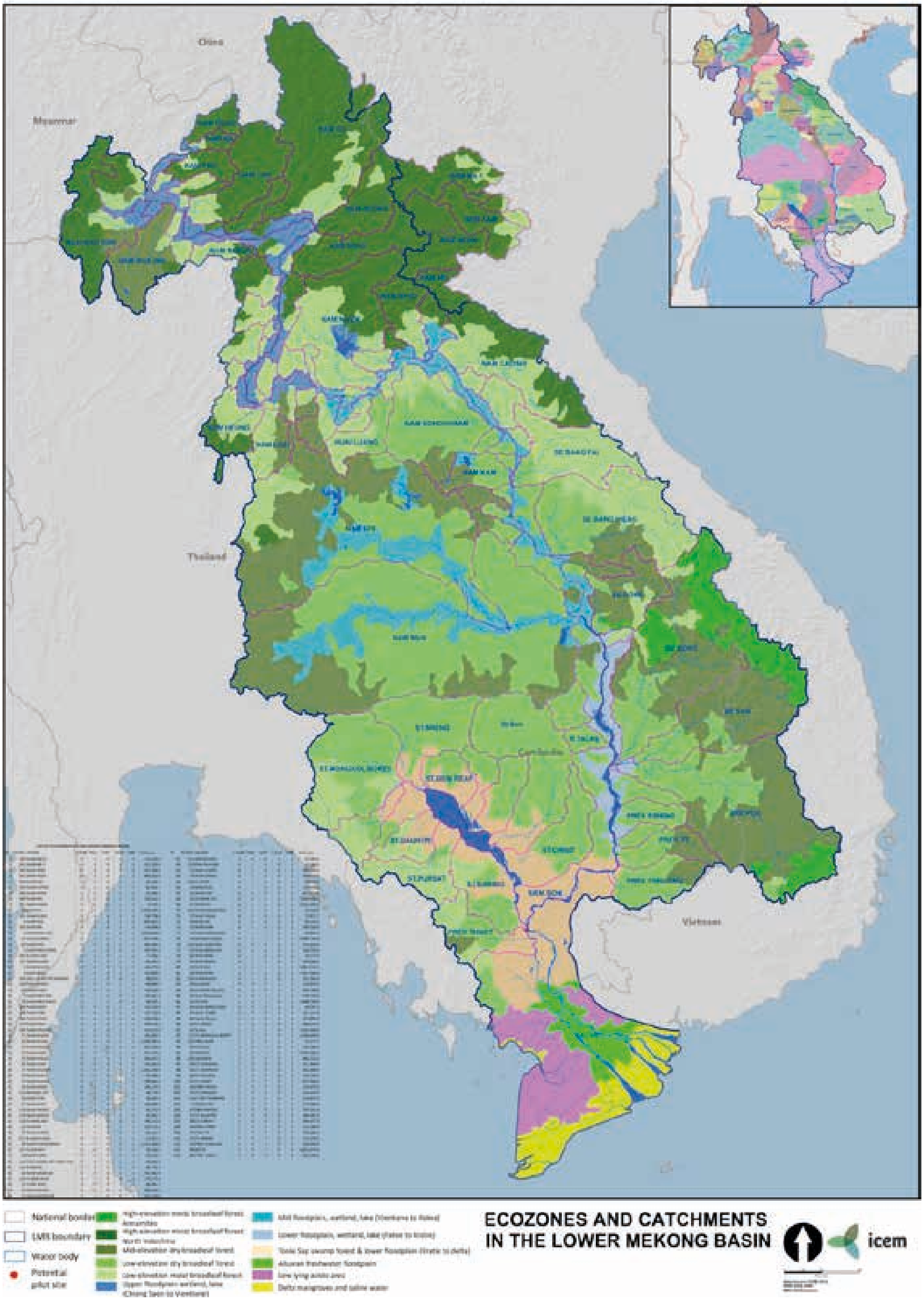


Figure 2: Ecozones and catchments in the Lower Mekong Basin



3.2 HIGH-ELEVATION MOIST BROADLEAF FOREST (NORTH INDOCHINA)

This large zone contains a wide range of freshwater resources. Wetlands are estimated to cover 153,219 ha and there are an estimated 3,347 ha of rivers. There are no estuarine waters.

Some small-scale pond aquaculture is found in this zone. Often a small stream is diverted and the water retained by an earthen embankment. The ponds typically contain a mixture of stocked fish such as carp and tilapia and some indigenous fish species that enter along with the stream water. Fish production from this typically shallow, clear water, flow-through pond systems is low, usually <1,000 kg/ha/yr. Water in these ponds does not respond well to fertilization, and feeds, aside from cut vegetation may not be available. A study of upland Lao communities in Luang Prabang found that the average yearly production per household from aquaculture ponds was the same as the average catch of the much larger number of households fishing in paddies, streams, and rivers nearby. Nevertheless, small-scale aquaculture is often proposed as a solution to aquatic foods shortages. For example, the Lao PDR government promotes aquaculture in this zone in order to *'contribute to the gradual reduction of slash-and-burn shifting cultivation by integrating fish culture into upland farming systems'*.

3.2.1 IMPORTANT FISHING AREAS AND HABITATS

River catchments found in this zone include the following: Nam Mae Kok; Nam Nuao; Nam Ma; Nam Pho; Nam Tha; Nam Beng; Nam Ou; Nam Suong; Nam Khan; Nam Ngum; Nam Nhiep; Nam Sane; Nam Cadinh; Nam Ngeun; Nam Heung; and Nam Mae Ing.

This ecozone contains freshwater resources that support extensive fisheries, albeit mainly of a small-scale nature. The headwater areas, made up of small streams and upland valleys, are locally important fisheries areas for highland communities. The Nam Khan supports larger-scale fisheries and full time fisheries-based livelihoods.

In the relatively small-sized water resources found in this zone, fishing is mainly carried out along the streams and small rivers and canals for rice field irrigation. These streams can be very shallow in the dry season, consisting of occasional pools connected by channels and their water levels and volumes can change rapidly in response to a single rain shower. Small-stream pools and undercut bank areas are frequently targeted by fishermen.

Fishing in and around wet season rice fields is an important seasonal activity for many farming families. A longitudinal study of rice-based ecosystems in 4 upland provinces in Lao PDR (LARReC 2007) highlighted the importance of rice fields in terms of aquatic animal collection. In the study, total aquatic animal consumption in households in upland villages of Xieng Khouang Province was estimated at around 100g/person/day, i.e., 36.5 kg/year.

The numerous small reservoirs created for local irrigation found throughout this zone also function as fisheries although their productivity tends to be low. Some communities and local authorities attempt to enhance these fisheries through the stocking of fingerlings of indigenous and exotic fish species. In some lower elevation areas, these reservoirs could be used for aquaculture. Pond aquaculture tends to be practiced in sheltered valleys. No obvious concentrations or centers for aquaculture are known to exist in this zone.

3.2.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

The fish fauna in this ecozone is less diverse than the communities found within the lowland ecozones. An SDC study from 2007 of the upper reaches of the Nam Khan in Lao PDR found that even at the highest elevations, villagers were regularly harvesting around 20 species of fish, four species of frogs, and three species of mollusks. Fishing in this zone is predominantly small scale and although fish catches are relatively small, its role in providing animal protein in upland communities can be significant.

The wetlands in this zone are home to a surprisingly wide diversity of Black and White Fish species, all of which are harvested for food. Snails, turtles, frogs, crabs, shrimps, snakes, and monitor lizards are also collected by local people for food and local income. In terms of biodiversity Nam Ou, Nam Tha, Nam Khan and Nam Soung have a predicted range of fish species in these tributaries of 118–149 species, of which more than 34% to 38% are migratory and 27% to 38% are endemic. The Nam Ou is thought to have 13 endangered fish species present (Meynell 2003).

The SDC study also provided insight into the high aquatic biodiversity of some upland areas in this zone, with a wide range of fish species being found. In terms of nutrition, the most important fish species are as follows: *Schistura spp., Clarias batrachus, Monopterus albus, Scaphiodonichthys acanthopterus, Carrasius spp.**[4], *Bangana lippus, Rasbora spp., Channa gachua, Cyprinus carpio*, Oreochromis spp.*, Channa striata, Opsarius spp., Tambroides spp., Poropontius spp., Hampala macrolepidota, Mystacoleucus spp., Hemibagrus nemurus, Onychostoma gerlachi, Rhinogobius spp., Oxyeleotris spp., Glossogobius spp., Tetradontidae spp., Notopterus spp., Mastacembulus armatus, Mekongina erithrospila, Trichopsis spp., Systomus spp., Hypsibarbus lagleri,* and *Acheilognathus deignani.*

Of the study's 30 indicator species, 14 are found or likely to be found in this zone. These are: *Bangana behri; Barbonymus gonionotus; Channa lucius; Channa striatus; Clarias batrachus; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Mekongina erthrospila; Mastocembalus armatus; Pomacea canaliculata; Scaphiodonichthys acanthopterus; Schistura kengtungensis; and Tor tambroides.*

For aquaculture, the common carp is popular with small-scale farmers due to its relative cold tolerance and ease of breeding at lower temperatures. Tilapia species (*Oreochromis* spp.) are often found in ponds and are mainly grown for food security. In fact, over populating of tilapia is common due to the few predatory fish, such as snakehead (*Channa striatus*), reaching upland areas associated with this ecozone. Some local wild fish species (including small cyprinids, clariads, and eels) are also found in the ponds due to the flow-through design. At high-elevation locations the culture of exotic fish such as rainbow trout

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[4] Species marked with a star (e.g., *Carrasius spp.**) are exotic, probably introduced to the zone for aquaculture purposes and subsequently established populations in natural waters.

(*Salmo gairdneri*) and sturgeon (*Acipenser baerii)* may have potential as these species are cultured in a similar ecological zone in Northern Thailand outside of the LMB.

3.2.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

While many households are involved in small-scale fishing in this ecozone, few can be considered full-time fishers. The local fishers use a variety of small-scale gears including cast nets, wicker baskets, and spears (sometimes used with a diving mask) for river and stream fishing. Women and especially children are typically involved in these fishing activities. In the lower reaches of the Nam Ou, Nam Khan and Nam Suong the fishing is good enough to support full-time fisher families and investment in fishing boats and larger gears, such as long lines and gill nets.

Fishing in the upland streams flowing through forested areas is compatible with Non-Timber Forest Product (NTFP) collection, as riparian zones are often followed by villagers who alternate between fishing the small pools and undercut banks and collecting plants for food and medicine (SDC 2007). Several studies have suggested that many communities turn to small stream and wetland fishing as their main source of animal protein as constraints to hunting animals develop (SDC 2007, Degen et al. 2005).

Commercial-scale pond aquaculture is rare in this ecozone, aside from some hatchery and nursery complexes. The most common small-scale aquaculture system involves small valley ponds, linked to small streams adjacent to rice fields. The creating of small ponds in valley areas close to streams is one way that water surface area can be increased for aquatic foods production. The easiest way to create these small waterbodies is by putting up an embankment to hold back water, rather than through excavation of land. A series of ponds can be created in a linked series running parallel to local watercourses. Most ponds in this zone are small, shallow, and infertile and may be located a long way from the homestead, making security difficult. The main inputs used are cut vegetation and animal manure.

Ponds created in this way are managed extensively, i.e., they are used for aquaculture, left for aquatic plants or wild aquatic animals to inhabit, or managed with a combination of these objectives in mind. They can be useful sources of aquatic foods at times when the collection of aquatic foods from natural waterbodies is difficult. They can also operate as fish refuge areas for the surrounding capture fishery. Some fish species (e.g., grass carp) are cultured in small cages in streams or canals. Grass and vegetation is cut on a regular basis as food.

3.2.4 TOLERENCES AND LIFE CYCLE CONDITIONS

Fish and other aquatic animal production in this zone is constrained by a number of factors including water availability during the dry season, steep river gradients that are prone to flash flooding, and the low productivity of the water. At higher elevations, e.g., >1,500 m, low overnight temperatures will adversely affect fishery productivity. The aquatic fauna of these upland areas also have to cope with fast changing water flows and levels. Waterfalls and physical obstructions constrain the distribution of fish in some streams although some fish species are able to overcome small waterfalls, e.g., *Osteochilus* *melanopleurus, Hypsibarbus spp.,* and *Osphronemus exodon.* Low overnight temperatures limit growth of most fish species and pond production. Flow-through ponds are usually infertile and productivity low.

3.2.5 TRENDS, THREATS, AND OPPORTUNITIES

The water quality and quantity and therefore the fisheries productivity in upland streams in some areas is perceived by local people to be deteriorating, due to a number of factors:

- The loss of forest cover resulting in rapid changes in water level and increased river sedimentation after heavy rains
- The practice of watering livestock and dumping rubbish in streams
- The use of chemical fertilizers and pesticides for agriculture[5]
- Mining operations, resulting in changes in river morphology and pollutants such as sodium cyanide and mercury

Fishing in the dry season, in the few remaining pools, threatens the viability of some fisheries. These small river systems are vulnerable to the intensification of fishing and illegal fishing techniques, including the use of rotenone (a traditional piscicide) and explosives in pools during the dry season.

Other pressures on the fisheries resources of these areas include:

- An increase in the numbers of people fishing and the move towards fishing for the market rather than for subsistence
- Small-sized nets and the harvesting of juvenile animals
- The damming or 'weiring' of streams for diversion irrigation may also constrain localized fish migrations
- The establishment of feral populations of exotic fish species, e.g., the use of guppies (*Poecilia reticulata*) for mosquito control in northeastern Thailand is thought to be responsible for the sharp decrease of indigenous fish populations in hill streams in Loei and Nongkhai Provinces (Kottelet et al. 2012)

Throughout this ecozone, where stream velocities are high, the installation of village-scale hydro-electric devices is common especially in Lao PDR. Little is yet known of the effects of these structures on local fisheries.

In terms of opportunities, initiatives aimed at improving catchment forests and supporting the communal management of river and wetland resources is seen as progressive. The creation of new reservoirs is resulting in new fisheries and livelihood opportunities for local people.

Aquaculture in this ecozone is growing in importance for food security, as hunting and small-stream fishing becomes more difficult. It tends to involve wealthier, less vulnerable households. Remoter areas

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[5] The extensive nature of rice cultivation and the limited use of pesticides make it unlikely that rice farming is having a negative effect on aquatic foods and in the case of fertilizer application may actually be enhancing production.

may experience difficulties with finding fingerlings for stocking in ponds. Elevated temperatures resulting from climate change will be less likely to negatively affect aquaculture in this ecozone. If anything, aquaculture will become more viable as temperatures rise. However, flash flooding through increased precipitation could affect aquaculture infrastructure in this ecozone due to the steep hillside gradients.

3.3 MID-ELEVATION DRY BROADLEAF FOREST

This large ecozone contains a wide range of freshwater resources. Wetland areas are substantial with an estimated 1,465,939 ha. In addition, this ecozone contains an estimated 3,652 ha of rivers. Temperatures are more suitable for aquaculture in this ecozone (31°C mean daily maximum) compared to higher-elevation forests.

3.3.1 IMPORTANT FISHING AREAS AND HABITATS

Much of the wetland areas of this ecozone are associated with river systems including the Nam Mae Ing; Nam Chi; Nam Mun; Huai Bang Sai; Se Done; Sesan; Srepok; and Prek Te. Smaller areas of the catchments of the following are included in this ecozone: Nam Mae Kok; Nam Loei; Huai Mong; Huai Nam Som; Nam Songkrahm, Nam Kam; Se Bang Hieng; Sekong; Prek Thnot; and Prek Chhlong.

The characteristics of the upper reaches of these rivers can be diverse. For example, the upper reaches of the Sesan include a number of long tributaries of up to 40 km in length creating a substantial and favorable habitat for many fish species. Some reaches are characterized by successions of sand banks and islands and other sections are rocky and include minor rapids. The creation of the Yali Dam on the Sesan River has changed the characteristics of the river completely, forming a large lacustrine environment.

Paddy rice growing areas and their adjacent wetlands are often located close to river valleys in this ecozone and often support significant small-scale fisheries, dominated by Black Fish species. This is particularly true of the Nam Mae Ing river system and the upper Chi and Nam Mun rivers in Northeast Thailand.

In terms of aquaculture, the Thailand part of this ecozone in 'Isan' has the highest concentration of aquaculture, although much of it is small scale. Fish seed is widely available in this area and small-scale aquaculture is a useful contributor to farm production.

3.3.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

The rivers and streams of this ecozone maintain high fish biodiversity and many of them support more than 100 species of which a large percentage is migratory. For example, in the upper reaches of the Prek Chhlong more than 90 Black and White Fish species have been identified. In addition, a projected 208 fish species are found in the Nam Mae Kok (Meynel 2003). Important fish species in these river systems include *Barbodes spp., Puntioplites spp., Hypsibarbus spp., Pangasius spp., Catlocarpio siamensis, Henicorhynchus spp., Paralaubuca spp., Ompok spp., Wallago attu,* and *Cirrhinus microlepis* (Degen et al. 2005).

Of the study's 30 indicator species, 21 are found or likely to be found in this zone. These are *Bangana behri; Barbonymus gonionotus; Channa lucius; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Cyclocheilichthys enoplos; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Hypsibarbus malcolmi; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius pangasius; Pomacea canaliculata; Probarbus jullieni; Puntioplites falcifer; Scaphiodonichthys acanthopterus; Tor tambroides;* and *Trichogaster pectoralis.*

Most of the aquaculture in this ecozone operates in small ponds using predominantly carps, rather than tilapia. Clarias catfish would also be suitable for culture in this ecozone due to the small ponds required and the short growing season.

3.3.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

Given the diverse wetland types and the high fish biodiversity, a wide range and scale of fishing gears are used throughout this ecozone. At the small-scale end, these gears include baskets, scoop nets, spears, hooks and lines, bamboo traps, gill nets, seine nets, brush parks, cast nets, lift nets, and push nets. In addition to the small-scale gears used in the higher reaches, larger-scale fishing gears such as bagnets, grid traps, fish weir traps are also found at the 'bottlenecks' of the more productive fisheries.

The villagers living in the Nam Mae Ing still largely depend on catching migratory fish for their livelihoods. Lower down, the river empties into Kwan Payao, a large, permanent, freshwater lake of 1,980 ha, fringed by approximately 3,000 ha of rice paddy. The lake fishery is now dominated by the exotic tilapias, *Oreochromis* spp., which supports a local gill net fishery.

Rainfed pond culture predominates in this ecozone, although there are very few commercial-scale fish farms apart from hatcheries and nursery complexes. Many rice farms have small ponds dug for irrigation, which are often utilized for fish production. Traditionally, farm inputs such as rice bran and cow dung have been used to increase production from these ponds but more recently farmers are turning to pelleted feed, particularly for catfish. The fish harvest usually contains wild fish species such as snakehead, which find their own way into the ponds during the culture cycle. In some irrigated rice farming valley areas, the culture of common carp has been a long established practice. Typically, *Cyprinus carpio* and *Carassius auratus* are produced and these spawn naturally in the rice fields and adjoining ponds. Since the farmers can produce their own fish seed, this activity is popular since little cash is required. Often production is only enough for the farmer and his family, although small surpluses can be sold or given away.

3.3.4 TOLERANCES AND LIFE CYCLE CONDITIONS

Migratory fish species are important in many of the streams and tributaries of this zone and most upstream migrations are triggered by the onset of the wet season. The wide range of river and wetland environments result in a wide range of species and corresponding life cycles, which can be found within the same river system. For example, the fish assemblages found in river rapids would be completely different from those found in a reservoir on the same river system. The connectivity of the river systems and the ease with which fish can move through are key elements to maintain in these fisheries.

Shortages of water during the dry season also affect fish production from aquaculture and, in some cases force the farmer to harvest fish prematurely. Low temperatures during the cool season constrain fish production. The window for fish production is therefore quite short. However, as many parts of this ecozone have shortages of fish from capture fisheries, generally speaking people are ready to accept smaller fish (such as 200g) for consumption.

3.3.5 TRENDS, THREATS, AND OPPORTUNITIES

The hydrology and productivity of the Sesan has been seriously affected by the construction of many hydro-electric dams in Vietnam. Water levels and flows in the Sesan have changed significantly since the completion of the Yali dam in 1996. The connectivity of the Vietnamese part of the Upper Sesan Basin has also been compromised by the construction of at least 61 physical structures (small and medium reservoirs) and 177 small weirs (Baran et al. 2011). Upland logging is reported to be affecting the water quality in some catchments including the Prek Chhlong.

The continued expansion of the number of farmers raising fish in small ponds and rice fields in this zone will likely continue as wild fish catches decline. However, extreme weather events such as droughts and flash flooding may deter farmers from continuing with this practice if they become more frequent.

3.4 LOW-ELEVATION DRY BROADLEAF FOREST

This ecozone contains a wide range of freshwater resources. Wetlands are extensive and estimated to cover 958,897 ha. The area of rivers is greater than in the ecozones described previously with an estimated 40,085 ha. This ecozone has temperatures that are very suitable for aquaculture (32°C mean daily maximum). The scale of aquaculture development varies across this zone based on the economic development of the respective countries. For example in Thailand, small-scale fish culture in ponds and cages is found throughout the region. However, in Cambodia it is less common.

3.4.1 IMPORTANT FISHING AREAS AND HABITATS

This ecozone is an important one for capture fisheries. Many of the tributaries that flow into the Tonle Sap, Cambodia's Great Lake, originate in this zone. Another important wetland area is the Nam Songkhram and Nam Chi and Nam Mun catchments, which support a wide range of commercial and subsistence-scale fisheries. The lower reaches of the '3S' rivers, Srepok, Sekong and Sesan, draining the eastern side of the LMB in Cambodia also support important fisheries.

This ecozone includes the lower Songkhram River Basin, an important fishery in Northeast Thailand. This basin is considered highly important in terms of biodiversity and for fish migration. The Prek Chhlong River is also regarded as having high importance for migratory fish species as well as for creating local floodplains which are important spawning and nursing grounds for a wide range of Black and White Fish species.

There are any tributaries of important river systems in this ecozone such as the Nam Songkrahm; Nam Chi; Nam Mun; Se Bang Hieng; Sekong; Sesan; Sepok; Prek Krieng; Prek Te; Prek Chhlong; O Talas;

Tonle Repon; St Sen; St Sreng; St Mongkol Borey; St Staung; and St Chikreng. Smaller areas of the catchments of the following are included in this ecozone: Huai Luang; Se Bang Fai; Huai Khammouan; St Battambang; St Dauntri; St Pursat; St Baribo; St Chinit; Siem Bok; and St Sangker. Although aquaculture is widespread throughout this ecozone there are no clearly identifiable centers or concentrations of fish culture.

3.4.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

The lower reaches of the Srepok, Sesan and Sekong Rivers are characterized by a high level of fish biodiversity amounting to 329 species, which corresponds to 42% of all Mekong fish species within an area representing only 10% of the Mekong Basin. In terms of migratory fish species, the Sekong, Sesan and Srepok Rivers have 64, 54, and 81 migratory fish species respectively. Some of these migratory fish species are the most economically important fish for many riverside communities. These three rivers are also home to 14 endangered fish species, including the critically endangered species *Aaptosyax grypus* (giant salmon carp), *Catlocarpio siamensis* (giant carp), and *Pangasianodon gigas* (giant catfish). Fifteen species are found exclusively in the Sekong River and two in the Srepok River; they are found in no other Mekong tributary and nowhere else in the world.

Of the study's 30 indicator species, 18 are found or likely to be found in this zone. These are *Bangana behri; Barbonymus gonionotus; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Cyclocheilichthys enoplos; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Hypsibarbus malcolmi; Macrobrachium rosenbergii; Mastocembalus armatus; Mekongina erthrospila; Oreochromis niloticus; Pangasius pangasius; Pomacea canaliculata; Probarbus jullieni; and Trichogaster pectoralis.*

Several studies have shown declines in the number of fish species in many of the important rivers in this zone (Baran 2011). These include marked reductions in the '3S' (Sesan, Srepok, Sekong) river populations of *Henicorhynchus siamensis* & *H. lobatus*, *Hypsibarbus pierrei, Hypsibarbus wetmorei, Labeo erythropterus, Scaphognathops bandanensis, Bangana behri,* and *Wallago attu.*

A wide range of aquaculture species is cultured in this zone including tilapias, carps, and catfishes. In pond aquaculture, these fish are often grown together in polycultures. Tilapia and in some cases snakehead (*Channa striatus*) are cultured in cages, particularly in reservoirs in this ecozone.

3.4.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

A wide range of commercial and small-scale fishing gears are used including bag nets, big traps, cast nets, gill nets, hooks, lift nets, scoop nets, small bamboo traps, and spears. In the smaller reservoirs, a variety of cyprinids and blackfish are exploited on a subsistence or semi-commercial basis using gill nets and traps. In larger reservoirs fishing operations include large lift nets.

Data on these reservoir resources and their fisheries productivity are few. However, estimates of reservoir fish production hint at the relative extent of these resources. Northeast Thailand has by far the highest fish production (187,500 tonnes per annum) followed by Cambodia (22,750) and Lao PDR (16,700) (Zalinge et al. (2003).

A range of different aquaculture systems exist in this ecozone including fish cages in reservoirs, rice fish culture in irrigated areas, and rainfed pond culture. Increasingly farmers are turning to pelleted feeds to intensify their fish production. Big head and silver carp are raised in cages in reservoirs where the water is fertile enough and no supplementary feed is necessary.

3.4.4 TOLERANCES AND LIFE CYCLE CONDITIONS

Large parts of this zone are characterized by annual drought and flood. Fish and other aquatic animals inhabiting these areas have evolved to survive the harsh conditions through the dry season and at the onset of the rains to quickly mature and breed. The survival of fish through the dry season depends to a large extent on the availability of perennial waterbodies

In flowing water, environmental conditions in the waters surrounding cage fish farms can be maintained through the dilution of wastes from cages by new water. However, in still waters, such as reservoirs, local eutrophication caused by waste from cage farms can result in poor water quality conditions and loss of stocks. This limits the numbers of cages that a reservoir can support.

3.4.5 TRENDS, THREATS, AND OPPORTUNITIES

The pressure on Black Fish during the dry season is intense in many parts of this ecozone where the repeated netting and pumping of waterbodies greatly reduces the stocks that can survive the dry season. Some countries of the LMB (especially Cambodia) are now implementing the conservation of dry season refuge areas and fish conservation areas to try and ensure that enough brood stocks survive the dry season each year from which the fishery can be replenished. Cambodia allows only limited large- and medium-scale capture fishing during the breeding season (June–September) in order to allow fishes to migrate to inundated areas for spawning, breeding, and feeding time.

There are considered to be around 25,000 man-made reservoirs in the LMB, mostly constructed for irrigation. The larger ones have been built for flood control and electricity generation. However, the importance of the river and floodplain fisheries needs to be assessed before the completion of the dam. For example, due to the completion of the Nam Ngum dam, at least ten migratory species are not found any more upstream of the dam (Schouten 1998). However, these reservoirs can be managed to produce fish in large quantities, particularly in the first few years following dam completion, and several countries have extensive stocking programs which can include the introduction of hatchery-reared indigenous and exotic fingerlings. The unrestrained stocking of these waterbodies with exotic fish species could result in increasing numbers of species becoming established in the wild, and thereby affecting indigenous fish populations.

The number of farmers raising fish in small ponds, cages, and rice fields in this ecozone will likely continue. Seed availability, already well-developed in Thailand, is improving in Cambodia, providing more farmers with the opportunity to produce fish on-farm. The excavation of small ponds for emergency irrigation is already prevalent throughput this zone and will probably continue. These resources can very easily be used for fish production, albeit on an extensive scale. The proliferation of reservoirs in this zone is also creating new opportunities for cultured fish production as well as enhanced fisheries dependent on hatchery-produced fingerlings.

3.5 LOW-ELEVATION MOIST BROADLEAF FOREST

This ecozone contains a wide range of freshwater resources. Wetlands coverage is high and estimated to be 619,469 ha in extent. The area of river coverage is also extensive at 4,302 ha. This ecozone, being at a higher elevation than *Low-elevation Dry Broadleaf Forest*, has less potential for aquaculture due to the lower temperatures (29°C mean daily maximum) and problems with water retention in ponds.

3.5.1 IMPORTANT FISHING AREAS AND HABITATS

This zone includes several important fishing areas including Se Bang Hieng; Se Bang Fai; Nam Cadinh; Nam Songkhram; Huai Luang; Nam Ngum; Nam Nheip; Nam Ou and Nam Suong. Also included in this zone are the upper reaches of tributaries to the west of the Tonle Sap: Prek Thnot; St Pursat; St Dauntri; St. Mongkol Borey; St Battambang; and St Baribo.

Smaller catchments include Nam Loei; Nam Heung; Nam Phone; Nam Hoang; Nam Phoul; and Nam Khop. Fragments of other catchments include Se Done; Sekong; Nam Mae Ing; Nam Mae Kok; and several other small northern LMB river systems.

The Nam Ngum reservoir, which supports an extensive fishery in Lao PDR, is located on the edge of this ecozone. This dam now supports a significant fishery. Completed in 1972, the Nam Ngum reservoir was reported to have produced 6,833 tonnes of fish in 1998, nearly 30% of which was made up by the small clupeid *Clupeichtys aesieamensis*. However, 10 species of migratory fish that were found above the dam site prior to its completion are now absent.

No known centers of aquaculture are found in this zone. In fact, large parts of this zone have no appreciable aquaculture established.

3.5.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

Of the study's 30 indicator species, 15 are found or likely to be found in this ecozone. These are *Barbonymus gonionotus; Channa lucius; Channa striatus; Clarias batrachus; Cyclocheilichthys enoplos; Cyprinus carpio; Henicorhynchus siamensis; Hypsibarbus malcolmi; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pomacea canaliculata; Probarbus jullieni; Puntiplites falcifer;* and *Trichogaster pectoralis*.

MRC 2010 reports 183 fish species inhabiting the lower Nam Songkhram basin, which is dominated by Black Fish species. *Anabas testudineus, Hemibagrus nemurus, Mystus singaringan, Channa striata, Clarias batrachus, Clarias macrocephalus, Barbonymus gonionotus, Hampala dispar, Henicoynchus siamensis, Labiobarbus lineatus, Osteochilus hasseltii, Rasbora borapetenis, Rasbora trilneata, Pristolepis fasciata, Notopterus notopterus, Trichopsis vittata,* and *Ompok urbaini*. In the Nam Ngum reservoir, the clupeid *Clupeichthys aesarnensis*, as mentioned above, now dominates the fishery. The traditional culture of carps in rice fields and small ponds is the only aquaculture system of note in this ecozone.

3.5.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

Rice farmers in this ecozone have developed effective traditional ways of capturing Black Fish species from their fields and adjacent waterbodies. Many use bamboos and local materials, although modern gears such as gill nets are becoming more common. Many of these are used during the 'back migration' of stocks at the end of the wet season.

Light fishing for clupeids is carried out in the Nam Ngum reservoir, which now makes up 28% of the total catch (about 10% of the total value). Around 80% of the catch is dried and sold to fish traders. Some is consumed locally and a small percentage is used for aquaculture as feed in fish cages (Mattson et al. 2001).

Where aquaculture is practiced, it is done in small ponds and irrigated rice fields. It is only small scale in nature and fish production levels are usually only enough to meet household requirements. Wild fish do infiltrate the ponds in this zone but tend to be of a small size.

3.5.4 TOLERANCES AND LIFE CYCLE CONDITIONS

The importance of the Black fishery in this ecozone is a result of the extensive wetlands that are created every wet season through rainfall and river inundation. As with other ecozones with extensive wetlands, productivity depends on the connectivity of the wetlands, and the existence of areas where the fish can pass the dry season unmolested. The marketing of Black Fish species is aided by their capacity to withstand low DO conditions (in many cases they are air breathing). This enables them to stay alive in the market place for long periods (days). The low temperatures and shortages of water availability during the dry season constrain aquaculture development in this zone.

3.5.5 TRENDS, THREATS, AND OPPORTUNITIES

Traps and obstacles which constrain the out migration of fish from refuge areas onto the floodplain and rice fields in the early wet season are thought to result in reduced fish catches in subsequent years. The trapping of fish during the back migration to refuge areas is not as critical (Gregory et al. 1996).

The targeting of fish in dry season refuges, and the trapping of them as they move from refuges onto the floodplain is detrimental to the health of the floodplain fisheries in many areas. Similarly the use of micromesh bag nets between rice bunds, which catch all but the smallest fish and shrimp, is also detrimental.

The drainage of wetlands for rice production, coupled with the use of chemical fertilizers and pesticides, is thought to be resulting in declines in the Black fishery in some areas. The promotion of environmentally friendly farming techniques and the establishment of numerous, well-connected dry season refuges where brood stocks can survive low water conditions is an opportunity to preserve the Black fishery within this ecozone.

Despite the natural constraints there are efforts to promote aquaculture in this ecozone. For example, Cambodian government policy in recent years has been to promote aquaculture in fish deficit areas to the west of the capital Phnom Penh, which falls in this ecozone. This has been successful and readily taken up by local farmers. Several countries of the LMB are focusing on cage aquaculture in reservoirs to meet local and regional fish demand and are training local people in basic cage aquaculture techniques. Tilapia appears to be the most popular fish being promoted.

3.6 UPPER FLOODPLAIN WETLAND, LAKE (CHIANG SEAN TO VIENTIANE)

This ecozone contains a range of river and wetland resources. Wetland areas are estimated to be 36,313 ha in extent. The area of rivers is comparable at 37,947 ha.

3.6.1 IMPORTANT FISHING AREAS AND HABITATS

In this zone, the mainstream Mekong falls into at least three different ecological zones: fast mountain river with extensive rock outcrops and rapids; wider, slower moving meandering river; fast moving river with braided channels and deep pools. All of these areas are important for fish life cycles and fisheries (Meynell 2003). In addition to the mainstream, the adjacent floodplains are important seasonal fishing areas. Rapids and deep pools on the Mekong in this zone are important habitats to protect.

This ecozone covers several provinces in Thailand along the Mekong River where aquaculture is important. These are Chiang Rai, Leoi and Nongkhai. The maximum daily mean temperature in Chiang Rai Province between 2002 and 2007 is 34.16°C, highlighting this ecozone's suitability for fish culture.

3.6.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

Of the study's 30 indicator species, 20 are found or likely to be found in this zone. These *are Bangana behri; Barbonymus gonionotus; Channa lucius; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Hypsibarbus malcolmi; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius pangasius; Pomacea canaliculata; Probarbus jullieni; Puntioplites falcifer; Scaphiodonichthys acanthopterus; Tor tambroide;* and *Trichogaster pectoralis.* Through fisher interviews, market surveys, and sampling, Meynell (2003) identified 85 fish species in the mainstream Mekong upstream of Chiang Kong in Thailand. The migratory *Henicorhynchus* spp. is probably the most important capture fisheries species in this ecozone.

According to fishery statistics recorded by the Department of Fisheries (Thailand) for 2009, most fishers in the Thai provinces within this ecozone culture Tilapia as the dominant species following by *Clarias spp., Barbodes, and Pangasids*. In 2009, the total area under aquaculture in Chiang Rai, Nongkhai, and Leoi was 28,138.7 rais, 17,066.02 rais, and 16,298.61 rais, respectively.

3.6.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

No information was found on the fishing systems used in this ecozone, although they can be expected to be similar to those found in the Lower Floodplain, wetland, lake ecozone (from Pakse to Kratie). There are four types of aquaculture including culture fish in ponds, paddy fields, ditches, and cages, although the use of earthen ponds is the most popular. Most of aquaculture in Chaing Rai Province is commercial scale. There are a number of fish breeding farms in the area so there is high competition for selling fingerlings.

3.6.4 TOLERANCES AND LIFE CYCLE CONDITIONS

As this zone is situated in the northern part of Thailand surrounded by mountains and an unpolluted environment, native and exotic fish species can be expected to survive comfortably in the zone.

3.6.5 TRENDS, THREATS, AND OPPORTUNITIES

Damming of tributaries and planned mainstream dams threaten migratory stocks by disrupting the annual flood pattern that triggers fish migrations and causes inundation of floodplains. If this fluctuation does not occur, the required spawning triggers may occur haphazardly. It is also important that the migration corridors between downstream dry season refuge habitats and upstream spawning habitats are maintained.

At present, the number of fish farms including fish production in this ecozone is increasing steadily even though the mean temperature in these provinces are a bit lower than for other parts of Thailand.

3.7 MID FLOODPLAIN, WETLAND, LAKE (VIENTIANE TO PAKSE)

This ecozone contains more extensive wetlands and river areas. Wetland areas are estimated to be 300,385 ha. The area of rivers is estimated at 75,815 ha. Parts of the mainstream Mekong are vitally important for a number of migratory fish that can pass the Khone Falls. Temperatures (33°C mean daily maximum) in this ecozone are conducive to fish culture, particularly in cages in the main river system and as a result aquaculture has developed in areas close to urban centers.

3.7.1 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

Of the study's 30 indicator species, 20 are found or likely to be found in this ecozone. These are *Bangana behri; Barbonymus gonionotus; Channa lucius; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Hypsibarbus malcolmi; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius pangasius; Pomacea canaliculata; Probarbus jullieni; Puntioplites falcifer; Scaphiodonichthys acanthopterus; Tor tambroides;* and *Trichogaster pectoralis.*

For aquaculture, the most popular fish being produced in river-sited cages at the present time is Tilapia. Monosex stocks are preferred as feed is not wasted on maturing females. However, several other fish species are reported to be cultured in this zone including *Pangasius larnaudiei, Channa striata, P. hypopthalmus*, silver barb and a variety of carp species.

3.7.2 IMPORTANT FISHING AREAS AND HABITATS

The mainstream Mekong near to Vientiane, Khammouan, and Mukdahan is important for aquaculture. Commercial scale peri-urban pond complexes and hatcheries can be found in Vientiane, Nong Kai, and Mukdahan.

3.7.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

Cage culture in the mainstream Mekong is an important activity in areas close to major urban centers. LARReC (2001) reported 1,193 cages in the Mekong close to Vientiane. Common cage dimensions are 2x4x6 m floating with oil barrels. Nylon nets are commonly used. Traditional bamboo cages not used so much nowadays. Commercial-scale cage farms use a range of feeds, mostly imported commercial diets with a protein content of 30% to 32%. Smaller-scale operators tend to use locally made feeds. These include water hyacinth, rice bran, broken rice, duckweed, boiled corn meal, golden apple snails, and earthworms as supplementary feeds.

3.7.4 TOLERANCES AND LIFE CYCLE CONDITIONS

The availability of quality monosex tilapia for cage aquaculture constrains the sector. It is difficult to assess the percentage of males present in stocks until they have matured.

3.7.5 TRENDS, THREATS, AND OPPORTUNITIES

Given its dependence on migratory fish species, the fisheries productivity of this zone is threatened by constraints to migration created by the construction of mainstream and tributary dams. The planned Don Sahong Dam is of particular concern to health of the fisheries of the Khone Falls area. The exotic common carp (*Cyprinus carpio*) is reported to have established a feral population in the mainstream Mekong in part of this ecozone (Kottelat et al. 2012). Its impact on indigenous fish species has yet to be determined.

The cage farms sited on the Mekong in this ecozone are vulnerable to the changing water quality conditions of the river. Low flows during the dry season can result in higher losses through disease and poorer growth. Poor regulation means that many are poorly sited and vulnerable to pollution from upstream fish farms and other sources.

3.8 LOWER FLOODPLAIN, WETLAND, LAKE (PAKSE TO KRATIE)

This ecozone contains less extensive wetlands areas than the middle floodplain ecozone; they are estimated to cover 56,507 ha while the area of rivers is comparable at 74,726 ha. Floodplains are restricted to areas adjacent to the mainstream Mekong. Very little aquaculture occurs in this ecozone, which remains highly dependent on catches of fish from the wild. The development of aquaculture is not expected.

3.8.1 IMPORTANT FISHING AREAS AND HABITATS

This ecozone contains the critical site of the Khone Falls in Lao PDR. The Khone Falls area represents an important and unique ecological region consisting of a series of shallow braided channels that enter a 40 km wide stretch of waterfalls and cascades created by a geological fault line. The fish that inhabit this area have evolved to live in an extremely turbulent environment where water flow in the wet season can be 30 times as high as in the dry season (Kottelat et al. 2012). Although the Khone Falls are a zoogeographic barrier for some fish species, in particular species of marine origin, several of the falls are passable for many species, e.g., *Cirrhinus microlepis*. Important fish migrations take place over the falls, both in the flood and dry seasons.

The rise in water levels at the beginning of the flood season triggers migrating fish to move from the dry season habitats just below the Khone Falls (for example, the deep pools along the Stung Treng-Kratie stretch) towards the southern floodplain feeding habitats on the Mekong Plain. Some species spawn on or near the floodplain; others spawn far upstream and their larvae drift down with the current to the floodplains. Fish are targeted throughout these migrations. Many species migrating north use the Sesan/Srepok/Sekong system rather than navigating the Khone Falls. For example, large quantities of trey riel migrate into the Sesan from the Mekong during the dry season.

The deep pools found in this zone are vitally important to the ecology of the river system and function as dry season refuges for many fish species, as well as the Irrawaddy Dolphin. The pools vary in depth between 10–60 m deep and can be as long as 300 m (Hill 1995). The large fish that these pools sustain form the brood-stock supporting local fisheries and floodplain fisheries downstream (Chan et al. 2005). The riverine flooded forests in the mainstream Mekong above Stung Treng offer a unique aquatic habitat.

Of the 10 most important species in the Dai fishery of the Tonle Sap over the period 1995 to 2000, six have been reported to use deep pool habitats in northern Cambodia (Poulsen et al. 2002). Three species (*Dangila spp., Thynnichthys thynnoides, and Osteochilus hasselti*) have also been listed as important species in the Khone Falls "Tone" trap fishery and are believed to migrate from the Tonle Sap River to the Khone Falls during the dry season (Baird et al. 1999). They also possibly utilize deep pool habitats during the dry season. It is thought that up to 75% of the total catch from the Dai fisheries may depend on the availability of deep pool habitats in northern Cambodia (i.e., Kratie to the Khone Falls and the Sesan/Srepok/Sekong catchment).

3.8.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

The small cyprinid fish, *Cirrhinus lobatus,* is the most abundant fish species caught in the Khone Falls area, and is usually the first species to migrate upstream in December–February. Another important cyprinid is the large species *Probarbus jullieni*, caught mainly in November–January when it is migrating to spawning sites or is actually engaged in spawning activity. Important catfishes include *Pangasius macronema* and *P. krempfi*. *Pangasius krempfi* is a diadromous species, spending much of its life in coastal waters of the South China Sea, but returning to the Mekong River to spawn.

3.8.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

Although a wide variety of fishing gear is available in this zone, the trend in recent years has been to use nylon monofilament gillnets as well as cast nets, hook and line, and some specialized nets for the deepest parts of deep pools. The majority of fish are now being caught with gillnets, which are very cheap and readily available. The traditional gears that are used in the Khone Falls area have to tolerate extreme conditions and the practice of fishing in the falls is a dangerous occupation.

3.8.4 TOLERANCES AND LIFE CYCLE CONDITIONS

The Khone Falls area is home to a number of fish species adapted to live in the turbulent waters around the falls. The Siphandone area is renowned for its rich fisheries, with at least 201 species known to reside in the area at least part of the year, many of which are of high commercial value.

3.8.5 TRENDS, THREATS, AND OPPORTUNITIES

There appears to be an increasing number of exotic fish being caught from deep pools by fishers. These are predominantly Chinese carps, tilapias and African catfish (and hybrids). There is a threat that these exotic species, which routinely escape from fish farms, may establish feral populations in certain parts of the Mekong system, marginalizing some indigenous fish species. The planned Lower Sesan 2 Dam on the Sesan River in Northeast Cambodia has the potential to significantly impact fish diversity and productivity of this ecozone.

3.9 TONLE SAP SWAMP FOREST AND LOWER FLOODPLAIN (KRATIE TO DELTA)

The most important of the ecozones in terms of fisheries, as it includes the Boeung Tonle Sap and the lower reaches of the tributaries; St Sreng; St Mongkol Borey; St Siem Reap; St Battambang; St Sangker; St Dauntri; St Pursat; St Baribo; St Chikreng; St Staung; St Chinit; St Sen and floodplain as well as the extensive floodplains south of Phnom Penh, including Prek Thnot and Siem Bok. The total area is estimated as 1,354,690 ha in area, although the inundated area varies greatly during the course of the year. The area of rivers in this zone is estimated at 74,726 ha. To the south there is a very small area of coastal waters included in this ecozone.

This zone has a long tradition of aquaculture, especially cage and pen aquaculture on the Great Lake. The temperatures are suitable (30°C mean daily maximum) for a wide range of warm water fish species to be cultured.

3.9.1 IMPORTANT FISHING AREAS AND HABITATS

The Tonle Sap Lake and surrounding floodplain are important year-round fisheries, peaking at the beginning of the dry season. The floodplains, made up of lakes, inundated riparian forest, marshes, small pools, inundated grasslands, and rice fields are vitally important to the productivity of the entire Mekong system. Permanent water areas are important as refuge areas and the flooded forest areas, although greatly reduced, remain an important fisheries habitat.

The productivity of the ecosystem is generally attributed to two of its particular characteristics: the flood cycle with extensive long-lasting floods, and the vegetation of the floodplain usually described as flooded forest. The natural floodplain habitats in this zone are generally in a better condition than in the floodplains south of Phnom Penh, which have largely been turned into rice fields and the flooded forest vegetation removed extensively. The migration of fish from the Tonle Sap Lake downstream through the Tonle Sap River is a major site for exploitation through the Dai fisheries.

A study of ricefields in Battambang Province, which during peak water levels are part of the Great lake, (Hortle et al. 2008) estimated fish and other aquatic animals (OAAs) production as 119 kg/ha. As this fishery is predominantly small-scale the value of products from ricefields is an important source of cash for rural households. Much of this catch is during the wet season, before the rice harvest, when income levels are low. As might be expected, deeper ricefield areas with longer flood duration produced the highest fish yields.

3.9.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

Estimates of the number of fish species in the Tonle Sap Great Lake range from 150-200 all of which are eaten and at least 70 of which are considered to be of important commercial value. Meynall (2012) predicts that there may be as many as 346 fish species found in the Tonle Sap.

Lamberts (2001) reports that the most important fish species by weight from the Tonle Sap are as follows: *Henicorhynchus* spp., *Channa micropeltes, Cyclocheilichthys enoplos, Dangila* spp., *Osteochilus melanopleurus, Cirrhinus microlepis, Pangasius* spp., *Barbodes gonionotus, Paralaubuca typus,* and *Channa striata.* Some of these species remain in the lake permanently, while many other species use the lake and the floodplain only temporarily and migrate back and forth to the Mekong. In addition to the high biodiversity of fishes, 23 snake species, 13 turtle species, and one crocodile species are still found in the Great Lake. In recent years, there has been unsustainable exploitation of the endemic watersnake *Enhydris longicauda* for use as both crocodile food (crocodiles are farmed commercially near the lake) and human food.

Of the study's 30 indicator species, 20 are found or likely to be found in this zone. These are *Bangana behri; Barbonymus gonionotus; Channa lucius; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Hypsibarbus malcolmi; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius pangasius; Pomacea canaliculata; Probarbus jullieni; Puntioplites falcifer; Scaphiodonichthys acanthopterus; Tor tambroides;* and *Trichogaster pectoralis.*

Fish catches from rice fields surrounding the Great Lake are important sources of food and are dominated by a number of Black Fish species, e.g., *Channa striata, Clarias batrachus, Macrognathus siamensis, Anabas testudineus, Trichogaster trichopterus, Monopterus alba* as well as the planktophagous *Rasbora* spp. Frogs, crabs, snakes, snails, and aquatic insects are also found in abundance in and around rice fields and are important food items.

Up until the mid-1990s there was a profitable bagnet fishery for *Pangasius* juveniles in Cambodian riverine waters, with much of the catch being sold to fish farmers in Vietnam. Through policy changes in Cambodia and breakthroughs in the induced breeding of *Pangasius* in Vietnam, this fishery has declined considerably.

Fish culture in and around the Tonle Sap is dominated by two species, *Channa micropeltes* and *Pangasius hypoththalmus*. Crocodile (*Crocodylus siamensis*) farming is also found around the Great Lake, particularly in Siem Reap, which also takes advantage of the abundance of low value fish and other aquatic animals such as snakes, at certain times of the year. The availability of a greatly increased diversity of fingerlings of fish species is offering farmers the opportunity to diversify their fish farming systems. Nowadays, hatchery-produced seed of *Pangasius* spp., *Macrobrachium,* and exotic products such as sex-reversed tilapia are becoming more widely available.

Aquaculture developed first in Cambodia due to the need to manage the gluts of fish that occur in many areas, at the end of the wet season. For many years, fish culture stayed close to sources of low value fish for feed and juveniles from the wild for stocking. Aquaculture therefore became a common activity in floating villages in the Great Lake and in terrestrial villages close to landing sites where low value fish is easily available. Peri-urban commercial-scale aquaculture of catfishes is common on the outskirts of Phnom Penh in Cambodia.

Until recently, poor infrastructure limited the distribution of fish feed, fingerlings, and the products of the industry. This has now changed as fish seed and technology for fish farming have become more widely available. Cage culture expanded greatly in the last two decades; for example, fish are held in hundreds of floating cages in the Great Lake and along the Tonle Sap and the Mekong near Phnom Penh. These fish are fed on the flood-recession excess of cheap wild fish, either directly or in fishmeal, which is one way of storing fish during times of abundance. The main hatchery centers for aquaculture seed are found in Phnom Penh and Prey Veng in Cambodia. Both public and private hatcheries operate.

3.9.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

The drawdown of the floodplain at the end of the wet season supports the harvesting of fish from rice fields and channels by countless rural households in Cambodia. The downstream multi-species migration from the Great Lake to the mainstream Mekong supports the commercially important bagnet fishery which peaks for short durations depending on the lunar cycle, between December and February each year.

More than 150 types of large and small-scale fishing gears are used in the floodplain and in the Tonle Sap. Deap et al. (2003) categorize fishing techniques and gears into 16 groups: capture by hand, scooping devices, wounding gear, hook & line, traps, gill nets/entangle nets, surrounding seine nets, dragged gears, push nets, lift nets/dip nets, covering devices, bagnets, anesthetic methods, pumping, attracting devices, and fish scaring methods.

During the dry season, pockets of water in ponds and wetlands may be pumped dry and the fish removed. This traditional practice has increased in efficiency due to the widespread availability of diesel water pumps. The loss of these fish refuges and their contribution to the fishery the following year has been recognized by the Cambodian FiA who has put in place a program to support the establishment and management of fish refuges throughout the country.

The previously lucrative capture of *Channa micropeltus* juveniles for cage aquaculture has recently been banned by the Cambodian Government, allowing for improved recruitment of this species. The use of low-value fish from the Great Lake for use in animal and aquaculture feeds is also now discouraged by the Cambodian Government.

The culture of fish in cages/pens in the Great Lake is one of the oldest aquaculture systems known in the world. In more recent times, pond aquaculture has become common on the floodplain. Both these types of aquaculture systems have relied heavily upon wild-caught juveniles and the availability of cheap, low-value fish to be used as seed. It should be noted that not all fish cages can be classified as aquaculture, as some cages are used for the storage of live fish prior to sale. Even though some food may be provided to these fish, no increase in the stock weight is anticipated.

In cage culture the most popular species are carnivorous, high-value snakeheads (Channidae), but river catfishes (Pangasiidae), walking catfish (*Clarias* species), and introduced fishes such as Nile tilapia (*Oreochromis niloticus*) are also commonly grown, being fed on fishmeal and rice bran. Pond culture in and around the Tonle Sap is also expanding, based on these species as well as some herbivorous fishes, but is still of very minor importance. Much of the cage aquaculture entails rearing of wild-caught fish or fingerlings, which are fed with small wild fish, often caught from the same fishery. Peri-urban pond culture of *Pangasius* and *Clarias* catfish is common around urban centers, particularly Phnom Penh due to its proximity to the Dai fishery and access to low-value fish for feed.

Perhaps because of the availability of hard wood, cage farmers in Cambodia continue to use wooden cages and wire mesh instead of synthetic materials, which are commonly used in other areas. Some farmers cite problems with puffer fish, *Tetronodon* spp., biting through plastic mesh materials. Rice fields in Cambodia have been used for wild fish collection for generations. However the practice of culturing fish in rice fields has not become established in this ecozone, perhaps because of the continued productivity of the rice field capture fishery.

3.9.4 TOLERANCES AND LIFE CYCLE CONDITIONS

In terms of productivity, the Great Lake floodplain fishery in this ecozone is considered robust and able to withstand high fishing pressure. In line with much smaller floodplains, key elements to maintaining this productivity are thought to be the fish refuge areas, where adult fish can withstand the dry season conditions, and the degree of connectivity of the system, which allows for the unhindered distribution of adults and juveniles during the wet season (Gregory 1997).

Water availability in floodplain areas, even close to the Great Lake, is a constraint to fish production in many locations in the dry season. Conversely, the inundation of ponds in a heavy flooding year is also a threat to fish farmers.

3.9.5 TRENDS, THREATS, AND OPPORTUNITIES

The greatest threat to the Great Lake and floodplain fishery lies in disruption to the 'pulse effect', i.e., the cycle of inundation, which fuels the fisheries productivity. If the extent and duration of the flooding is reduced (which could conceivably result from the operations of mainstream and tributary dams, upstream) then this is almost certain to result in a reduction of the productivity of the whole fishery system.

In recent years, the Cambodian Government has taken steps to try and improve the management of the Great Lake fishery and has handed over several of the fishing lots to communities, hoping for more sustainable management to result. Despite these steps, major declines in the numbers and sizes of the larger, slower maturing fish species, e.g., *Catlocarpio siamensis*, has been noted. Catches from the Great Lake and floodplain areas are now dominated by smaller, rapidly reproducing species.

The increased availability of *Pangasius* seed from hatchery-reared stock has boosted aquaculture in this ecozone. Several public and private hatcheries in Cambodia now produce seed for sale to the private sector.

The traditional use of low-value fish for fish feed is slowly changing as commercial feeds become more widely available, better quality and more affordable. The Cambodian Government policy is to reduce the dependence of aquaculture on trash fish. For carnivorous species, typically 5 kg of fish as feed is required to produce 1 kg of fish as product (Hortle et al. 2004). However, some farmers are reluctant to change to commercial diets and many choose to use them only as a maintenance diet during times when low-value fresh fish are unavailable.

Traditionally aquaculture has focused on the culture of *Pangasius* species and *Channa micropeltis*. This was due to the availability of undersized fish caught from the capture fishery that could be fattened and sold at a later time. In recent years 'new' species, such as the climbing perch (*Anabas testidudineus*) and *Clarias* catfish has become more popular and this diversification of culture species seems likely to continue.

In the recent past, the high-value fish species *Oxyeleotris marmorata* was cultured in small cages in rivers but this tricky practice appears to have declined in recent years, probably due to the reduced availability of juveniles from the wild. The successful breeding of *Macrobrachium rosenbergii* in Cambodia is creating new opportunities for aquaculture and the restocking of depleted water bodies with this species is a major government initiative.

3.10 DELTA FRESH WATER SWAMP FOREST (FRESH)

This zone contains relatively few wetlands (1,278 ha) but the influence of the river systems is important (53,509 ha). A small area of this zone is considered estuarine. Irrigated by an intricate system of canals and sub-canals linked to the river system, this extensive flat area supports a range of diverse freshwater aquaculture systems. Aquaculture has boomed in recent years due largely to the development of lucrative export markets for *Pangasius*. Growth in the sector is estimated as 20% per year between 2000 and 2008 (World Bank 2010). However, this may have now slowed.

3.10.1 IMPORTANT FISHING AREAS AND HABITATS

Capture fisheries is conducted throughout the rivers and canals and other wetlands in this zone. Although perhaps less important in present day due to the upsurge of aquaculture, these fisheries still remain important to many poorer households in the delta. The delta is the most important part of Vietnam's aquaculture production. In 2008, 75% of Vietnam's cultured fish production was from the delta. Much of this was from *Pangasius* culture in this ecozone. An Giang (especially around Chau Doc) and Dong Thap are important centers for *Pangasius* seed production. Can Tho and Vinh Long are also important centers for aquaculture.

3.10.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

Of the study's 30 indicator species, 18 are found or likely to be found, in this zone. *Barbonymus gonionotus; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Colossoma macropomum; Cyclocheilichthys enoplos; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Labeo rohita; Lates calcarifer; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius krempfi; Pangasius pangasius; Pomacea canaliculata;* and *Trichogaster pectoralis.*

The following White and Black Fish species are important commercially in this ecozone: *Cirrhinus jullieni, Puntioplites proctozysron, Paralaubuca spp., Somaniathelphusa sinensis, Puntius leiacanthus, Pristolepus fasiatus, Puntius goniotus, Anabas testudineus, Channa striatus,* and *Macrobrachium equidens*.

A 1992 floodplain fisheries survey conducted at two sites at Binh Long and Phu Thanh found more than 50% of the catch at Binh Long was Cyprinidae including *Cirrhinus jullieni, Puntioplites proctozysron, and Paralaubuca spp*. At Phu Thanh, crabs (*Somaniathelphusa sinensis*) and the snakehead (*Channa striatus*) dominated the catch.

Aquaculture is dominated by *Pangasius* spp., primarily *P. hypopthalmus* as *P. bocourti* culture is now less popular. Cage aquaculture of *Pangasius* has been practiced since 1960 using wild-caught juveniles predominantly from Cambodia. The successful breeding of *P. hypopthalmus* in 1996 and effective technology transfer to farmers revolutionized the industry by reducing its dependence on wild-caught seed. Other indigenous species, *Anabas testudineous, Channa striatus, Trichogaster pectoralis, Barbodes gonionotus,* and *Macrobrachium roesnbergii,* are cultured in this ecozone along with the exotic species *Cyprinus carpio, Labeo rohita,* and *Pachu*. Some of these species can also be cultured in cages in this ecozone, sometimes in polycultures but not normally in the same cages as *Pangasius*.

3.10.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

Traps and fyke nets are commonly used gears in the floodplain areas of this ecozone. Seine nets are also used. Fishery surveys carried out in the delta provinces of An Giang and Tra Vinh show that respectively 66% and 58% of households were part-time and respectively 7% and 4% full-time involved in fishing in 1999 and 2000 (Sjorslev 2001). Most of the catch is for home consumption. Overall fish consumption in the Vietnamese parts of the LMB was estimated to be 1,021,700 tonnes annually (Sjorslev 2001). This estimate includes other aquatic animals and fish from aquaculture, but excludes sea fish.

Over the past decades, the traditional aquaculture systems used in the Mekong Delta, such as rice fish and livestock fish-integrated systems for domestic consumption, have been replaced by intensive *Pangasius* farming systems aimed at export markets. Many of the traditional ponds were created through families excavating earth for the raising of a small land area for their homestead or for embankments.

Intensive *Pangasius* culture in floating wooden cages and bamboo pens has become less popular in recent years and pond culture in riverside and canal-side ponds is now preferred. *Pangasius* farming in ponds can be highly productive. However, it remains a mostly small-scale activity with typical pond areas of around 0.4 ha and less than 10% of farmers reported as having more than four ponds. The traditional farming of fish in rice fields is still present in this ecozone and often uses the indigenous species *Trichogaster pectoralis* and *Macrobrachium roesnbergii* as well as the exotic *Cyprinus carpio.* The traditional system of siting latrines over *Pangasius* fishponds has been discouraged by the authorities in Vietnam for several years and is now less acceptable as a practice.

3.10.4 TOLERANCES AND LIFE CYCLE CONDITIONS

Relatively low yields (<80 kg/ha/year) estimated for the Phu Thanh area may be the result of low water pH, as this floodplain is located on acid sulfate soils that have been disturbed following the excavation of irrigation works in the recent past.

The average temperature of this zone (32°C mean daily maximum) and the low range make it a highly suitable area for aquaculture. *Pangasius* performs well at around 30°C due to increased metabolic rates and appetite. This results in a shorter growing period. *Pangasius* are tolerant of poor water quality conditions including high suspended solid loadings and low levels of dissolved oxygen. *Pangasius* are air-breathing fish and can tolerate water with very low oxygen content. This leads to very intensive culture, 45–50 individuals/m^3 in ponds and 70–80 individuals/m^3 in cages and pens, resulting in inevitable problems with diseases and the discharge of harmful effluents from ponds creating problems for the wider environment.

3.10.5 TRENDS, THREATS, AND OPPORTUNITIES

Although data are scarce, the trend for capture fisheries in this ecozone is almost certainly downward. This is not helped by the rapid development of aquaculture in the zone, which may now bias attention from fisheries specialists. Pollution from intensive aquaculture during the low flow periods may also have an adverse effect on capture fisheries. A number of exotic fish species have established feral populations in this ecozone, including the Pacu (*Collossoma sp.*), probably through escapes from cage farms.

Due to the intensive aquaculture systems practiced, *Pangasius* culture area accounts for only a small percentage of total aquaculture area of the delta if compared with shrimp farming and other extensive aquaculture systems. However, there are indications that limits to the levels of intensity and production may have been reached and suggestions that the sector may be in decline due to falling export demand, increased production costs, and marginal economic benefits to farmers. The declining economic viability of *Pangasius* farming has in recent years forced many *Pangasius* farmers out of business.

Large parts of this zone are at risk of flooding from the Mekong River during the end of the rainy season, particularly An Giang & Don Thap. Farmers manage their ponds and stocks in ways to limit their exposure to this threat—e.g., *Pangasius* farmers. Sea level rise and increased rainfall will increase this threat level. An increment of 2–2.5 m of water during the wet season is projected to affect 62% of catfish ponds in An Giang. Increased flooding during the rainy season will require higher pond embankments and increased farm construction & maintenance costs. The SIWRP model simulates water flow through the existing complex system of canals, embankments, and sluices. This model suggests an expansion of the water levels of 3m in the northern freshwater areas of the delta. To an extent, polderization and embankment work aimed at protecting rice-growing areas in this zone will also benefit fish farmers.

Lower rainfall during the dry season and increased air temperatures will result in increased evaporation losses from inland and coastal ponds. This is likely to result in increased demand for freshwater to compensate. However, hydro-electric schemes planned for the Mekong and tributaries may well result in an increase in dry season flows in the Mekong by 10% to 50% and decrease wet season flows by 6% to 16%. This could compensate for increased demand for dry season freshwater.

The World Bank (2010) EACC study suggests that the direct economic impact of climate change on *Pangasius* farming will be strongly negative. Without adaptation, net incomes will likely fall by 3,000 million Vietnamese Dong (VND) per ha by 2020. By 2050 losses could be three times this amount. These losses could be offset by progress on selective breeding programs for salinity tolerant *Pangasius*; improved feeds and feed conversion ratios; and the consolidation of value chains through vertical integration of industry. In addition, new species for culture such as *Hemibranchus brachysoma* has a wider temperature tolerance range and could have potential once upper temperature limits for *Pangasius* culture have been reached.

3.11 DELTA PEAT SWAMP FOREST (BRACKISH)

This ecozone contains significant wetland areas comprising 49,174 ha, which alternate between fresh and brackish water, depending on the time of year. The ecozone also contains 49,431 ha that are coastal and therefore brackish/saline for longer periods. The area of rivers is minimal (91 ha). Although this ecozone is characterized by brackish water conditions, during the wet season much of the zone is fresh. Temperatures are highly conducive for aquaculture (32°C mean daily maximum) and with low variability.

3.11.1 IMPORTANT FISHING AREAS AND HABITATS

The northeastern part of the delta includes a part of the Plain of Reeds, a vast wetland depression of about 1.3 million ha that is an important freshwater fishery providing refuge areas for both Vietnam & SE Cambodia. *Melaleuca* forests in freshwater wetlands in this ecozone are important fish breeding and nursery areas during the wet season. In this brackish water zone, fish, crabs, and prawns migrate within and across the saline transition zone from fresh to saltwater. Some are undertaking long migrations, such as the giant freshwater prawn (*Macrobrachium rosenbergii*), which migrates to freshwaters in Cambodia.

Aquaculture in this zone is mixed with the pond culture of *Pangasius* common in the northern (fresher) parts of this ecozone while Penaeid shrimp culture is more common in the southern parts of the ecozone, particularly around Ca Mau. *Macrobrachium* and a range of freshwater fish (during the wet season) are cultured throughout the ecozone.

3.11.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

WWF estimates that there are more than 400 fish species caught in the Mekong Delta. Black Fish species tend to predominate in this fishery due to the low levels of oxygen found in many habitats. Commonly found species include Snakehead (*Channa striatus*), catfishes, (*Clarias batrachus, C. macrocephalus*), Anabantids, climbing perch (*Anabas testudineus*), and spiny eels (*Mastocembalus* spp.).

Of the study's 30 indicator species, 21 are found or are likely to be found in this zone. These are *Anadara granosa; Barbonymus gonionotus; Channa striatus; Cirrhinus microlepis; Clarias batrachus; Colossoma macropomum; Cyclocheilichthys enoplos; Cyprinus carpio; Hemibagrus nemurus; Henicorhynchus siamensis; Labeo rohita; Lates calcarifer; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius krempfi; Pangasius pangasius; Penaeus monodon; Pomacea canaliculata; Pseudapocryptes elongates;* and *Trichogaster pectoralis.*

While there is some *Pangasius* culture, shrimp and prawn production is more important to aquaculture in this ecozone. In recent years due to breakthroughs in breeding techniques, the giant freshwater prawn, *Macrobrachium rosenbergii*, has become an important species economically. According to Sinh (2008), in 2006 the total culture area of *M. rosenbergii* in the Mekong Delta was 9,077 ha and production was around 9,500 tonnes. More than one hundred hatcheries are active and producing more than 400 million post larvae annually. Tilapia is growing in importance due to its salinity tolerance.

3.11.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

Traditional gears used in the floodplains of this ecozone include trap ponds in rice fields, bamboo traps in rice-farming canals, gill netting in rice fields and mini bag nets between rice fields. Larger-scale gear, such as bag nets are used in the bottlenecks in fish migration routes. A number of illegal gears are commonly used in this zone including electro-fishing gear.

Aquaculture systems have evolved to take advantage of the changing salinity conditions. Most aquaculture in this ecozone is carried out in ponds or flooded fields. *Macrobrachium* is cultured throughout this ecozone in rice fields, ponds, orchard gardens, and in pens along river banks. Some farmers adopt a rotational system of rice and prawn in this ecozone. The 2002 production of *M. rosenbergii* based on aquaculture reached over 10,000 tons per year.

3.11.4 TOLERANCES AND LIFE CYCLE CONDITIONS

Saline intrusion limits some fisheries and offers opportunities to others. The freshwater fisheries depend on the continued existence of refuge areas (small ponds, canals, and wetlands) which do not dry up during the dry season and in which adults of key species such as snakehead and catfishes can survive until the inundation of the floodplain. Conversely, interference with the diurnal flooding of mangrove areas will affect species adapted to this environment.

Species grown in this ecozone tend to be saline tolerant due to the changing conditions through the year. For example, *Pangasius* can tolerate salinities of 6 ppt. Soil conditions are also an important factor. Sulfur toxicity is found, particularly in the low-lying acidic areas in which 65% of the soil is affected. Low pH waters are less suitable for pond aquaculture of carps and tilapias as plankton blooms are difficult to generate, although these can be corrected to a degree by the timely application of lime.

3.11.5 TRENDS, THREATS, AND OPPORTUNITIES

The capture fisheries of this ecozone are generally regarded as being in decline, as indicated by reductions in catch per unit effort. For example, in Tien Giang, Vietnam, a large decline in catches is associated with construction of a dike to cut off saltwater flow into mangrove habitat so it could be used for rice farming. Estuarine fish and other animals rely on these intertidal habitats for feeding so impacts on fisheries are to be expected and are widely reported. In addition, a number of other factors are thought to be negatively affecting the fishery:

- The permanent loss of wetlands through urban expansion
- The conversion of wetland areas for rice farming and the use of pesticides in rice crops adjacent to dry season refuges
- The targeting of dry season refuge areas by fishermen including the de-watering of them by pumping, which impacts the productivity of the local fishery
- Paradoxically, the conversion of wetlands for fish production through aquaculture

In the southern part of this ecozone, conflict situations between rice and shrimp farmers are common due to their differing water quality requirements. Rice farmers require freshwater for irrigating rice in the dry season, while shrimp farmers require brackish water during this low-flow period. In dry years, rice farmers suffer through being unable to clean the salt from their fields. In wetter years, shrimp farmers struggle to get enough salt into their systems. Climate change may exacerbate this situation leading to increased disagreement and possible conflict. Sea level rise may well result in an expansion of the brackish water area suitable for shrimp farming and the retreat of freshwater prawn and fish systems northwards.

3.12 DELTA MANGROVES (SALINE)

This ecozone is saline for the majority of the year due to the large coastal area, which comprises 121,689 ha. Freshwater wetlands are minimal (1,535 ha) but 11,275 ha of river area is included. The ecozone is dominated by the estuarine and coastal fishery, which includes extensive mangrove areas.

As with the other parts of the Mekong Delta, the temperatures are suitable for aquaculture (32°C mean daily maximum). This ecozone is saline for much of the year. Delta erosion/retreat is estimated at 30–50 m a year in the eastern areas facing the South China Sea, while deposition and shoreline accretion in the west is as high as 70–100 m a year in areas facing the Gulf of Thailand.

3.12.1 IMPORTANT FISHING AREAS AND HABITATS

The nutrients and organic material in the Mekong's plume support a significant coastal fishery. This organic material supports clam production on mud flats and mangrove areas for shrimp and crab fisheries. In recent years, Soc Trang and Bac Lieu have become important areas for juvenile mudskipper collection.

The Ca Mau peninsula, Bac Lieu, Soc Trang, Tra Vinh, and Ben Tre are important shrimp farming provinces. Bivalve production (mainly blood cockles and clams) occurs in mud flats off Ben Tre, Tien Giang, Tra Vinh, Soc Trang, and Kien Giang. At present, mud skipper culture is centered on Bac Lieu and Soc Trang.

3.12.2 IMPORTANT SPECIES (ECONOMIC AND FOOD SECURITY)

Of the study's 30 indicator species, 12 are known to or are likely to inhabit this ecozone. These include *Anadara granosa; Channa striatus; Lates calcarifer; Macrobrachium rosenbergii; Mastocembalus armatus; Oreochromis niloticus; Pangasius krempfi; Pangasius pangasius; Penaeus monodon; Pomacea canaliculata; Pseudapocryptes elongate;* and *Trichogaster pectoralis.*

Mekong marine fisheries are a productive component of the Mekong system and are dependent on the nutrient and sediment dynamics of the river. The Mekong marine fishery is a significant component of the Vietnamese delta economy, with a production in the order of 500,000–726,000 tonnes per year. Important families of fish harvested commercially in this ecozone include Clupeidae, Carangidae, and Scombridae. In addition, shrimp (tiger shrimp, *Penaeus monodon*, pink shrimp, *Metapenaeus ensis,* white shrimp, *Penaeus merguiensis),* crabs, *Scylla serrata,* and mollusks (cockles, mussels, and clams) are also economically important in this ecozone.

A wide variety of low-value fish species (mainly demersal species but with some pelagics) for use in livestock or aquaculture feeds are exploited. Spoiled higher-value species may also be used as trash fish. Most trash fish from coastal waters is from trawling, hence one of the common names in Vietnamese for trash fish, "trawling fish". The major trash fish species by area are anchovy (*Stolephorus* spp.), lizard fish (*Saurida* spp.), and pony fish (*Leistognathus* spp.) (Edwards et al. 2004).

Since 2001 a profitable fishery has grown up around the capture of wild mudskipper, *Pseudapocryptes elongates*, destined for aquaculture. Juveniles of the mudskipper are caught in bagnets during spring tides.

Aquaculture in this zone is dominated by the farming of tiger shrimp (*P. monodon)*. However, the difficulty in managing WSSV (White Spot Syndrome Virus) is resulting in a shift towards other shrimp species, and since 2008 white shrimp (*Litopeneaus vannamai*), which was introduced in the late 1990s, has been promoted in 'safe aquaculture zones'. Other marine species are cultured in this ecozone including the mud crab (*S. serrata*) and a wide range of mollusks on tidal mudflats fringing the coastal provinces. In recent years, the culture of mudskippers has gained in popularity. The cage culture of marine fish (spiny lobster, grouper, and cobia species) occurs mainly in Kien Giang Province.

3.12.3 FISHING SYSTEMS (COMMERCIAL AND SMALL SCALE)

The main gears used in the commercial coastal fishery are the trawl net, gill net, encircling net, longline, stow net, and scrape net. Large coastal ponds are used for shrimp culture. Tiger shrimp ponds account for nearly 75% of the aquaculture area of the delta. The ponds rely on tidal water exchange. Traditionally, these systems relied on natural stocking of wild seed but most are now stocked with post larvae from hatcheries. Fertilizers are used to promote natural food production. Smaller ponds with more intensive stocking and formulated feeds are found. These rely on pumps and aeration and are significantly higher risk ventures than the traditional system. Integrated shrimp & mangrove farms have become established in southern Camau. In these, the culture of shrimp in conjunction with mud crab and brackish-water fish is practiced.

3.12.4 TOLERANCES AND LIFE CYCLE CONDITIONS

Although tiger shrimp are tolerant of a wide range of salinities (their optimum salinity is 25 ppt), they are vulnerable to rapid changes that lower salinity and temperature caused by heavy rainfall or sea water inundation. This is thought to result in outbreaks of WSSV in tiger shrimp and can cause significant mortalities. Increased salinities in shrimp ponds are expected as a component of climate change, particularly in areas unprotected by coastal embankments as is the case from Tra Vinh to Ca Mau.

3.12.5 TRENDS, THREATS, AND OPPORTUNITIES

As with much of Southeast Asia's coastal waters, the Mekong Delta inshore fishery is considered over-exploited and is an example of the phenomenon known as 'fishing down the food chain', whereby smaller and smaller fish of lesser and lesser value are targeted. This has resulted in a fishery that focuses increasingly on 'trash fish'.

The degradation of mangrove areas through deforestation and polderization of lands has affected the coastal fishery in this zone. The area of mangrove forests in the region has been reduced especially in Tra Vinh Province. Between 1965 and 2001, the total coverage of mangrove forests decreased by 50%.

The loss of nutrients, either dissolved or in organic silt, from the plume of the Mekong/Bassac will certainly diminish productivity in the near-shore areas and to a lesser extent in the off-shore areas. Sediment retention by dams is expected to have a major impact on coastal fish production, and subsequently on the Vietnamese fishing sector and fish trade. This could also impact on the delta aquaculture sector which is still dependent on protein from marine 'trash fish' (ICEM 2010).

The World Bank EACC study suggests that the direct economic impact of climate change on shrimp farming in 2020 will be negative. Without climate change adaptation measures, net incomes are likely to fall by 130 million VND per ha rising to 950 million VND per ha by 2050. Increased temperatures and fluctuating salinities are likely to add to the stress conditions already affecting shrimp culture. Future projections of the profitability of shrimp culture do not look positive. However the trends do not look as unfavorable as for *Pangasius* farming in the freshwater parts of the delta.

The World Bank study also suggests that sea level rise will be higher along the coastline facing the South China Sea where most of the brackish water shrimp ponds (Tra Vinh to Bac Lieu) are located. This will require additional investment in infrastructure. However, these investments may be countered by the increased severity and frequency of cyclones and storms that will affect exposed coastal aquaculture sites; and lead to increased wave erosion on pond embankments and higher tides affecting the drainage of inland waters. These factors will involve increased pumping costs to control pond levels and water exchange.

In the past, the growth of shrimp production in the Mekong Delta has resulted in conflicts between rice farmers and shrimp farmers over water. To expand the freshwater zone for rice production, the government has invested in dams and sluice gates on the Ca Mau Peninsula to block inflows of the brackish water which is critical for producing shrimp. Conflict situations can result, e.g., in 2001 in Bac Lieu Province shrimp farmers destroyed a major diversion to allow the flow of brackish water inland to service their production systems.

SECTION 2
CLIMATE CHANGE VULNERABILITY AND ADAPTATION

This section presents the methodology and results of the LMB fisheries vulnerability assessments. They were carried out using the Climate Change Vulnerability Assessment and Adaptation Methodology (CAM) (ICEM 2012) for six climate change hotspots identified by the USAID Mekong ARCC Climate Change Study (Chiang Rai, Khammouan, Gia Lai, Mondulkiri, Kien Giang, and Stung Treng). Having assessed these areas for capture fisheries and aquaculture vulnerability, adaptation approaches are discussed. This section also examines the linkages between the fisheries sector and the other sector foci in the USAID Mekong ARCC study. Finally, the section discusses other development pressures on the LMB fisheries and how adaptation strategies must also take these additional challenges into account.

I VULNERABILITY ASSESSMENT METHODOLOGY

The CAM method is a systematic approach to assessing fisheries vulnerability to climate change. It involves a framework of questions in the context of (1) species/type of aquaculture system, (2) locality/ecozone, and (3) type of climate change threat to identify which components of the fishery or aquatic system are likely to be most vulnerable to climate change.

An overlay of catchments on the study's ecological zones (Appendix 1) and hotspot areas (Appendix 2) allows for approximations of those species that are likely to be found in a given location. The hotpots selected were not chosen from a fisheries or aquaculture perspective but from a number of considerations in terms of the extent of anticipated climate change, e.g., temperature increases, and the cumulative importance to all sectors considered in the study. As a result, a Tonle Sap province was not selected, which is perhaps regrettable from a fisheries perspective.

At the heart of the Fisheries CAM is the Aquatic Species Database. From this database, indicator species representing a range of fish types can be used as proxies to visualize what specific climate change threats might mean for the wider group.

Typically, three capture fish and three cultured fish species have been used in the CAM for each hotspot. Overall, the number of high or very high vulnerability ratings for each proxy species or system in each hotspot provides an impression of the overall vulnerability of that area's fisheries to climate change.

The database currently holds information on 30 aquatic species from a range of Mekong environments consisting of upland, migratory, black, estuarine, and exotic/invasive species. During presentation of this model at workshops it was felt that the approach could be strengthened by adding a new category of fish termed Grey Fish (short-migratory species). The database also includes information on current IUCN status ranging from 'endangered' to 'of least concern'. Some of these species are important in the Mekong's capture fisheries, some in the aquaculture systems, and some in both. Information on biology, migration, and water quality tolerances, where it was available, has also been entered into the database.

While information on cultured fish species is quite plentiful, far less is known about the biological requirements for many of the capture fish species. So the CAM database is far from complete. The continuous addition of new information enrichment of the species (and systems) databases and verification of the ecological zone check list would allow for better judgments to be made and would strengthen the approach.

CAM analysis for key fish species representing upland, white, black, and estuarine groups as well as aquaculture systems (and species) were conducted for the five hotspot provinces (Chiang Rai, Khammouan, Gia Lai, Mondulkiri, and Kien Giang. A CAM was also conducted for three fish species based on the anticipated hydrological changes for Stung Treng Province.

During the course of discussions for the study, six hypotheses had been developed as being likely responses of different fish types and systems to climate change in the LMB. The CAM methodology enables these hypotheses to be examined in the hotspot areas, in a more systematic way.

The hypotheses to test are as follows:

1. Upland fish would be vulnerable to climate change
2. Migratory white fish would be vulnerable to climate change
3. Black fish would be more 'climate-proof' than other fish types
4. Invasive species will tend to become more prevalent through climate change
5. Aquaculture would be more vulnerable to climate change than capture fisheries
6. Intensive aquaculture would be more vulnerable to climate change than semi-intensive or extensive systems

2 VULNERABILITY ASSESSMENT RESULTS

2.1 SUMMARY

Table 3 highlights the 'high' and 'very high' vulnerabilities generated from the CAM analysis for capture fisheries and aquaculture in the five hotspot provinces.

Overall, the analyses suggest that with the exception of aquaculture in the upland hotspots **increased temperatures will have significant impacts on elements of the capture fisheries and aquaculture systems** affecting food security and the livelihoods of the people living in these areas.

Droughts and reduced water availability through decreased precipitation will be more manageable by some species and aquaculture farmers in some areas, but will seriously impact others. Storms and flash flooding will likely affect the viability of aquaculture systems, more so than slow-paced flooding, which allows for greater adaptability.

Vulnerabilities appear to exist in all five of the hotspots. Fisheries in Chiang Rai, Gia Lai, and Mondulkiri will be impacted at a significant level and the aquaculture systems of Kien Giang are particularly at risk.

The projected changes in the hydrology of the Mekong at Stung Treng and Champasak appear unlikely to be major challenges for the migratory fish species that dominate the capture fisheries of these areas. However, the hydrological changes to river flows and levels caused by the construction of mainstream and tributary dams will likely completely mask the changes in river hydrology caused by increased precipitation throughout the catchment.

Table 3: Main climate change threats in the hotspot areas

Hotspot	Production System	Increased temperatures	Increased precipitation	Decrease in precipitation	Decreased water availability	Drought	Flooding	Storms and flash flooding	Sea level rise	Increased salinity
Chiang Rai	Fisheries									
	Aquaculture									
Gia Lai	Fisheries									
	Aquaculture									
Khammouan	Fisheries									
	Aquaculture									
Kien Giang	Fisheries									
	Aquaculture									
Mondulkiri	Fisheries									
	Aquaculture									

The shaded areas show which climate change threat is of concern in each of the hotspot provinces.

2.2 VULNERABILITY AT THE HOTSPOT LEVEL

Table 3 does not illustrate the subtleties of the CAM analyses, which are best viewed at the individual hotspot level. Summaries for each of the hotspot provinces follow. Full details of the analyses for each species and ecozone can be found in the annexes to this report.

Chiang Rai

Capture fisheries	○ **Upland fish species appear most vulnerable to increased temperatures, decreases in rainfall, and flash flooding** ○ **White fish species appear most vulnerable to increased temperatures and decreases in rainfall** ○ **Black fish species appear less vulnerable to the changing conditions**
Aquaculture	○ Intensive catfish pond systems are vulnerable to increased water temperatures, decreased water availability, droughts, flooding, and flash flooding ○ Semi-intensive polyculture systems are vulnerable to increased water temperatures, decreased water availability, droughts, flooding and flash flooding ○ Extensive polyculture systems are vulnerable to decreased water availability, droughts, and flooding

Gia Lai

Capture fisheries	○ **Upland fish species appear most vulnerable to increased temperatures and decreases in rainfall** ○ **White fish species were not identified** ○ **Black fish species appear less vulnerable to the changing conditions**
Aquaculture	○ Intensive catfish pond systems are vulnerable to flooding and flash flooding ○ Cage aquaculture of cyprinids are vulnerable to storms

Khammouan

Capture fisheries	○ **Upland fish species appear less vulnerable to changing conditions** ○ **White fish species appear most vulnerable to increased temperatures** ○ **Black fish species appear less vulnerable to the changing conditions**
Aquaculture	○ Intensive catfish pond culture is vulnerable to decreases in water availability, flooding, and storms and flash floods ○ Extensive pond culture of carps is vulnerable to decreases in water availability, flooding, and storms and flash floods ○ Extensive pond culture of tilapias is vulnerable to storms and flash floods

Kien Giang

Capture fisheries	○ **Estuarine species appear most vulnerable to increased temperatures and flash flooding** ○ **Invasive aquatic species such as the Golden Apple Snail will benefit from the changing conditions, possibly at the expense of some indigenous species**
Aquaculture	○ Semi-extensive inland pond aquaculture of prawns is vulnerable to increased temperatures, increased precipitation, decreased water availability, and drought ○ Intensive coastal aquaculture of shrimp is vulnerable to increased temperatures, increased precipitation, storms and flash flooding, and sea level rise

Mondulkiri

Capture fisheries	○ **Upland fish species appear vulnerable to increased temperatures, decreases in rainfall, and flash flooding** ○ **White fish species appear vulnerable to increased temperatures and decreases in rainfall** ○ **Black fish species appear less vulnerable to the changing conditions**
Aquaculture	○ Semi-intensive catfish pond aquaculture is vulnerable to flooding and storms, and flash floods ○ Extensive pond polyculture aquaculture is vulnerable to increased temperatures, decreased water availability, flooding and storms, and flash flooding

Stung Treng (Hydrobiology)

Capture fisheries	○ **Large migratory species do not appear very vulnerable to the anticipated changes** ○ **Small migratory white fish species do not appear at all vulnerable to the anticipated changes**
Aquaculture	N/A

2.3 HYPOTHESES RESULTS

Returning to 'the six climate change hypotheses', the CAMs provide some indication as to which of them hold true in the five provinces considered in more detail by the study.

Table 4: Hypotheses results

Hypothesis	CR	GL	KH	KG	MK	Overall
1. Upland fish would be especially vulnerable to climate change	true	true	false	n/a	true	supported
2. Migratory white fish would be vulnerable to climate change	true	n/a	true	true	n/a	supported
3. Black fish would be more 'climate-proof' than other fish types	true	true	true	n/a	true	supported
4. Invasive species will become more prevalent through climate change	n/a	n/a	n/a	true	n/a	supported
5. Aquaculture would be more vulnerable to climate change scenarios than capture fisheries	true	false	true	true	true	supported
6. Intensive aquaculture would be more vulnerable to climate change than semi-intensive or extensive systems	false	true	false	false	false	not supported[6]

[6] The CAM does not support this hypothesis. The vulnerability of even the extensive aquaculture systems is noticeable. Climate change will likely affect intensive, semi-intensive, and extensive aquaculture systems similarly.

3 ADAPTATION STRATEGIES FOR THE HOTSPOT PROVINCES

Through the CAM vulnerability assessment we have identified those types of fish and aquaculture systems that are the most vulnerable in each of the hotspots and the specific impacts that require an adaptation response (see table below). Specific threats to proxy species and aquaculture systems for each hotspot can be found in the annexes.

Table 5: Summary of 'very high' and 'high' vulnerability for species and systems by hotspot

Hotspot	Capture fisheries species	Aquaculture system
Chiang Rai	• Upland fish • Migratory white fish	• Intensive pond catfish • Semi-intensive pond polyculture • Extensive pond polyculture
Gia Lai	• Upland fish	• Intensive pond catfish • Cage aquaculture
Khammouan	• Migratory white fish	• Extensive pond culture, silver barb • Extensive pond culture, tilapia • Semi-intensive pond culture, *Pangasius*
Kien Giang	• Estuarine fish including mollusks • Inland freshwaters threatened by the invasive Golden Apple Snail	• Inland freshwater extensive prawn ponds • Coastal semi-intensive shrimp ponds
Mondulkiri	• Upland fish • Migratory white fish	• Semi-intensive pond, catfish • Extensive pond polycultures

The following sections suggest possible measures that can be employed to lessen the effects of climate change on the capture fisheries and aquaculture systems most at threat.

3.1 CAPTURE FISHERIES ADAPTABILITY

Identifying adaptive climate change measures that can reverse declines and protect resources and stocks for the capture fisheries faces four challenges.

First, the overriding influence on the capture fisheries of the Mekong will be the development of dams for hydropower with climate change being something of a side issue; potentially important but more subtle with its effects. It is all very well to talk about the effect of increased temperatures on migratory fish in the upper Mekong, but that assumes that migratory fish can reach these areas. The planned dams may make some climate change considerations all but academic. The second challenge is that capture fisheries by their nature are open systems, and their productivity depends more on natural variations than on planned controlled management. Third, the sheer size of the capture fisheries areas means that adaptation actions to be effective would need to be large scale and therefore probably expensive. Last, given the extensive 'noise in the system', which affects year-on-year production from the capture fisheries, measuring the impact of any adaptation effort is likely to be a considerable challenge.

In the Southeast Asia region, there is a growing trend towards encouraging fishery managers to adopt ecosystem-based approaches to fisheries management, i.e., fisheries management that focuses on stocks and the environment; not just stocks. This approach will likely become increasingly important as the climate warms and weather patterns become more unpredictable.

For each of the various fish types, the following recommendations for adaptation measures are suggested. For upland fish, in order to protect the stream environments, forest cover should be retained or recovered. Protection of the small valley catchments is needed to reduce the effects of flash flooding so that the specialist upland fish species can remain prolific. These streams should be maintained and/or improved to preserve alternate shallow, fast-flowing areas to increase dissolved oxygen levels; and deeper pools in which fish can rest when conditions dictate. As a restoration or enhancement measure, new pools can be created by diverting currents. These pools require occasional de-silting in order to stay attractive to fish. Low weirs can also be used to retain water in some areas. The creation of varied habitat areas along the stream course will provide refuges and allow for more varied species to co-exist. All of these measures can be found in basic trout stream habitat improvement manuals for Europe and the US. These technical measures would have to be accompanied by the establishment of conservation zones where local people did not fish at certain times of the year. Support to communities to manage their own upland fisheries for sustainable use should be encouraged. The organized trapping of invasive species may also become necessary.

For migratory white fish, the focus should be on improving their access to spawning grounds and the habitats in those areas. This includes restoration of the flooded forests around the Tonle Sap and lower Mekong, which are vital to the health of the fishery and the migratory species that live there. This may mean the seasonal dismantling of some structures in the tributaries that prevent the movement of these fish species, such as small-scale hydro or irrigation installations. The seasonal protection of stocks in the deep pool areas of the mainstream should also be promoted in the communities who depend on these resources. Involving communities in recording catches for specific migratory species should be done so that trends in fish numbers and sizes can be noted. Where populations of endangered fish cannot be supported through habitat and fishing protection, their artificial propagation in hatcheries and the subsequent release of juveniles into the capture fishery can help maintain viable fish populations. This is already being done by the Fisheries Department in Thailand in the case of the giant Mekong catfish (*Pangasionodon gigas)*.

While the black fish species of the LMB do not appear particularly vulnerable to the changing climatic conditions, steps can still be taken to ensure their biodiversity remains intact and their contribution to productivity remains high. The single most important management intervention for these fish species is the creation and management of dry season refuge areas, from which they can repopulate the flood plains each wet season. The creation of reservoirs through damming of Mekong tributaries will almost certainly damage parts of the fishery; they will also create new environments that may suit these types of fish. Fish catches from these new environments could contribute significantly to local food security and livelihoods.

For estuarine species, the replanting of mangrove forests in coastal areas can do much to protect against sea level rise and storms and associated erosion, and thereby help maintain fish biodiversity and production. Non-interference with natural tides and current patterns is also required to ensure that mangrove areas remain healthy and able to support the estuarine fishery. Certain areas must be protected from both fishing and wood collection. Special protection measures may be necessary for some sedentary species such as mollusks. This might entail the installation of substrates, followed by seeding of spat, in these new areas. Co-management of coastal fisheries involving communities and government may be practical and effective in some cases.

The monitoring of invasive aquatic species should be done at varying levels (community and government) to plot the spread of species considered harmful to the wider environment. Eradication drives may be necessary to keep some invasive populations in check. Community awareness of invasive species should be raised through a range of media and people need to be encouraged to report unusual sightings and catches.

For all fish types, a number of key species, considered the most valuable and vulnerable to climate change, will require specific protection and enhancement measures. These adaptations will need to be species- and habitat-specific and will need to be integrated with programs to reduce fishing pressure on these valuable stocks. While communities must be involved in such initiatives, they may need to be initiated by government departments, possibly supported with fishery laws aimed at protecting the most vulnerable species. There is a need for increasing efforts for key species protection, particularly those that appear most vulnerable to climate change. The breeding of some of the most vulnerable species for re-introduction (e.g., *Pangasionodon gigas*) has been successfully done in Thailand since the 1980s and future populations of this fish may become entirely dependent on the release of hatchery-produced juveniles.

Finally, despite the threats and uncertainties, it should be remembered that fishing communities in Southeast Asia are extremely resilient to the vagaries of the weather and seasons, which in the case of the Mekong River and floodplain are already extreme. There will be an inherent capacity to adapt and change practices based on the prevailing conditions of the time. So their 'management window' is wide.

The uncertainty is whether climate change will push some communities into areas where their traditional management tricks and mechanisms no longer work.

3.2 AQUACULTURE

Aquaculture, due to its diversity of systems, scales of production, inherent manageability, and control of environments, offers more scope for adaptation to climate change than capture fisheries.

The more intensive systems will tend to have the greatest adaptive capacity due to the high level of investment and management (although there are limitations). The vast majority of aquaculture practiced in the LMB is extensive or semi-intensive and is open to the elements with little contingency for managing climate change issues outside of a few simple preventative measures. These may be enough for the present and near future but may fall short of securing the production systems during the climate change extremes expected.

In intensive systems, some climate change threats can be managed through advanced technology such as aeration although this may be costly. If this is not practical, climate change threats can be managed through changes to the intensity of the culture system, the species raised, and the use of other inputs. Some intensive systems, such as *Pangasius* farming in the delta, are already pushing the limits of production from their systems and already suffer regular losses through disease and water quality problems. These problems will only increase as climate change effects are felt. For super-intensive systems, the eventual solution may be to move fish production 'inside', i.e., within buildings where the environmental conditions can be completely controlled. This would be accompanied by efficient water bio-filtration and reuse. The technology to do this has already been developed in Europe and the US and will probably be copied once the climate makes other adaptive measures too unreliable.

The CAM vulnerability assessments for the hotspot areas have identified the following adaptations for aquaculture systems, which mainly focus on managing increased temperatures, dry season water supplies, and flood control. Most of these measures apply to different production intensities; including intensive, semi intensive, and extensive.

Increased temperatures may make upland and mid-level areas, which are currently sub-optimum in terms of growth, more suitable for aquaculture. In these areas, the pond should be exposed to full sunlight for as long as possible and not be shaded. However, in lower elevations, projected temperatures will be above optimum for many species and adaptive measures should be taken. This may mean shifting from carp species to tilapias, which are generally more tolerant of high temperatures and low dissolved oxygen levels. Farmers may have to adjust growing cycles and stocking densities to manage around expected high temperature periods. High temperatures can be offset to an extent by regular aeration of deeper ponds to prevent stratification and therefore risk of water column turnover; and by reduction in the use of low-value fish for aquaculture feeds in favor of pelleted feeds in order to maintain water quality.

Many aquaculture farms may have to invest in on-site water storage to reduce the risks of reduced water availability during the dry season. For intensive farms, reuse of pond water will be an important strategy to reduce water use, and to mitigate the release of effluents to the environment. In most cases, water will have to be pumped from the reservoir, as required. If possible, water should be fed to the ponds by gravity. For some ponds, weak embankments and sandy soils may have to be strengthened through the addition of clay soils to prevent water loss through seepage.

The strengthening of embankments to also protect against flooding will be necessary for ponds in many areas. This may be a significant cost with large pond systems, such as shrimp farms, and may result in the investor giving up and leaving the site. Some species are more prone to leave a flooding pond than others. For example, silver barb will leave at the earliest opportunity, while other species, such as *Pangasius* catfish and Chinese carps are more reluctant. Protecting ponds from flash flooding offers more of a challenge as pond embankments may be eroded in such cases and need reconstruction. Diversion canals may have to be dug to channel water away from vulnerable pond areas. If flooding becomes unmanageable, then culture cycles would have to be adjusted so that fish harvests were timed to occur before high-risk periods.

In coastal areas, farmers should be able to manage salinity levels quite well, through their choice of species; some being tolerant of a wide range of salinities. Many shrimp ponds are shallow which can result in a rapid reduction in water salinity after heavy rain, early in the wet season, which can increase stress levels in the shrimp and make them more susceptible to diseases, including WSSV[7]. Conflict between shrimp farmers and rice farmers may increase as sea levels rise and it becomes more difficult to manage salt water. Integrated water management plans will need to be implemented in many areas to contain these types of conflicts.

Giant freshwater prawn farmers in the delta may shift to Penaeid shrimp culture as sea levels rise. This poses the interesting question of what to do with derelict coastal shrimp farms if they become unmanageable due to sea level rise. Many of these ponds in the delta would have been mangrove forests before they were cleared for shrimp culture. Efforts should be made to redress this situation through the replanting of mangrove forest for protection and to encourage siltation. These areas may not return to mangroves without help. Climate-friendly systems, e.g., tiger shrimp/crab production in mangrove replanted areas of the delta, should be more widely promoted.

The creation of reservoirs will create new environments that can be used for cage aquaculture and possibly culture-based fisheries that will create new livelihood opportunities for some local people. However, only sheltered sites will be suitable as these systems are vulnerable to storms, which can damage infrastructure and result in loss of stocks.

Finally, the creation of small on-farm ponds, as promoted by Thailand's King Bhumibol for several decades, can be viewed as an excellent local climate change adaptation strategy for a wide range of farming activities that are reliant on rainfall. This includes both the crop and livestock sectors. These multi-use ponds will benefit small-scale aquaculture and allow the trapping of wild fish from the local capture fisheries, thereby helping rural households meet their food security requirements.

[7] White Spot Syndrome Virus

4 PROPOSED ADAPTATION RESPONSES

Acronyms: *CR – Chiang Rai; GL – Gia Lai; KH – Khammouan; KG – Kien Giang; MK – Mondulkiri.*

4.1 CAPTURE FISHERIES

4.1.1 UPLAND/FOREST STREAM FISH

THREAT	PROPOSED ADAPTATION	CR	GL	KH	KG	MK
Increased temperature	Plant forest cover along upland streams	✓	✓			✓
	Create fast-flowing, shallow water areas to increase oxygen levels and improve spawning grounds	✓	✓			✓
	Remove silt from deeper pools to reduce BOD and enhance DO	✓	✓			✓
	Ensure that streams have variable habitats (sunken trees, undercut banks, etc.) that allow fish to move easily from one area to the next	✓	✓			✓
Increase in precipitation	Improve forest cover to reduce levels of soil erosion from heavy rain					✓
Decrease in precipitation	Create connections between pools that allow for fish to move through the stream during low water conditions	✓	✓			
	Create low weirs to retain water during the dry season. However, these weirs must not create obstacles to migrating white fish intending to spawn in the upper river reaches	✓	✓			
	The establishment of conservation areas where adult and juvenile stocks of key species can be protected and their propagation encouraged	✓	✓			
Storms and flash floods	Improve forest cover to reduce levels of soil erosion from heavy rain	✓				

4.1.2 MIGRATORY WHITE FISH

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Increased temperature	Focus will have to be on improving habitats in upstream tributaries, similar to that proposed for upland fish, as little can be done to assist adaptation to elevated temperatures in the main rivers	✓				✓
Decrease in precipitation	Identification and protection of the deep pool areas where these fish species reside during the drier months	✓				✓
	Creation of new refuge areas/sanctuaries for particular adult and juvenile white fish species	✓				✓
	Monitoring of migratory white fish species proportions and numbers by local fishers to identify species in decline, for which protective measures can be afforded	✓				✓

4.1.3 ESTUARINE SPECIES

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Increased temperatures	Recovery of coastal ecology such as mangrove re-forestation is essential to protect estuarine species from stresses created through temperature elevation				✓	
	Non-interference with natural tidal fluctuations and drainage patterns. This could involve the installation of culverts and bridges to ensure that tidal exchange is not constrained				✓	
	The creation of no fishing areas in key spawning and nursery areas of the estuarine zone				✓	
	Special protection will be required for the sedentary species such as mollusks that may not be able to avoid harmful warm water conditions					
Storms and flash floods	The re-establishment of mangrove areas to act as buffers to cyclones and storms, protecting both natural and human habitats and constructions				✓	

4.1.4 INVASIVE SPECIES[8]

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Increased temperature	Monitoring of the spread of invasive aquatic species in new upland areas. Many exotic aquaculture species used have been selected due to their wide tolerance ranges, including capacity to withstand high temperatures				✓	
Increased water availability	Community eradication campaigns to prevent invasive species colonizing new areas				✓	
Flooding	Prevention of escapes from aquaculture (see Section 2)				✓	
	The promotion of the culture of indigenous fish rather than exotic species				✓	

[8] With invasive aquatic species, the recommendations for adaptation steps are aimed at preventing the invasive species from becoming more prevalent in the environment rather than protecting them from climate change threats.

4.2 AQUACULTURE SYSTEMS

4.2.1 INTENSIVE POND CATFISH CULTURE

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Decrease in water availability	Reduce seepage from ponds through embankment repair and maintenance	✓				
	Excavate on-farm reservoir ponds to aid dry season supplies	✓				
	Treatment and re-use of water on the farm rather than discharge of polluted water into watercourses	✓				
Drought	Excavate on-farm reservoir ponds to aid dry season supplies	✓				
	Reductions in fish stocking densities and farm biomass in advance of expected drought periods	✓				
Floods	Increase the height of embankments	✓	✓			
	Change management cycles so that farms have low stocking rates during high-risk periods	✓	✓			
Storms and flash floods	Do not build ponds on the side of stream valleys	✓	✓			
	Ensure that excess water can be more easily diverted away from pond areas	✓	✓			
	Ensure that embankments are maintained to a high standard.	✓	✓			

4.2.2 SEMI-INTENSIVE POND CATFISH CULTURE

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Floods	Increase the height of embankments					✓
	Change management cycles so that farms have low stocking rates during high-risk periods					✓
	Fences erected around ponds to prevent catfish escaping					✓
Storms and flash floods	Do not build ponds on the side of stream valleys					✓
	Ensure that excess water can be more easily diverted away from pond areas					✓
	Ensure that embankments are maintained to a high standard					✓

4.2.3 SEMI-INTENSIVE CARP & TILAPIA POLYCULTURES

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Increased temperatures	Shift from carp to tilapia-biased polycultures	✓				
	Provide supplementary aeration to boost DO levels	✓				
	Provide afternoon shade on one side of the pond	✓				
	Feeding regimes adjusted to coincide with anticipated high DO levels	✓				
	Ponds excavated that have both shallow and deep areas, where fish can move to, as diurnal temperatures change	✓				
Decrease in precipitation	Maximize opportunities for water collection and storage during the dry season	✓				
	Regular use of aeration to prevent water column stratification	✓				
Floods	Increase the height of embankments	✓				
	Change management cycles so that farms have low stocking rates during high-risk periods					
	Change bias of polyculture species in favor of those fish which are least affected by embankment inundation, e.g., *Pangasius* and Chinese carps	✓				
Storms and flash floods	Do not build ponds on the side of stream valleys	✓				
	Ensure that excess water can be more easily diverted away from pond areas	✓				
	Ensure that embankments are maintained to a high standard	✓				

4.2.4 CAGE AQUACULTURE OF CARPS

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Storms and flash floods	Siting of cage farms in sheltered inland areas		✓			
	The installation of floating breakwaters around the cage farms to reduce wave action on the cages		✓			

4.2.5 EXTENSIVE CARP TILAPIA POND POLYCULTURES

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Decrease in water availability	Reduce seepage from ponds through embankment maintenance	✓		✓		
	Excavate on-farm reservoir ponds to aid dry season supplies	✓		✓		
Drought	Shift bias of fish species towards those tolerant of poorer water conditions, such as tilapias	✓		✓		
Flood	Increase the height of embankments	✓		✓		
	Change management cycles so that farms have low stocking rates during high-risk periods	✓		✓		
	Change bias of polyculture species in favor of those fish which are least affected by slow flooding, e.g., *Pangasius* and Chinese carps	✓		✓		
Storms and flash floods	Do not build ponds on the side of stream valleys			✓		
	Ensure that excess water can be more easily diverted away from pond areas			✓		
	Ensure that embankments are maintained to a high standard			✓		

4.2.6 FRESHWATER PRAWN POND CULTURE

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Increase in temperatures	Reduce stocking densities in ponds				✓	
	Supplementary aeration in ponds to boost DO levels and improve water circulation and mixing				✓	
	Ponds excavated that have both shallow and deep areas, where fish can move to, as diurnal temperatures change				✓	
	Feeding regimes adjusted to coincide with anticipated high DO levels				✓	
Decrease in water availability	Shifting to other species which require less regular water exchange				✓	
	Water treatment and reuse rather than discharge into water courses				✓	
	On-farm water storage capacity increased				✓	
Drought	Shifting to other species which require less regular water exchange				✓	
	On-farm water storage capacity increased				✓	

4.2.7 SEMI-INTENSIVE COASTAL SHRIMP CULTURE

THREAT	ADAPTATION	CR	GL	KH	KG	MK
Increase in temperatures	Reduced stocking densities in ponds				✓	
	Shifts to other species of shrimp or fish that are more tolerant of high water temperatures				✓	
	Supplementary aeration in ponds to boost DO levels and improve water circulation and mixing				✓	
	Ponds excavated that have both shallow and deep areas, where fish can move to, as diurnal temperatures change				✓	
	Feeding regimes adjusted to coincide with anticipated high DO levels				✓	
Increase in precipitation	The excavation of deeper ponds, which will slow the salinity changes, as well as providing some protection against increased temperatures (although this does increase the risk of stratification)				✓	
	Installation of additional sluice gates for improved water management				✓	
Storms and flash flooding	Higher embankments				✓	
	Reestablishment of mangrove fringes in front of coastal shrimp farms				✓	
	Sudden reductions in salinity caused by heavy rainfall can induce disease outbreaks such as WSSV in shrimp ponds. Deep ponds are required to buffer the effect of large amounts of freshwater entering the pond				✓	
Sea level rise	Higher embankments to protect against sea level rise				✓	
	Relocation of shrimp farming areas further inland				✓	

5 LINKAGES WITH THE OTHER USAID MEKONG ARCC STUDY SECTORS

This section examines the potential impacts that adaptation measures implemented for the other sectors, i.e., agriculture, livestock, natural systems, and socio-economics, might have on the fisheries sector.

5.1 FISHERIES AND AGRICULTURE

The responses of the crop-farming sector to climate change will likely result in both gains and losses for fisheries in the region. The adaptations below, suggested by the USAID Mekong ARCC study team do have implications for fisheries. Both capture fisheries and aquaculture will be affected by changes in land use, crop varieties, and farming methods, as explained below. Ricefield fisheries and rice-fish aquaculture are important rural livelihood options, which adaptation measures for rice should not undermine.

Impacts of planting a diversity of rice varieties within farmer plots

- Positive: More variety of habitat and food items such as insects
- Negative: Will possibly override water management options or encourage short-duration rices in floodplains and dry season rice in marginal areas

Impacts of the promotion of the System of Rice Intensification (SRI)

- Negative: Frequent drainage of the field will impact paddy fish and aquatic animal diversity. In addition, infrastructure may affect fish mobility (more culverts/sluice gates/water storage)
- Positive: Fish and other aquatic animals have more space in SRI fields to move about

Impacts of improving access to irrigation from groundwater, rainwater collection, and small-scale water storage

- Positive: Creation of small ponds for wild fish collection or aquaculture, functioning as refuge ponds during the dry season

Impacts of conservation agriculture with permanent vegetal cover (only for medium to large scale agriculture)

- Positive: Reduced erosion can improve water quality in small catchments
- Negative: Increased use of herbicides affecting runoff into water bodies and affecting aquatic life

Impacts of bioengineering methods with tree plantation and physical barriers

- Positive: Reduced erosion can improve water quality in small catchments.
  Increased biodiversity

Impacts of rubber, fruit, and coffee altitude shifts to avoid rising temperatures

- Negative due to increased soil erosion and increased use of fertilizer

5.2 FISHERIES AND LIVESTOCK

Integrated farming, where livestock wastes are used to promote natural foods in fishponds, and generate increased fish yields are still practiced throughout the LMB and are important livelihood strategies for many poorer farmers. Compared to crop farming, there are fewer linkages between livestock and the fisheries sector; and these mostly relate to aquaculture.

Impacts of efficient use of wild forage (e.g., selection and nutritional balance)

- Positive: Better quality animal manures for use in pond aquaculture

Impacts of more efficient use of crop residues (e.g., addition of urea)

- Negative: Reduced crop residue inputs for aquaculture

Impacts of increased cultivation of forage

- Positive: More animal waste and more crop residues for aquaculture

Impacts of minimizing exposure to extreme events

- Positive: Penned or housed livestock allow for the more efficient collection of waste for aquaculture

5.3 FISHERIES AND NATURAL SYSTEMS

There are a large number of linkages and overlapping areas between natural systems and fisheries—many, but not all of them, relating to capture fisheries and mostly positive in terms of impact.

Impacts of strengthening the management and status of protected areas so they can provide the backbone for adaptation strategies in farming ecosystems and rural livelihoods

- Positive: Improved protection of upland fisheries areas

Impacts of construction of check dams in streams and bioengineering measures

- Positive: Increased opportunities for wild fish and aquaculture

Impacts of integrated watershed management

- Positive: Improved water quality and availability

Impacts of the provision of sluice gates in coastal areas to enable the controlled movement of saline waters

- Negative: Fish migrations constrained by physical obstructions

Impacts of attention paid to conservation in biodiversity action plans and plans for other developments

- Positive for capture fisheries

Impacts of setting aside of areas of forest for regeneration

- Positive effect on catchment water quality and upland fisheries

Impacts of additional scientific research into the basic biology and ecology of the plants and animals concerned

- Positive: Increased awareness of fisheries resources

Impacts of monitoring of populations of key plants and animals

- Positive: Increased awareness of fisheries resources

Impacts of selective breeding of individuals that show resilience traits to the changes in climatic conditions

- Positive if aquatic species are selected

Impacts of expanding and strengthening the LMB protected areas system

- Positive: Increased protection for fisheries

Impacts of strengthening the authority and capacity of protected area managers

- Positive: Improved fisheries management

Impacts of an integrated adaptation into protected area management planning

- Positive: Improved fisheries management

Impacts of the rehabilitation of degraded areas

- Positive: Improved catchment drainage and water quality

Impacts of understanding the maintenance requirements of key biological processes giving priority to 'keystone' species

- Positive: Increased awareness of fisheries resources

Impacts of the identification, maintenance, and proactive management of refugia and pockets of resilience

- Positive: Improved fisheries management

Mitigation of threats from invasive species and pests

- Positive: Aquatic biodiversity protected

5.4 FISHERIES AND SOCIO-ECONOMICS

A more conflicting picture emerges when linkages between fisheries and the socio-economic sector are assessed. Adaptation responses in this sector must cover health and infrastructure issues.

Impacts of protection of ecosystem services that support community health, such as non-timber forest products (both for food and commercial use), fisheries (particularly for protein), and clean freshwater supply

- Positive: Improved fisheries environments

Impacts of the revision of infrastructure planning given threats posed by climate change, particularly the location of key infrastructure such as roads, community buildings, and dwellings

- Negative: Climate proofing road infrastructure may affect drainage and fish movements

Impacts of strengthening natural coastal protection from inundation through community-based rehabilitation and protection programs, particularly for mangrove ecosystems

- Positive: Improved coastal environments (including mangroves) for fisheries production

Impacts of improvements to canal networks that are required to cope with more intense flood events, particularly to ensure effective drainage of fields and waterways

- Positive: Possible new sites for aquaculture
- Negative: Reduced floodplain areas and loss of fisheries areas.

Impacts of strengthening sustainable management of forest resources by developing stronger land tenure systems, enhancing capacity of protected area management, and providing communities with incentives to protect forests

- Positive: Better catchment management and positive if it extends to community fisheries management

Improve road access to remote communities, including extension of the road network, construction of embankments and bridges, and community-based bioengineering projects

- Negative: Climate proofing road infrastructure may affect drainage and fish movements

Impacts of educational programs regarding water-borne disease and heat stress

- Positive: The promotion of biological controls for disease vectors can favor fish production

Impacts of enhanced food security and flood protection by strengthening sustainable management of forest and river resources

- Positive: Better catchment management

Climate change-sensitive bridge construction, road elevation and design, and other civil engineering programs to secure road access to flood-prone communities

- Negative: Climate proofing road infrastructure may affect drainage and fish movements

6 THE IMPACT OF OTHER DEVELOPMENT PRESSURES ON LMB FISHERIES

6.1 CAPTURE FISHERIES

As mentioned in the baseline section of this report, other factors threatening the future of LMB fisheries may completely overshadow the effects of climate change. The productivity of the Mekong capture fisheries is inextricably bound to the seasonal pulse of dry and wet seasons, as well as to the connectivity of the rivers, streams, and floodplains. Developments that affect these characteristics will reduce productivity and biodiversity of the fishery, with significant secondary impacts to the millions of people depending on the fishery for their livelihoods.

The greatest threat to capture fisheries includes (1) the alteration of river morphology and hydrology caused by hydropower projects, (2) the excavation of channels to aid navigation, and (3) the extraction of ground and surface waters for irrigation (Kottelat et al. 2012). Physical barriers constraining the migration of fish species will result in sudden failures of components of the fishery. Plans for cascades of dams, as proposed for Nam Ngum, could be catastrophic for this tributary's fisheries diversity and productivity. Periodically there are reports of plans to divert water from tributaries in Lao PDR under the Mekong, or from the mainstream Mekong to the drier northeastern part of Thailand, for irrigation purposes. In March 2013, Cambodia launched a $200 million project to divert water from the Mekong River to irrigate 300,000 hectares of rice fields in Prey Veng, Svay Rieng and Kampong Cham Provinces. If such projects come to fruition then their impact on the Mekong's capture fisheries would be considerable regardless of the impacts stemming from climate change.

As mentioned in the previous section, the use of river waters and other water bodies for agriculture can have a negative effect on capture fisheries, although generally benefits aquaculture. However, the creation of new water bodies for agricultural irrigation will tend to benefit both.

Many of the capture fisheries adaptation recommendations focus on the protection of higher-elevation catchments and forests. The adaptation response for some upland crops such as rubber and litchi will target these same areas, requiring an integrated landuse approach to ensure that fisheries do not suffer from such a shift.

Dry season demands on small water sources for irrigation of these upland crops may also increase pressures on upland fisheries. Where dams are erected in small streams, low crest weirs should be used, which would allow the passage of fish in the wet season, but probably not the dry season.

The creation of small water bodies for irrigation will allow them to be used by aquatic animals as dry season refuge areas. In order to maximize their contribution to the floodplain fishery, the ponds should be designed with a low embankment connected to a canal, which allows for the free passage of fish into and out of the water body.

Climate change adaptations for other sectors are particularly important when considering coastal fisheries. The estuarine species require natural tidal exchanges and salinity variation. Any climate change mitigation activities that affect this natural ebb and flow will have negative effects on the coastal fishery, as well as the habitats upon which so much productivity depends.

Through increased sea levels, the balance between rice farming and shrimp farming in the delta may become more difficult to maintain. It is not uncommon to have conflicts between rice and shrimp farmers over the salination of water supplies and land. Large infrastructure projects aimed at keeping seawater out of some polders may benefit rice farmers but not shrimp farmers or coastal fisheries.

The re-establishment of mangrove areas in the delta, which could be climate change adaptation for other sectors such as storm protection, would tend to have positive impacts on fisheries.

The use of invasive species in agriculture or livestock, perhaps introduced as climate change adaptation measures, would likely have negative impacts on natural fisheries and aquaculture. For example, exotic aquatic plants can take over some water bodies, such as water hyacinth, causing a reduction in fisheries production and a nuisance to aquaculture farmers. The education programs recommended under the natural systems component should of course cover fisheries aspects, and highlight the dangers of exotic species establishment.

Improved access to water will benefit both crop farmers and livestock farmers. Where this involves the creation of perennial or seasonal water bodies, then fisheries will undoubtedly benefit.

Flood control infrastructure put in place to protect agriculture and livestock farms, from the increased rainfall and runoff anticipated through climate change, might impact negatively on capture fisheries depending on the design of embankments and sluices.

6.2 AQUACULTURE

There are far fewer external threats to the Mekong's aquaculture systems than those facing the capture fisheries. The control measures put in place to mitigate climate change pressures on other sectors will by and large benefit aquaculture as it also requires a high degree of control over resources. However a number of adaptation measures for the other sectors that could impact either negatively or positively on aquaculture do exist and these include the following:

Efforts to increase dry season water availability for irrigation will benefit aquaculture by making more water available for fish farms. Although competition between crop farmers and fish farmers can be expected and aquaculturists may be seen as rather wasteful in terms of their water demand; in fact, many aquaculture systems do not use water, except that lost through seepage and evaporation. Water from aquaculture systems can often be used effectively in agriculture.

Increased use of chemical fertilizers and/or pesticides during the dry season could affect water quality in fish farm water supplies, thereby impacting negatively on fish survival, growth, and possibly even market acceptance. The use of pesticides and drugs in the more intensive aquaculture systems of the LMB are of concern. Their use may well be affected by climate change, if certain diseases become more virulent as a result of the changing conditions, e.g., increased temperatures. Conflict over clean water supplies in the dry season may be exacerbated through climate change.

The clearing of upland catchments for other crops such as rubber, coupled with increased rainfall, may significantly increase the risks of flash flooding, making some valley aquaculture sites unmanageable.

The creation of reservoirs and canals for irrigation could benefit cage aquaculture significantly, if fish farmers are permitted to use these resources.

Livestock feedlot systems, should they become more prominent through climate change pressures, will favor aquaculture as they allow for more efficient collection of waste, which can then be used in ponds to generate productivity. However, the future of these integrated livestock-fish systems is in some doubts due to pressures from international markets and regional health authorities.

Pollution and increasing demand for water during the dry season has the potential to constrain aquaculture development, particularly in the Mekong Delta. Adaptation efforts in other climate-affected sectors that reduce the availability of water for aquaculture could be a serious check to future growth. On this issue there is some contradiction, as it is also expected that the increase in dams in the Mekong and its tributaries will result in increased dry season water flows, which would be advantageous for aquaculture.

REFERENCES

Akataweewat, S. 2004. Knowledge of Freshwater Fish in Thailand, Volume 1. Khurusapha (the Council of Teachers), Bangkok. 264 pp. (in Thai).

Akataweewat, S. 2003. Public Manual for Identification of aquatic Food safety. Fisheries Technology Transfer and Development Bureau. Department of Fisheries. Bangkok. 164 pp. (in Thai)

Alison A.H, Beveridge M.C.M, van Brakel M.L. (2012) Climate Change, small-scale fisheries and smallholder aquaculture. Fisheries Sustainability and Development.

Baird, I.G., Vixay Inthaphaisy, Phongsavat Kisouvannalat, Bounpheng Phylaivanh & Bounhong Mounsouphom 1999. *The Fishes of Southern Lao* (In Lao). Lao Community Fisheries and Dolphin Protection Project, Ministry of Agriculture and Forestry, Pakse, Lao PDR, 162 pp.

Baran E, Makin I, Baird I.G. 2003. Bayfish: a model of environment factors driving fish production in the Lower Mekong Basin. Contribution to the Second International Symposium on Large Rivers for Fisheries. Phnom Peng, Cambodia, 11–14 February 2003.

Baran E., Saray Samadee, Teoh Shwu Jiau, Tran Thanh Cong. 2011. Fish and fisheries in the Sesan River Basin - Catchment baseline, fisheries section. Project report. Mekong Challenge Program project MK3 "Optimizing the management of a cascade of reservoirs at the catchment level". World Fish Center, Phnom Penh, Cambodia. 61 pp.

Baran E. and Mith S; Fish biodiversity along the Mekong. From the Himalayas to the Coast. Power point presentation.
http://www.jsps.go.jp/english/eastrategy/date/07_asiahorcs_03_p1/keynote/keynote5_%20Baran.pdf

Baran E, and E Guerin. PP Presentation. River Sediments and Coastal Fish Production: What about the Mekong? Project "A Climate Resilient Mekong: Maintaining the Flows that Nourish Life" led by the Natural Heritage Institute and funded by USAID.

Bonheur, N. 2001. Tonle Sap Ecosystem and Value. Technical Coordination Unit for Tonel Sap, Ministry of Environment, Phnom Penh, Cambodia.

Boonyaratpalin, M., K. Kohanantakul, B. Sricharoendham, T. Chittapalpong, A.Termvitchagorn, W.Thongpun and M. Kakkaew. 2002. Ecology, Fish Biology and Fisheries in the Lower Songkhram River Basin. Technical Paper no. 6/2545. Department of Fisheries. Bangkok. (in Thai).

Chan S., Putrea S. and H.G. Hortle (2005) Using local knowledge to inventory deep pools, important fish habitats in Cambodia. In Proceedings of the 6 Technical Symposium on Mekong Fisheries (6 Technical Symposium on Mekong Fisheries, Pakse, Lao PDR, 26–28 November 2003) T.J. Burnhill and M.M. Hewitt, eds. Mekong River Commission, Vientiane, pp. 57–76 pp.

Chea Vannaren and Sean Kin 2000, Fisheries Preservation in the Mekong River Pools in Stung Treng and Kratie Provinces. Presentation at the 2nd Mekong River Commission Fisheries Programme technical symposium, Phnom Penh, 13–14 December 1999, 6 pp.

Chinvanno S. Information for sustainable development in light of climate change in Mekong River Basin. Part II Remote Sensing and Geographic Information Systems (GIS) Applications for sustainable development.

Chunsawang, B., T. Poompipat, P. Sodsook, S.Tanusutuch and P. Kaewjarune. 2000. Survey on Fish Population in Chulaporn Reservoir. Chaiyapoom province. Technical Paper No. 122. Inland Fisheries Research Institute. Bangkok. (in Thai).

Deap L., P Degen and N. van Zalinge. 2003. Fishing Gears of the Cambodian Mekong. Inland Fisheries Research and Development Institute of Cambodia, (IFReDI), Phnom Penh. Cambodia Fisheries Technical Paper Series Volume IV (2003) 269p ISSN: 17263972.

Degen P. Piseth C., Swift P. and Mary H. 2005. Upland Fishing and Indigenous Punong fisheries management in southern Mondulkiri Province, Cambodia. Report for WCS.

De Graaf G.J. & N.D. Chinhi. Floodplain Fisheries in the Souther Provinces of Vietnam.

Department of Fisheries. 2003. Survey and design of Kwan Phayao for restoration project and public hearing. Final Report. Kasetsart University. Bangkok. (in Thai).

Department of Fisheries. 1983. Tilapia (Pla Nil) Technical Paper no. 17. Department of Fisheries. Bangkok. (in Thai).

Department of Fisheries. 2011. Manual for Good Aquaculture Practice. Improvement of Standard Farm of Tilapia Culture for Export Project. Ministry of Agriculture and Cooperatives. 32 pp. (in Thai).

Duangsawat, M. and S. Duangsawat. 1992. Fishery Resources and Status in Mun River. Technical Paper no. 136. Department of Fisheries. Bangkok. (in Thai).

Duangsawat, S. and T. Chukajorn. 2000. Fishery Status, Species and Distribution in Mun River. Technical Paper no. 125. Department of Fisheries. Bangkok. (in Thai).

Duangsawat, S., Y. Leenanon, B. Sricharoendham and D. Ruttanachumnong. 1994. Fishery Resources and Status in Nonghan Reservoir after Restoration Programme. Technical Paper no. 158. Department of Fisheries. Bangkok. (in Thai).

Duangsawat, S., B. Sricharoendham, P. Kaewjarune, M. Aimsub, W. Somchun and N. Promkrun. 2003. Ecology and Fish Population in Nonghan, Sakonnakorn Province. Technical Paper no. 6. Department of Fisheries. Bangkok. (in Thai).

Duangsawat, S. 1993. Survey on Fish Species and Abundance in Pakmun Dam. Technical Paper no. 152. Department of Fisheries. (in Thai).

Eastham, J., F. Mpelasoka, M. Mainuddin, C.Ticehurst, P. Dyce, G. Hodgson, R. Aliand M. Kirby, 2008. Mekong River Basin Water Resources Assessment: Impacts of Climate Change. CSIRO: Water for a Healthy Country National Research Flagship.

Edwards, P., Le Anh Tuan and Allan, G.L. 2004. A survey of marine trash fish and fish meal as aquaculture feed ingredients in Vietnam. ACIAR Working Paper No. 57.

FAO (2008) Climate Change for Fisheries and Aquaculture. Technical background document from the expert consultation held on 7 to 9 April 2008, FAO Rome.

FAO Fisheries Country Profile, (Lao PDR), http://www.fao.org/fishery/countrysector/FI-CP_LA/en

FAO RAP 2001: Niklas S. Mattson, Wolf D. Hartmann, Thomas Augustinus. MRC Fisheries Programme Vientiane, Lao PDR. Reservoir Fisheries Information: From Statistics to Management in New Approaches for the Improvement of Inland Capture Fishery Statistics in the Mekong Basin.

Ficke AD, Myrick CA, Hansen LJ. 2007. Potential impacts of global climate change on freshwater fisheries. Rev Fish Biol Fisheries (2007) 17: 581–613 pp.

Fisheries Research and Development Bureau. 2003. Regulations and Standard for Giant Freshwater Prawn Culture 2003. Department of Fisheries. Bangkok. 102 pp. (in Thai).

Fisheries Technology Transfer and Development Bureau. n.d. Public Manual for Aquaculture. Department of Fisheries. Bangkok. 44 pp. (in Thai).

Fisheries Technology Transfer and Development Bureau. 2006. Common Fishes for Aquaculture. Department of Fisheries. Bangkok. 64 pp. (in Thai).

Fisheries Technology Transfer and Development Bureau. 2005. Guideline for Snakeskin Gourami Culture. Department of Fisheries. Bangkok. 36 pp. (in Thai).

Fisheries Technology Transfer and Development Bureau. 1993. Guideline for Brackish Water Fish Culture. Department of Fisheries. Bangkok. 48 pp. (in Thai).

Fisheries Technology Transfer and Development Bureau. 2010. Guideline for Tilapia Culture. Department of Fisheries. Bangkok. 34 pp. (in Thai).

Fisheries Technology Transfer and Development Bureau. 2006. Guideline for Striped Catfish Culture. Department of Fisheries. Bangkok. 24 pp. (in Thai).

Gregory, R., Guttman, H., and T. Kekputherith. 1996. Poor in All But Fish. A Study of the Collection of Ricefield Foods from Three Villages in Svay Theap District, Svay Rieng. Working Paper No. 5. 1 – 27. AIT Aqua-Outreach Programme, Phnom Penh, Cambodia.

Gregory, R.G. 1997. Ricefield Fisheries Handbook. Cambodia-IRRI-Australia Project, Cambodia. 38 pages.

Hill M.T. 1995 Fisheries ecology of the Lower Mekong River: Myanmar to Tonle Sap River. National Historical Bulletin, Siam Society. 43263-288.

Hortle, K.G. 2007. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No. 16, Mekong River Commission, Vientiane. 87 pp.

Hortle KG and Bamrungrach P (2012) Fisheries habitats and yield in the lower Mekong basin. MRC Technical Paper (in press).

Hortle K.G., Troeung R., and S. Lieng. 2008. Yield and value of the wild fishery of rice fields in Battambang Province, near the Tonle Sap Lake, Cambodia. MRC Technical Paper No.18. Mekong River Commission, Vientiane. 62 pp.

Hortle, K.G., S. Lieng and J. Valbo-Jorgensen. 2004. An introduction to Cambodia's inland fisheries. Mekong Development Series No. 4. Mekong RiverCommission, Phnom Penh, Cambodia. 41 pages. ISSN 1680-4023.

ICEM 2010, MRC Strategic Environmental Assessment (SEA) of hydropower on the Mekong mainstream. Hanoi, Vietnam.

Jangkij, M., J. Dumrongtripob, N. Sriputanipol and N. Sukumasavin. 2004. Ecology and Fishery Resources in Pong Chi and Mun Rivers. Technical Paper no 30. Roi-et Fishery Research and Development Center. Roi-et. (in Thai).

Johnston, R.; Hoanh, Chu Thai; Lacombe, G.; Noble, A.; Smakhtin, V.; Suhardiman, D.; Kam, Suan Pheng; Choo, Poh Sze. 2009. Scoping study on natural resources and climate change in Southeast Asia with a focus on agriculture. Report prepared for the Swedish International Development Cooperation Agency by International Water Management Institute, Southeast Asia (IWMI-SEA). Vientiane, Laos: International Water Management Institute, South East Asia Office (IWMI-SEA). 118p. doi: 10.3910/2010.201

Kam S.P, Badjeck M-C, Teh L., Teh L., Bé Năm V.T, Hiền T.T, Huệ _N.T, Phillips M., Pomeroy R. , Sinh L.X. 2010. Economics of adaptation to climate change in Vietnam’s aquaculture sector: A case study. Report to the World Bank.

Kaw-anantakul, K., C. Vidthayanon, A. termvidchakorn, C. Sirikul and N. Junprathad. 2003. Fishes of the Bueng Borapet Swamp (Lower Chao Phraya basin). Inland Fisheries Research and Development Bureau. Department of Fisheries. Bangkok. 84 pp. (in Thai).

Kottelat, Maurice, Ian G. Baird, Sven O. Kullander, Heok Hee Ng, Lynne R. Parenti, Walter J. Rainboth & Chavalit Vidthayanon. 2012. The status and distribution of freshwater fishes of Indo-Burma. Pages 36-65 in Allen, D.J., Smith, K.G., and Darwall, W.R.T. (Compilers. The Status and Distribution of Freshwater Biodiversity in Indo-Burma. IUCN, Cambridge, UK and Gland, Switzerland.

Lamberts, D. 2001. Tonle Sap fisheries: a case study on floodplain gillnet fisheries in Siem Reap, Cambodia. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2001/11, 133 pp.

LARReC 2001. A report on cage culture in Lao PDR, LARReC Research Report 0002. ISSN 1608 5604.

Limsuwan, C., 1992. Manual for Black Tiger Shrimp Culture. Tansettakij Limited Company. Bangkok. (in Thai).

Marod. D., Watcharinrat, C., Duengkae, P., and Jenkitkan, S. 2004. Draft Final Report on Implementation of the Ramsar Convention in Thailand: Management and Protection of Wetland Areas (Phase 2: Nong Bong Khai ecological study).

Mattson, N. S., Balavong, V., Nilsson, H., Phounsavath, S. and Hartmann W.D. 2001. Changes in Fisheries Yield and Catch Composition at the Nam Ngum Reservoir, Lao PDR. In: De Silva, S.S. (Ed.). Reservoir and Culture-Based Fisheries: Biology and Management, pp 48–55. Proceedings of an International Workshop held in Bangkok, Thailand 15–18 February 2000. ACIAR Proceedings No. 98. Australian Center for International Agricultural Research, Canberra, Australia.

Meynell P.J. 2012. Assessing the Ecologocal Significance of the Mekong Tributaries. MRC ICEM 2012. January 2012. 119 pp.

Meynell, P.J. 2003. Scoping Study for Biodiversity Assessment of the Mekong River in Northern Laos and Thailand, IUCN Mekong Water and Nature Initiative and Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme, Bangkok.

MRC 2010. State of the Basin Report 2010. Mekong River Commission, Vientiane, Lao PDR. ISBN 978-993-2080-57-1. 2010. Mekong River Commission.

MRC 2010. MRC SEA Assessment Report Fisheries Baseline Assessment, Working Paper.

MRC 2002. Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental managament. MRC Technical Paper No 8.

MRC 2009. Adaptation to climate change in the countries of the Lower Mekong Basin, MRC Management Information Booklet Series No.1.

Phan Minh Thu & J, Populus. 2007. Status and changes of mangrove forest in Mekong Delta: Case study in Tra Vinh, Vietnam. Estuarine, Coastal and Shelf Science 71 (2007) (98–109).

Prommanon, P. and S. Sahawatcharin. 1968. Experiment of Giant Freshwater Prawn Culture in Cement Tank. Songkla Fisheries Station Annual Report. Department of Fisheires. (in Thai).

Pongsuwan, A. and A. Sittimung. 1989. Manual for Fish Culture in the Northeast. Department of Fisheries. (in Thai).

Poulsen A. F., Ouch Poeu, Sintavong Viravong, Ubolratana Suntornratana & Nguyen Thanh Tung. 2002. Fish migrations of the Lower Mekong Basin: implications for development, planning and environmental management. MRC Technical Paper No 8. Mekong River Commission, Phnom Penh. 62 pp. ISSN: 1683-1489.

Poulsen, Anders, Ouch Poeu, Sintavong Viravong, Ubolratana Suntornratana & Nguyen Thanh Tung. 2002. Deep pools as dry season fish habitats in the Mekong Basin. MRC Technical Paper No. 4, Mekong River Commission, Phnom Penh. 22 pp. ISSN: 1683–1489.

Rainboth, W.J. FAO species identification field guide for fishery purposes. Fisheries of the Cambodian Mekong. Rome FAO. 1996. 265 p., 27 colour plates.

Rainboth, W.J. 1996. Fishes of the Cambodian Mekong. FAO, Rome.

SDC Report 2007. Unpublished. Upland Aquatic Resources in Laos PDR. Their Use, Management & Spatial Dimensions in Xieng Khouang & Luang Prabang Provinces.

SDC Report 2007. Unpublished. An assessment of the importance of riparian ecosystems as generators of agro-biodiversity resources at a gradient of elevations and farming systems.

Shang, U.C. and T. Fujimura. 1977. The production economics of freshwater prawn, Macrobrachium rosenbergii. Aquaculture 20: 251–256 pp.

Schouten R (1998) Effects of dams on downstream reservoir fisheries, case of Nam Ngum. Mekong Fish Catch and Culture Vol. 4, No. 2. December 1998.

Sinh L.X. (2008) Application of bio-economic model for improving economic efficiency and technique of giant freshwater prawn (Macrobrachium rosenbergii) hatcheries in the Mekong Delta, Vietnam (abstract in English). Scientific Journal of Cantho University 2,143^156.

SIWRP 2008. The assessment of impacts of sea level rise on the flood and salinity intrusion in the Mekong River Delta and lower basin of Dong Nai River. Southern Institute for Water Resources Planning 2008. Southern Institute for Water Resources Planning, Ho Chi Minh City, Viet Nam.

Sinthavong Viravong, Sommano Phounsavath, Chanthone Photitay, Putrea Solyda, Chan Sokheng, J. Kolding, J. Valbojorgensen and Kaviphone Phoutavong.2006. Hydro- acoustic surveys of deep pools in Southern Lao PDR and Northern Cambodia. MRC Technical Paper No.11, Mekong River Commission, Vientiane. 76 pp. ISSN: 1683-1489.

Sjorslev, J. G. (ed.). 2001. An Giang Fisheries Survey. Vientiane: AMFC/MRC & RIA 2.

Smith H.M. 1945. The Fresh-Water Fishes of Siam, or Thailand. United States Government Printing Office, Washington. 622 pp.

Sricharoendham, B. and K. Ko-anantakul. 1993. Fish Catch and Fisheries Survey During the Rehablitation Program of Nong Han Swamp, Sakon Nakhon Province, 1992. Technical Paper No. 143. Department of Fisheries. Bangkok. 36 pp. (in Thai).

Sriwattana W. and Y. Wiwattanachaiset. n.d. Guideline for Red tailed Catfish Culture. Fisheries Technology Transfer and Development Bureau Department of Fisheries. Bangkok. 22 pp. (in Thai).

Sverdrup-Jensen, S. 2002. Fisheries in the Lower Mekong Basin: Status and Perspectives. MRC Technical Paper No. 6, Mekong River Commission, Phnom Penh. 103 pp. ISSN: 1683-1489.

Taracharanukij, W. and P. Tabtipwun. 1992. Fishery Resources before Constructing Hauy-Laung Irrigation System. Faculty of Fisheries. Kasetsart University. Bangkok. (in Thai).

Taracharanukij, W., P. Tabtipwun and S.Rourjai. 1992. Fishery Resources before Constructing Lahanna Irrigation System. Faculty of Fisheries. Kasetsart University. Bangkok. (in Thai).

Thongkum, T., V. Temiyajol, W. Thepaouichai and S. Didtabud. 1991. Study on Situation of Fishery resources and Socio-economics in Lower Mun River. Electricity Generating Authority of Thailand. Nonthaburi province. (in Thai).

Tiensongrudsamhee, B. 1978. Principles for Giant Freshwater Prawn Culture. Faculty of Fisheries, Kasetsart University 107 pp. (in Thai).

Tyson R. Roberts and Ian G. Baird. 1995. Traditional Fisheries and Fish ecology on the Mekong River at Rhone Waterfalls in Southern Laos. Nat. Hist. Bull. Siam Soc. 43: 219–262.

Vidthayanon, C., Karnasuta J. and J. Nabhitabhata. 1997. Diversity of Freshwater Fishes in Thailand. Office of Environmental Policy and Planning. Bangkok. 102 pp. (in Thai).

Vidthayanon C., 2008. Field Guide to Fishes of the Mekong Delta. Mekong River Commission, Vientiane, 288 pp.

Vidthayanon C., 2005. Thailand Red Data: Fishes. Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand. 108 p.23.

Welcomme, R.L. and C. Vidthayanon. 2003. The impacts of introductions and stocking of exotic species in the Mekong Basin and policies for their control. MRC Technical Paper No. 9. Mekong River Commission, Phnom Penh, Cambodia. 35 p. and annex.

Wickins, J.F. and Daniel O'C. Lee. 2002. Crustacean Farming Ranching and Culture. Blackwell Science Ltd, UK. 446 pp.

Wiwattanachaiset, Y. and R. Tipnate. n.d. Guideline for Giant Freshwater Prawn Culture. Fisheries Technology Transfer and Development Bureau. Department of Fisheries. Bangkok. 26 pp. (in Thai).

World Bank (2010) Vietnam: Economics of Climate Change Adaptation.

Zalinge, N.V. P. Degen1, C. Pongsri, S. Nuov, J.G. Jensen, N.V. Hao and X. Choulamany. 2003. The Mekong River System. Contribution to the Second International Symposium on the Management of Large Rivers for Fisheries Phnom Penh. 11–14 February 2003. 31-1-03.

ANNEXES

- ANNEX 1
  THE PRESENCE OF THE 30 AQUATIC ANIMAL SPECIES IN EACH OF THE HOTSPOT PROVINCES
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ANNEX I – THE PRESENCE OF THE 30 AQUATIC ANIMAL SPECIES IN EACH OF THE HOTSPOT PROVINCES

	Fish Species	Chiangrai	Mondul	Kieng Giang	Gia Lai	Khammoun	Champassak	Stung Treng	Type of fish	Aquaculture	Food Security	IUCN status
1	*Anadara granosa*								E	Y	Y	Least concern
2	*Bangana behri*								U	N	Y	Vulnerable
3	*Barbonymus gonionotus*								M	Y	Y	Least concern
4	*Channa lucius*								U	N	N	Least concern
5	*Channa striatus*								B	Y	Y	Least concern
6	*Cirrhinus microlepis*								M	Y	Y	Vulnerable
7	*Clarias batrachus*								B	Y	Y	Least concern
8	*Colossoma macropomum*								X	Y	N	Invasive
9	*Cyclocheilichthys enoplos*								M	N	Y	Least concern
10	*Cyprinus carpio*								X	Y	Y	Invasive
11	*Hemibagrus nemurus*								B	N	N	Least concern
12	*Henicorhynchus siamensis*								M	N	Y	Least concern
13	*Hypsibarbus malcolmi*								M	N	Y	Least concern
14	*Labeo rohita*								X	Y	Y	invasive
15	*Lates calcarifer*								E	Y	N	Not evaluated
16	*Macrobrachium rosenbergii*								M	Y	N	??
17	*Mastocembalus armatus*								B	N	Y	Least concern
18	*Mekongina erthrospila*								M	N	N	Endangered
19	*Oreochromis niloticus*								X	Y	Y	Invasive
20	*Pangasius krempfi*								E	Y	N	Vulnerable
21	*Pangasius pangasius*								M	Y	Y	Least concern
22	*Penaeus monodon*								E	Y	N	Least concern
23	*Pomacea canaliculata*								X	Y	Y	Invasive
24	*Probarbus jullieni*								M	Y	N	Endangered
25	*Pseudapocryptes elongatus*								E	Y	N	Least concern
26	*Puntioplites falcifer*								M	N	Y	Least concern
27	*Scaphiodonichthys acanthopterus*								U	N	Y	Least concern
28	*Schistura kengtungensis*								U	N	N	Least concern
29	*Tor tambroides*								U	N	N	Data deficient
30	*Trichogaster pectoralis*								B	Y	Y	Least concern

ANNEX 2 – THE PRESENCE OF THE 30 AQUATIC ANIMAL INDICATOR SPECIES IN THE 12 USAID MEKONG ARCC ECOZONES

	Fish Species	HEMBF (A)	HEMBF NI	UFW CS-V	LEMBF	MEDBF	MFWL V-P	LEDBF	LFWL P-K	TSSF LF K-D	LLAAD	AFFD	DMSW
1	*Anadara granosa*	N	N	N	N	N	N	N	N	N	L	P	F
2	*Bangana behri*	P	L	L	P	F	F	F	L	P	N	N	N
3	*Barbonymus gonionotus*	P	L	F	F	F	F	F	F	F	L	L	N
4	*Channa lucius*	P	L	F	F	F	P	P	P	P	P	P	N
5	*Channa striatus*	L	F	F	F	F	F	F	F	F	F	F	F
6	*Cirrhinus microlepis*	P	P	F	P	F	F	F	F	F	F	F	P
7	*Clarias batrachus*	L	F	F	F	F	F	F	F	F	F	F	P
8	*Colossoma macropomum*	P	P	P	P	P	P	P	P	F	F	F	P
9	*Cyclocheilichthys enoplos*	P	P	F	F	F	F	F	F	F	F	F	P
10	*Cyprinus carpio*	P	F	F	F	F	F	F	F	F	F	F	P
11	*Hemibagrus nemurus*	P	F	F	P	L	L	F	F	F	F	L	N
12	*Henicorhynchus siamensis*	P	F	F	F	F	F	F	F	F	F	F	N
13	*Hypsibarbus malcolmi*	P	P	L	F	F	F	F	F	F	P	P	P
14	*Labeo rohita*	P	P	F	P	P	P	P	P	F	F	F	P
15	*Lates calcarifer*	N	N	N	N	N	N	N	N	P	L	L	F
16	*Macrobrachium rosenbergii*	P	P	L	F	F	F	F	F	F	F	F	F
17	*Mastocembalus armatus*	P	F	F	F	F	F	F	F	F	F	F	F
18	*Mekongina erthrospila*	P	F	P	P	P	F	F	F	F	P	P	P
19	*Oreochromis niloticus*	P	P	F	F	F	F	F	F	F	F	F	F
20	*Pangasius krempfi*	N	P	P	P	P	P	P	F	L	F	F	F
21	*Pangasius pangasius*	P	P	L	P	F	F	F	F	F	F	F	F
22	*Penaeus monodon*	N	N	N	N	N	N	N	N	N	P	L	F
23	*Pomacea canaliculata*	P	F	F	F	F	F	F	F	F	F	F	L
24	*Probarbus jullieni*	P	P	L	F	F	F	F	F	F	P	P	N
25	*Pseudapocryptes elongatus*	N	N	N	N	N	N	N	N	N	P	L	F
26	*Puntioplites falcifer*	P	P	L	F	P	F	P	F	F	P	P	N
27	*Scaphiodonichthys acanthopterus*	P	L	L	L	L	P	P	L	N	N	N	N
28	*Schistura kengtungensis*	P	F	P	P	P	N	N	P	N	N	N	N
29	*Tor tambroides*	L	F	L	L	P	P	P	P	N	N	N	N
30	*Trichogaster pectoralis*	P	P	F	L	F	F	F	L	F	F	L	L

KEY:

N	NOT FOUND
P	POSSIBLY FOUND
L	LIKELY FOUND
F	FOUND

ANNEX 3 – FISH SPECIES DATABASE

1. Thai Mahseer (*Tor tambroides)*

For image see http://www.jjphoto.dk/fish_archive/warm_freshwater/tor_tambroides.jpg

Code No.	U1
Common name	Thai Mahseer
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Wien
Latin name	*Tor tambroides*
Family	*Cyprinidae*
Description of fish	Medium size to large size, with elongate, moderate compressed body, small head, long rostral and maxillary barbels, lower lip reaching a line connecting corners of mouth and upper lip with a median lobe.
Environment	A cyprinid fish living in fast flowing rivers in forested areas.
Maximum size	100 , up to 50 cm in the Mekong
Indigenous or Exotic	Indigenous
Breeding season	Spawning during November to December. Egg diameter is 3.2 mm and hatching between 82–125 hrs at water temperature 21.8°C to 26.0°C.
Used in Aquaculture	Since 2001, this species had been reproduced by Petburi Fisheries Research and Development Center and released them in Petburi River.(ref28)
Economic Importance	Highly valued has some sport fishing value
Food security importance	Well known in Petchaburi River as a food fish (see diet below)
Preferred Habitat	Adults inhabit pools and runs over gravel and cobble in rivers flowing through undisturbed forests Juveniles found in small pools in or near rapids.
Migration	Found in small rivers and streams during the dry season. Move downstream at the onset of the rainy season, but generally avoid turbid waters. After 2 months, mature individuals migrate upstream after two months and spawn near the mouths of small streams that the young subsequently ascend.
Diet	Omnivorous, feeding on both animal and vegetable matter, at times consuming toxic fruits in flooded forests, making them temporarily inedible.
Water quality requirements	
• **Temperature range**	Prefers cool stream water
• **Salinity range**	Probably intolerant
• **O_2**	Requires high levels
• **pH range**	Not known
Distribution in Mekong:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Petchburi
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Data Deficient
Sources	Fishbase

2. River Loach (*Schistura kengtungensis*)

Code No.	U2
Common name	River Loach
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Kor Chiang Tung
Latin name	*Schistura kengtungensis*
Family	Balitoridae
Description of fish	Scale tiny, 8 branched dorsal-fin rays, vent closer to anal fin than to pelvic fin origin caudal fin weakly forked to emarginate.8-12 bars that turn into blotches on lateral line and saddle-markings dorsally.
Environment	
Maximum size	11 cm.
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	No
Economic Importance	None
Food security importance	
Preferred Habitat	Inhabit small, shallow, high gradient streams with cobble or boulder substrates.
• **Migration**	Probably non-migratory
Diet	
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Sw, CP, MK (Ref1)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	Fish Base

3. *Scaphiodonichthys acanthopterus*

Code No.	U3
Common name	
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Murn
Latin name	*Scaphiodonichthys acanthopterus*
Family	*Cyprinidae*
Description of fish	Freshwater; benthopelagic, The number of branched dorsal rays range from 11 or 12 and scale in lateral line 41 or 42. (ref 27)
Environment	
Maximum size	Max length : 31.0 cm
Indigenous or Exotic	Indigenous
Breeding season	Apparently breeds after the end of the rainy season after water levels in upland areas have declined, and juveniles appear in catches during April.
Used in Aquaculture	Probably not
Economic Importance	Not seen in markets
Food security importance	
Preferred Habitat	Occurs in fast flowing, clear waters with stony substrate. Found in clear mountain streams usually under complete forest canopy. Encountered in rapid-running mountain streams of the middle Mekong.
• **Migration**	
Diet	Feeds mainly on insect larvae along with small amounts of detritus and periphyton.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	

4. Bangana behri

Image:
http://www.fishingworldrecords.com/bundles/hema/images/photographies/1050_Fishing%20Adventures%20Thailand_Jungle%20Labeo_Bangana%20behri.jpg

Code No.	U4
Common name	
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Wa Na Nor
Latin name	*Bangana behri*
Family	Cyprinidae, ~~Labeoninae~~
Description of fish	Medium sized migratory river fish. A characteristic head.
Environment	
Maximum size	Max length : 60.0 cm
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	No reports
Economic Importance	Commercial. Marketed fresh The species is targeted during the spawning season with gillnets. Heavy gillnetting during the feeding migrations is also a threat. Dams proposed on the Mekong and 3S rivers could have a major negative effect on the species during its migration
Food security importance	
Preferred Habitat	Mainstream river. Occurs in upland reaches of the Mekong. Found in riffle and slow deep reaches. Not known to persist in impoundments.
• **Migration**	Inhabits rocky stretches of the main stem of Mekong during the dry season and moves into tributary streams during high waters At Stung Treng below the Khone Falls, the species migrates upstream at the start of the rainy season in May–June and downstream in the dry season from November to February. At Sambor and Kratie as well as just south of Khone Falls, it moves downstream at the onset of the rainy season and upstream in the dry season. The reason for such movement seems to be the presence of the important tributary system, Sekong-Sesan-Srepok rivers. Fishermen reported that this fish migrates from this system into the Mekong during receding water and migrates upstream the tributaries during the rainy season, possibly to spawn. Upstream of the Khone Falls, this fish begins migrating upstream in the dry season (February–May) and continues into the beginning of the rainy season. This movement may, in fact, be two separate Migrations: a dry season non-reproductive Migration of smaller fish and an early rainy season Migration of larger fish in spawning condition. Undertakes upstream Migrations from Khone Falls all the way to Chiang Khong in northern Thailand which are triggered by the increase of water levels and the change in water-color from clear to red-brown. Migrates upstream in schools together with other cyprinids such as *Labeo cf. pierrei*, *Cirrhinus microlepis*, *Labeo chrysophekadion* and *Cyclocheilichthys enoplos* as well as the loach, *Botia modesta*.
Diet	Herbivorous, feeding on algae, phytoplankton and periphyton
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	
• **Vietnam**	
Trends and Threats	This is an abundant species throughout its range. However a population decline of approximately 30% to 50% is inferred due to heavy fishing pressure. It is expected to continue decline in the future at this rate or higher, as proposed dam constructions within its range will have a significant and immediate impact on migrations
IUCN Red List status	Vulnerable
Sources:	FishBase, IUCN Red List

5. *Channa lucius*

Image: http://www.jjphoto.dk/fish_archive/warm_freshwater/channa_lucius.jpg

Code No.	U5
Common name	Four-eyed Snakehead
Local name	**Vn:** Cá Day; **Kh:** Trey Kanh chorn chey; **L:** Pa Eejon; **Th:** Pla Gajon, Gasong.
Latin name	*Channa lucius*
Family	Channidae
Description of fish	Carnivorous fish. Snout concaved, length greater than interorbital width; 10-13 rows of scales between eye and angle of preopercle; large canine teeth on roof of mouth; 58-65 lateral-line scales. Dark to reddish brown body with black blotches and spots; large eye spot on cheek; fins dark with pale pin-point spot. The head has a snaky appearance.
Environment	Freshwater
Maximum size	Max length: 40.0 cm. In general 20–25 cm
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	No
Economic Importance	Marketed fresh and often alive
Food security importance	Locally common in the markets.
Preferred Habitat	Marshlands, hillstreams and floodplains. Inhabits slow moving streams and rivers, as well as lakes, ponds and swamps. A common species in forest streams. Often found in areas with plenty of aquatic vegetation, as well as submerged woody plants.
Migration	
Diet	Feeds on fishes, prawns, and crabs and slightly less on shrimps.
Water quality requirements	
• **Temperature range**	22°C to 26°C
• **Salinity range**	
• **O_2**	High tolerance of low DO. Can breathe atmospheric air.
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Mkl, St, E, CP, MK (Ref1). Thailand to Indonesia and Mekong basinwide. () Pong, Chi, Mun Rivers (Ref 7), Hauy-Laung Reservior (ref 8)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	FishBase

6. Henicorhynchus siamensis

Image: http://guru.sanook.com/dictionary/picture/fish/192.bmp

Code No.	M1
Common name	Siamese mud carp
Local name	**Vn:** Cá Linh ong; **Kh:** Trey Riel tob; **L:** Pa soi hua gom; **Th:** Pla Sroi hua glom
Latin name	*Henicorhynchus siamensis*
Family	*Cyprinidae*
Description of fish	A small fish found in large schools. Body stout; relatively deep; head large and broad, snout weakly projecting, maxillary barbel tiny, often under labial groove; 34–36 lateral line scales. Body plain silvery; fins pale grey or yellow, dorsal fin with dusky distal margin.
Environment	Freshwater;
Maximum size	Max length : 20.0 cm In general 15 cm
Indigenous or Exotic	Indigenous
Breeding season	Rainy season. May–June.
Used in Aquaculture	Yes, culture in paddy field in Amnadchareon province and high demand fingerling. Reproduced by artificial fish breeding by Amnadchareon Inland Fisheries Research and Development Center.
Economic Importance	Commercially very important. Supports the Prahok and fish sauce trades. Often seen in the aquarium trade.
Food security importance	Very important source of fish paste. Used to make prahoc along the Tonlé Sap, Cambodia.
Preferred Habitat	Mainstreams, tributaries and marshlands. Often found in great abundance at midwater to bottom depths in large and small rivers. Not known to prosper in impoundments.
Migration	Well known for its annual migrations out to the floodplains in wet season. Returns to rivers as water levels begin to fall in October with numbers increasing through December and then slowly declining. From just upstream Phnom Penh in Cambodia to the Khone Falls this species is reported to migrate upstream during the period October–February. At Muk Kompul in Kandal Province, it migrates upstream just before the full moon. Further upstream near Kratie, Migration occurs during full moon and at Sambor, Migration takes place immediately after full moon. Near the Khone Falls, upstream movements continue through March but in April fish are moving in both directions. From May to July, at the start of the rainy season, it migrates downstream from the Khone Falls to the Mekong Delta. Here, the fish is reported to move out of the Mekong into canals and flooded areas in August–September. When water recedes in November–December, fish migrates to the Mekong again. Upstream the Khone Falls near Ubolratchatani in Thailand, this species moves upstream between February and June, consisting mainly of juveniles in February–March and of adults (15-20 cm) in April–June. Further upstream from Xayabouri in Laos to Chiang Khong in Thailand, upstream Migrations takes place between March to July, first by juveniles, later by adults.
Diet	Herbivorous, algae grazers (). Feeds on algae, periphyton and phytoplankton
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	
• **Vietnam**	
Trends and Threats	High turbidity during season affect to concentration of DO and survival rate of fry.and also low abundance of phytoplankton (natural food for fry). High predators (such as tadpoles etc.) also found in paddy field.
IUCN Red List status	Least concern
Sources:	

7. *Probarbus jullieni*

Image: http://upload.wikimedia.org/wikipedia/commons/5/5f/Probarbus_jullieni.jpg

Code No.	M2
Common name	Isok Barb
Local name	**Vn:** Cá Sok; **Kh:** Trey Eesok; **L:** Pa Earn; **Th:** Pla Earn, Yeesok ()
Latin name	*Probarbus jullieni*
Family	*Cyprinidae*
Description of fish	Dorsal spine smooth; relatively small lips; free posterior margin of both sides of lower lip narrowly interrupted; 4 scale rows between lateral line and pelvic fin. Body golden or bright yellow, with 5 stripes between dorsal fin and lateral line; eyes with red pupil; breeding adult with dark or purple dark body marking. ()
Environment	Freshwater; ~~brackish~~; demersal; potamodromous
Maximum size	Max length : 150 cm. Attains 70 kg or more, In general 70 cm (ref 37)
Indigenous or Exotic	Indigenous
Breeding season	Spawns in winter (late December-early February) in big riverine deltas over sand and gravel substrate with water current of 1.3 m/sec. Egg is buoyant, yellow and 2 mm in diameter (Ref. 6459). Hatching occurs in 67–96 hrs at 21.5°C to 24°C **and female wt. 14 kg has 500,000 eggs.** The spawning season of the fish in Mekong River is from December to March (Amatyakul et al. 1995). The spawning ground has a depth of 0.5–2.0 m, with flowing water and stone or gravel substrate.
Used in Aquaculture	Used to be cultured commercially in Thailand
Economic Importance	An excellent food fish, sometimes consumed raw, but rather scarce so it fetches a high market price. Eggs are especially priced. May be caught individually or in small numbers of any size incidentally with gillnetting and other fishing activities, at virtually any time or place in the Mekong mainstream but mostly caught during November-January spawning Migration, when it is by far the most important species in fisheries catch. Mostly marketed size 5–20 kg.
Food security importance	Locally and seasonally common in the markets.
Preferred Habitat	It prefers deep, clear water with sand or gravel substrate and abundant mollusc populations. Mainstreams and tributaries, juveniles also nursing in floodplains and marshlands. () Inhabits mainly the mainstream of large rivers with sand or gravel substrates and abundant mollusks populations. Occurs in deep slow reaches. Upstream spawning Migrations take place between October and February from Kompong Cham in Cambodia to Chiang Khong in Thailand. At Chiang Khong, fishermen reported that *Probarbus* moves up the tributary Nam Ta in Laos to breed in March-April. Three *Probarbus* species were also reported to migrate together, but spawn separately, in January–February at Sungkom, Nong Khai Province in Thailand.
Migration	Undertakes spawning and trophic Migrations in the Mekong basin. Trophic Migrations occurs throughout its occurrence range which takes place mainly at the onset of the flood season and are mainly undertaken by juveniles and subadults In the Mekong River, the main spawning ground of the fish is in Nong Khai Province
Diet	Benthose feeder, mollusc, aquatic insect and detritus. Feeds on aquatic plants, insects and shelled mollusks. It is a night-time feeder that consumes aquatic weeds, small molluscs and crabs, aquatic insect larvae and zooplankton. Amatyakul et al. (1995) reported on an 80 cm fish with the stomach full of bivalves and concluded that the fish is an omnivore, with a preference for molluscs.
Water quality requirements	
• **Temperature range**	Hatching rate of eggs 72 hours at 23°C
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	In general, found in Mkl, CP, MK (Ref1), Songkram River (ref 5), Mun River (ref 3 and 13)
• **Vietnam**	
Trends and Threats	In the Mekong this important fisheries species is under serious long-term decline and this decline evidently is basin wide and the most obvious (but not necessarily only) reason is overfishing with gillnets during the reproductive Migrations and spawning periods
IUCN Red List status	Endangered
Sources:	Fish Base

8. *Barbonymus gonionotus*

Image: http://www.seriouslyfish.com/wp-content/uploads/2012/04/barbonymus_gonionotus5_1.jpg

Code No.	M3
Common name	Silver Barb, Java barb
Local name	**Vn:** Cá Me vinh; **Kh:** Trey Chhpin; **L:** Pa Pak; **Th:** Pla Pak **()**
Latin name	*Barbonymus gonionotus*
Family	*Cyprinidae*
Description of fish	Body is strongly compressed, dorsal profile arched; snout pointed; mouth terminal. Body plain silver without red coloration on body or fins; caudal and dorsal plain grey, anal and pelvic pale yellow. ()
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	35 cm. A specimen measuring 45 cm TL (2,100 g) was reportedly caught from Dan Tchang Reservoir, Thailand on 8 July 2003
Indigenous or Exotic	Indigenous Escapees from culture installations have become established in rivers and form the basis for capture fisheries on several Southeast Asian islands.
Breeding season	During rainy season (May to June in Thailand). Adult mature within one year, 50,000–100,000 eggs per female. Hatching period is about 8-12 hrs at water temperature 29°C to 30°C.
Used in Aquaculture	A very common fish in semi intensive and extensive pond aquaculture. OJuveniles are easy to produce in large numbers, sometimes supporting reservoir or open water stocking programmes. Also used as a pituitary donor for artificial propagation in aquaculture.
Economic Importance	Useful in cropping excessive vegetation in reservoirs. Occasionally seen in the aquarium trade.
Food security importance	Common in the markets and aquaculture. Used for lap pa (in the preparation of which the numerous small bones are ground fine or grilled or used to make som pa. Usually marketed fresh
Preferred Habitat	Mainstreams, marshlands and floodplains. Occurs at mid-water to bottom depths in rivers, streams, floodplains, and occasionally in reservoirs. Seems to prefer standing water habitats instead of flowing waters. Inhabits the flooded forest during high water period.
Migration	A migratory species but not considered to be a long-distance migrant. Regarded as local migrant which moves from the Mekong up into small streams and canals and onto flooded areas during the rainy season and back again during receding water. Some reports indicated that upstream Migration of this fish is triggered by the first rains and rising water levels. When it finds a tributary, canal or stream it moves upstream and eventually onto flooded areas. When water recedes, it migrates back into canals and streams and into the Mekong again.
Diet	Herbivorous, plant matters. Feeds on plant matter (e.g. leaves, weeds, *Ipomea reptans* and *Hydrilla*) and invertebrates.
Water quality requirements	
• **Temperature range**	25°C to 33°C
• **Salinity range**	Less than 7 ppt
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Mkl, St, E, CP, MK (Ref1). Kwan Phayao (ref2) Songkram River(ref 5), Mun River (ref), Pong, Chi, Mun Rivers (Ref 3,6,7,10,13), Hauy-Laung Reservior (ref 8), Lahanna(ref 9), Nonghan (ref 11,12,39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25).
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	

9. *Cirrhinus microlepis*

Image: http://www.sea-ex.com/thailand/images/fresh-fish/small-scale-mud-carp.jpg

Code No.	M4
Common name	Small scale mud carp
Local name	**Vn:** Cá Duong; **Kh:** Trey Pruol; **L:** Pa Porn; **Th:** Pla Porn, Nualchan ()
Latin name	*Cirrhinus microlepis*
Family	*Cyprinidae*
Description of fish	A large species with very small scales, no barbels, and distinctive coloration. Juveniles silvery with red caudal fin, larger fish with head and body violaceous, rosy, or bluish and caudal fin dusky. Body cylindrical; broad head; no barbel; lips entire; scales very small, with 53–60 on lateral-line. Highly silvery body flanks often with pinkish or bluish tinge head and body, rosy, or bluish and caudal fin dusky; dorsal and caudal fins with pinkish or reddish tips. Juveniles elongated, silver body with pink caudal fin
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	Max length: 70cm. Known to reach up to 15 kg in Thailand.
Indigenous or Exotic	Indigenous
Breeding season	June to July
Used in Aquaculture	Attempts made to culture this fish in Cambodia in late 1990s
Economic Importance	Commercial. Individuals caught with dais or traps are often immediately kept alive in fish cages for future sale. Marketed fresh and sometimes dried and salted
Food security importance	Locally common in the markets
Preferred Habitat	Mainstreams, tributaries juveniles nursing in floodplains. Inhabits large rivers and lowland floodplains. Occurs in riffle and deep slow reaches. Not known to persist in impoundments
Migration	Migration pattern is markedly different above and below the Khone Falls in the Mekong basin. Below the falls, it makes an upstream Migration from Phnom Penh to the Khone Falls between November and February, consisting mainly of sub-adults of sizes 10 to 50 cm. From April to July, it migrates in the opposite direction, from Khone Falls and downstream, constituting mainly of sub-adults up to about 50 cm. Above the Khone Falls, from Klong Kaem District, Ubolratchatani in Thailand, fish migrates upstream in February; at Khemmaratch further upstream in Ubolratchatani, it moves upstream in March-April; and at Mukdahan, it goes upstream in May. However, it migrates downstream at Klong Kaem in June–July. Only downstream Migrations are reported in the Mekong Delta in Viet Nam, constituting mainly of juveniles (2–20 cm), with the smallest fish mainly in June–July and fish between 10 and 20 mainly from September to November. From Xayabouri in Laos to Chiang Saen in Thailand, upstream Migrations take place from March to August. This appears to be two distinct Migrations: one of sub-adults measuring 15–50 cm during March–April and another one of larger fishes of sizes 40 to 90 cm during June–July.
Diet	Herbivorous, algae and phytoplankton. (). Moves out into the flooded forest where it feeds on leafy plant matter, phytoplankton and insects.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	MK (ref 1.) Mun River (ref 13) and extinct from Chaophraya river (Ref 22)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Vulnerable
Sources:	FishBase

10. *Cyclocheilichthys enoplos*

Image: http://tepbac.com/upload/species/ge_image/Cyclocheilichthys-enoplos.jpg

Code No.	M5
Common name	Soldier River Barb.
Local name	**Vn:** Cá Coc; **Kh:** Trey Chhkouk ; **L:** Pa Joke; **Th:** Pla Takoke ()
Latin name	*Cyclocheilichthys enoplos*
Family	*Cyprinidae*
Description of fish	Snout elongate, with 4 barbles; 16–20 gill rakers on 1st arch; dorsal spine long and thick; bifurcate or even multifurcate lateral-line tubes (not in small juveniles); 38–41 lateral-line scales. Plain, pale silver or yellowish hue body and fins. ().
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	Max length : 75 cm () In general 30–40 cm
Indigenous or Exotic	Indigenous
Breeding season	July–August. This species can be reproduced by hormone injection.
Used in Aquaculture	No
Economic Importance	Commercial. A desirable food fish, marketed fresh.
Food security importance	Commonly seen in markets of the basin wide, popular foodfish
Preferred Habitat	Occurs at midwater to bottom levels of rivers. Lives in rivers and spawns during the rainy season, probably on the floodplains or inundated riparian forests. Returns to the rivers from October to December. Does not occur in impoundments.). Found in the basin-wide mainstream of the lower Mekong.
Migration	A strongly migratory species that lives in the mainstream and larger tributaries of the Mekong. In the Mekong, it undertakes an upstream Migration from Phnom Penh to Khone Falls from November to February, and a downstream Migration from May to August. This Migration continues down to the Mekong delta area in Viet Nam, where it continues until the peak of floods in October–November. These two Migrations mainly constitute juveniles and sub-adults, although adults of 90 cm are reported very near the Khone Falls. Above the Khone Falls, upstream Migrations occur from April to September which are dominated by adult fishes and probably these are spawning Migrations because of the presence of mature fishes bearing eggs. These upstream Migrations above the Khone Falls are reported to be triggered by the first rainfall at the end of the dry season, rising of water levels and higher turbidity.
Diet	Carnivorous benthic; detritus. Feeds mainly on bivalves, roots of plants, zooplankton and green algae. Young are known to feed on zooplankton while adults prey also on insect larvae, crustaceans and fish.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	In general found in Mkl, St, CP, MK (Ref1) Songkram River(ref 5), Mun River (ref 3,6,10,13), Pong, Chi, Mun Rivers (Ref 7), Hauy-Laung Reservior (ref 8), Lahanna(ref 9), Nonghan (ref 12), Nong Bong Khai_Chiangsaen (Ref 25)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	

11. *Mekongina erythrospila*

Image: http://fishbio.com/wp-content/uploads/2011/03/SAM_2116-e1300216836674.jpg

Code No.	M6
Common name	
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** *Pla Sa-e*
Latin name	*Mekongina erythrospila*
Family	*Cyprinidae*
Description of fish	Has the upper lip not separated from the snout by a rostral groove; no mental disc; no barbels; no rostral lobe; 10 branched dorsal rays.
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	Max length : 45.0 cm
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	
Economic Importance	Commercial. Sold fresh, sometimes dried or salted.
Food security importance	
Preferred Habitat	Mainstream river. Found in rapidly flowing water in medium and large-sized rivers. Inhabits slower deeper reaches during dry-season. Prefers rocky stretches with rapids and a fast-flowing current.
Migration	Migrates in big schools, comprising several hundred fish, usually together with other cyprinids and loaches such *Hypsibarbus* spp., *Scaphognathops* spp., *Cirrhinus siamensis* and *Botia modesta*. Mekongina erythrospila migrates in big schools comprising several hundred fish, often together with other cyprinids and loaches such as Hypsibarbus spp., Scaphognathops spp., Henicorhynchus siamensis and Botia modesta. One Thai fisherman reported that the juveniles are also migratory. Few fishermen were able to give any detailed information about the reproduction habits of this species. One fisherman from Xayaboury, Lao PDR, reported seeing eggs in the abdomen of the fish during May and June. In Stung Treng and Kratie provinces, some fishermen said they had observed eggs from January to June, with most observations occurring in June. Those observations are consistent with a spawning time from June to August. The smallest juveniles, around 6 cm, were reported from the southern areas in Khammouan, Ubon Ratchathani, Champasak and Stung Treng provinces.
Diet	Feeds on aquatic chlorophytes, periphyton and phytoplankton.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	MK (Ref1)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Endangered
Sources:	

12. *Pangasius pangasius*

Image: http://img.21food.com/20110609/product/1211507625031.jpg

Code No.	M7
Common name	Striped catfish
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla sa-wai
Latin name	*Pangasius* pangasius recently changed from *Pangasianodon hypophthalmus* ?
Family	*Pangasiidae*
Description of fish	Eye small, its diameter more than 7 times in head length (in 18 cm long specimens); bright yellow caudal fin in adults; maxillary barbel extends to gill aperture;
Environment	Freshwater; brackish; benthopelagic; potamodromous
Maximum size	Max length : 100 cm In general 40-50 cm
Indigenous or Exotic	Indigenous
Breeding season	July to October in Thailand. Hatching period 23–33 hrs at water temp. 28°C to 31°C
Used in Aquaculture	Hugely important in the Mekong Delta, where it is reared in pens, cages and ponds. Also reared in Thailand, Cambodia and Laos
Economic Importance	Excellent food fish with very white fine grained sweet flesh. Marketed fresh. Or processed as fillets.
Food security importance	Important source of food for small-scale aquaculture households and river fishermen
Preferred Habitat	Found in large rivers and estuaries.
Migration	Occurs in high estuary (freshwater tidal zone) as juveniles, moving to brackish water as sub-adults, and finally as adults to river mouths and inshore areas.
Diet	Feeds on snails, other mollusk and plants.
Water quality requirements	
• **Temperature range**	23°C to 28°C
• **Salinity range**	Tolerant of ?? ppt.
• **O_2**	High tolerance of low DO conditions. Able to utilize atmospheric oxygen.
• **pH range**	6.0–7.5
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Mkl, CP, MK (Ref1) Pong, Chi, Mun Rivers (Ref 6,7,10,13)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	

13. *Puntioplites falcifer*

Image: http://www.fishbase.us/images/thumbnails/jpg/tn_Pufal_u0.jpg

Code No.	M8
Common name	Sickle fin barb
Local name	**Vn:** Cá Danh xam; **Kh:** Trey Chrakeng; **L:** Pa Keng; **Th:** Pla Keng ()
Latin name	*Puntioplites falcifer*
Family	*Cyprinidae*
Description of fish	Pale orange anal, pelvic and dorsal fins; last simple dorsal ray reaching the caudal fin in adults and with 28-36 serrae (in specimens 6–15 cm SL) serrated anal spine; silvery body coloration. Dorsal fin high; spine very elongated with over 26 serrations, anal spine serrated. Body silvery plain grey or pale brown; fin orange or brownish yellow.
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	Max length : 40.0 cm
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	
Economic Importance	Commercial
Food security importance	Common in the markets
Preferred Habitat	Mainstreams, marshlands and floodplains. Inhabits large upland rivers. Seems to avoid standing water. Marketed fresh.
Migration	Also reported to prefer deep pools in the river and to migrate into streams, canals and lakes during the flood season. Migrates in large schools. Migrates together with *Cosmochilus harmandi*, *Cirrhinus* spp., *Labeo chrysophekadion* and *Bangana* sp. Widely distributed in the Mekong basin. Breeds in both mainstream and tributaries. Social species, migrates in large shoals with other species. Migration triggered by changes in water level, Migrates back to main stream at end of wet season.
Diet	Carnivorous benthic. Like other members of the genus, it probably feeds mainly on plant matter and occasionally on insects and insect larvae
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	MK Pong, Chi, Mun Rivers (Ref 3,7,13)
• **Vietnam**	
Trends and Threats	Mekong endemic.
IUCN Red List status	Least concern
Sources:	FishBase

14. *Macrobrachium rosenbergii*

Image: http://b2bfoodmarket.com/buyingleads/img4_1macrobrachium_rosenbergii_01_x.jpg

Code No.	M9
Common name	Giant Freshwater Prawn
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** *Kung Kam Kram*
Latin name	*Macrobrachium rosenbergii*
Family	Palaemonidae
Description of fish	
Environment	
Maximum size	Can grow to a length of over 30 centimetres, body wt 380-400 grams
Indigenous or Exotic	Indigenous
Breeding season	In mating, the male deposits spermatophores on the underside of the female's thorax, between the walking legs. The female then extrudes eggs, which pass through the spermatophores. The female carries the fertilised eggs with her until they hatch; the time may vary, but is generally less than three weeks. Females lay 10,000–50,000 eggs up to five times per year. From these eggs hatch zoeae, the first larval stage of crustaceans. They go through several larval stages before metamorphosing into postlarvae, at which stage they are 0.28–0.39 inch (7.1–9.9 mm) long and resemble adults. This metamorphosis usually takes place about 32 to 35 days after hatching. These postlarvae then migrate back into freshwater.
Used in Aquaculture	Common cultured in earth pond in many provinces in Thailand. Commonky cultured in the Mekong Delta
Economic Importance	Commercially important for its value as a food source. Exported.
Food security importance	Growth rapidly when stocked in natural bodies and high demand for local fishers
Preferred Habitat	Freshwater connecting with estuarine (Ref 35)
Migration	While *M. rosenbergii* is considered a freshwater species, the larval stage of the animal depends on brackish water Once the individual shrimp has grown beyond the planktonic stage and become a juvenile, it will live entirely in freshwater.
Diet	Omnivorous
Water quality requirements	
• **Temperature range**	Can tolerance to 15°C to 35°C but prefer 31°C for good growth rate (ref 22)
• **Salinity range**	Can tolerance to 18 ppt but prefer 0-4 ppt for good growth rate.
• **O_2**	Optimum range 5–8 mg/l.
• **pH range**	7.8-9.0
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Found in rivers and estuaries connecting to the sea such as CP, Maeklong, Pranburi, Nakorn Nayok, Bankpakong, Chanthaburi, Weru, Lungsaun, Tapi, Kraburi, Trung, Pattani rivers and Songkla lake. (ref 18)
• **Vietnam**	
Trends and Threats	Number in the wild decline as a cause of dam or water gate construction to obstruct their migration during spawning period
IUCN Red List status	
Sources:	

15. *Hypsibarbus malcolmi*

Image: http://fishbase.sinica.edu.tw/images/species/Pomal_u0.jpg

Code No.	M10
Common name	Tinfoil Barb
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Jad
Latin name	*Hypsibarbus malcolmi*
Family	*Cyprinidae*
Description of fish	Upper body dark and greenish
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	Max length : 50.0 cm
Indigenous or Exotic	Indigenous
Breeding season	Spawning period during November and December. Breeds at the end of the rainy season, as the water levels fall, young of the year 2 cm length appear in February to March. Below the Khone Falls, fishermen reported that this species group undertook short local migrations, including lateral migrations. The migrations were reportedly triggered by rising and receding water levels, respectively. At three stations, migration from flooded areas and back to the main river was reported to occur just before the full moon. Above the Khone Falls, in the Lao PDR and Thailand, there was contradictory information regarding migratory patterns, i.e., both upstream and downstream movements were reported during the onset of the monsoon season. Such movements probably reflect different species within the group. Two fishermen from Chiang Khong and Loei, respectively, reported spawning behaviour in May. They both observed fish gathering in large groups in shallow waters near a sandy beach in the Mekong mainstream. April to June is the peak period for observing eggs in the fish, which further indicates a spawning period within that period. The spawning behaviour of Hypsibarbus malcolmi was previously studied at the Khone Falls (Baird and Phylavanh, 1999c). This species vocalises during its spawning season in November and December; based on these vocalisations, three spawning grounds were identified just below the Khone Falls, near the border between Cambodia and the Lao PDR (Baird and Phylavanh, 1999c). Hypsibarbus malcolmi is thus one of the few species to have a distinct spawning season in the early dry season.
Used in Aquaculture	This species be reproduced by artificial hormone injection by Petburi Fisheries Research and Development Center. Not commonly cultured.
Economic Importance	Commercial. Marketed fresh. Very popular in the aquarium trade
Food security importance	
Preferred Habitat	Occurs in midwater to bottom depths in large and medium-sized rivers. Usually found over coarse substrate. Has not persisted in any impoundments.
Migration	Found in large rivers in the dry season and moves to medium-sized rivers in the wet season.
Diet	Herbivore (ref 28). Its gut is usually full of fine matter with occasional insect exoskeleton.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Mkl, St, CP, MK (Ref1) Petch River in Petchaburi province and Ping River in Tak province (Ref 28), Songkram River(ref 5)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	FishBase

16. *Channa striatus*

Image: http://www.online-utility.org/image/ImageCache?file=0/05/Gabus_070909_0074_rwg.jpg/800px- Gabus_070909_0074_rwg.jpg

Code No.	B1
Common name	Striped Snakehead
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Chon
Latin name	*Channa striatus*
Family	*Channidae*
Description of fish	Body sub-cylindrical; head depressed; caudal fin rounded. The dorsal surface and sides is dark and mottled with a combination of black and ochre, and white on the belly; a large head reminiscent of a snake's head; deeply-gaping, fully toothed mouth; very large scales
Environment	Freshwater; brackish; benthopelagic; potamodromous
Maximum size	Max length: 100.0 cm. 3kg. In general 30-40cm
Indigenous or Exotic	Indigenous
Breeding season	In Thailand, spawning period staring from May to October (high peak during June to July). They prefer stagnant water at 30–100 cm deep for spawning ground. Optimum wt. of female is about at 800–1000 grams or more at the age of at least one year old. Hatching period 30–35 hrs. at water temp 27 C, pH 7.8.
Used in Aquaculture	Economic important cultured species. Both natural and artificial fish breeding. Predation by this species is a problem for small-scale fish farmers raising fish in ponds.
Economic Importance	Important food fish, usually marketed live. Processed into pra-hoc, mam-ruot, and mam-ca-loc (varieties of fish paste) in Cambodia Firm white flesh almost bone-free, heavy dark skin good for soup. The flesh is of good quality.
Food security importance	Important fish for many lowland rice farmers, as it can be caught from fields and trap ponds in rice growing areas. In Thailand there is a trade of dried pla chon mae-la well known in the central region.
Preferred Habitat	Adults inhabit ponds, streams and rivers, preferring stagnant and muddy water of plains. Found mainly in swamps, but also occurs in the lowland rivers. More common in relatively deep (1–2 m), still water. Very common in freshwater plains. Occur in medium to large rivers, brooks, flooded fields and stagnant waters including sluggish flowing canals. Survive dry season by burrowing in bottom mud of lakes, canals and swamps as long as skin and air-breathing apparatus remain moist and subsists on the stored fat.
Migration	Undertake lateral Migration from the Mekong mainstream, or other permanent water bodies, to flooded areas during the flood season and return to the permanent water bodies at the onset of the dry season.
Diet	Feed on fish, frogs, snakes, insects, earthworms, tadpoles and crustaceans
Water quality requirements	
• **Temperature range**	
• **Salinity range**	Freshwater (0 ppt) to 0.2–0.3 ppt
• **O_2**	Tolerance to low DO due to existing of accessory respiratory organ (labyrinth organ)
• **pH range**	pH range: 7.0-8.0
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Sw, E, Mkl, St, CP, MK (Ref1) Kwan Phayao (ref 2), Songkram River(ref 5), Mun River (ref 3,6,10,13), Pong, Chi, Mun Rivers (Ref 7), Hauy-Laung Reservior (ref 8), Lahanna(ref 9), Nonghan (ref 11,12,39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25) and common found in fresh water bodies; wide spread in the whole country
• **Vietnam**	
Trends and Threats	During winter and dry season, its flesh around coelomic cavity is heavily infested by a larval trematode *Isoparorchis hypselobargi*. Other parasites infecting this fish include *Pallisentis ophicephali* in the intestine and *Neocamallanus ophicepahli* in the pyloric caecae.
IUCN Red List status	Least concern
Sources:	FishBase

17. *Trichogaster pectoralis*

Image: http://forumimage.ru/uploads/20120807/134436685125009883.jpg

Code No.	B2
Common name	Snakeskin Gourami
Local name	**Vn:** Cá Sac ran; **Kh:** Trey Kawnthor; **L:** Pa Salid; **Th:** Pla Salid ()
Latin name	*Trichogaster pectoralis*
Family	Osphronemidae
Description of fish	An Anabantid. Dorsal fin with short spines and long soft rays. Caudal fin slightly emarginate. First soft ray of pelvic fins prolonged into a tentacle extending posteriorly to hind margin of caudal fin. Body with numerous dark oblique cross bands which are not always distinct; presence of irregular black stripe from eye to middle of caudal fin base Short snout, directed upwards; 10–11 dorsal spines; caudal fin slightly emarginate. Body brownish-yellow to greenish with dark oblique bars and longitudinal mid-body stipe. Juveniles with dark longitudinal midbody stipe and dark spot on caudal base.
Environment	Freshwater; benthopelagic; potamodromous
Maximum size	Max length: 25.0 cm 500 gm. In general 10–16 cm
Indigenous or Exotic	Indigenous
Breeding season	Spawn during rainy season starting from April to September. Adult mature about 7 months and one can spawn several times. 4,000–10,000 eggs per female. Hatching period take 24–30 hrs.
Used in Aquaculture	Cultured both for food and for export as aquarium fish. Often grown in large shallow ponds with emergenet grass vegetation. Difficult to culture intensively.
Economic Importance	Commercial. Highly economic species; both by capture and culture includes in the peat areas. Marketed fresh or dried. Common in the markets.
Food security importance	The flesh is of good quality; may be grilled or used for fish soup. In Thailand there is a trade of dried pla salid for the benefit of people in areas where it is not caught
Preferred Habitat	Marshlands and floodplains. Found in shallow sluggish or standing-water habitats with a lot of aquatic vegetation. Generally feeds on aquatic plants.
Migration	Occurs in flooded forests of the lower Mekong and gradually moves back to rivers and Great Lake as floodwaters recede
Diet	Omnivorous, plankton and insects.
Water quality requirements	
• **Temperature range**	23°C to 28°C
• **Salinity range**	
• **O_2**	Can breathe air directly, as well as absorb oxygen from water through its gills.
• **pH range**	6.0-8.3
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	E, Mkl, St, CP, MK (Ref1) Songkram River (ref 5), Pong, Chi, Mun Rivers (Ref 7), Nonghan (ref 11,12,39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25).
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	FishBase

18. Mastocembalus armatus

Image: http://teakdoor.com/Gallery/albums/userpics/10004/mastacembelus_armatus2.jpg

Code No.	B3
Common name	Zig Zag eel
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Ka ting
Latin name	*Mastocembalus armatus*
Family	Mastacembelidae
Description of fish	An eel like fish. Body dull brown with 1–3 darker, longitudinal zigzag lines, more or less connected to form a reticulated pattern, more or less distinct and restricted to the dorsal two thirds of the body
Environment	Freshwater; brackish; demersal; potamodromous
Maximum size	Max length: 90.0 cm. 500g. In general 30–50 cm (ref 37)
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	
Economic Importance	Marketed fresh and frequently seen in the aquarium trade Economic important species, both food and aquarium trades.
Food security importance	
Preferred Habitat	Adults live in highland streams to lowland wetlands. Usually found in streams and rivers with sand, pebble, or boulder substrate. They seldom leave the bottom except when disturbed. Also occur in still waters, both in coastal marshes and dry zone tanks. Sometimes stays partially buried in fine substrate. Enter flooded forest.
Migration	Reported to occur in areas with rocky bottoms in the Mekong mainstream during the dry season, but enter canals, lakes and other floodplain areas during the flood season. Common during the summer months.
Diet	Forages at night on benthic insect larvae, worms and some submerged plant material
Water quality requirements	
• **Temperature range**	22°C to 28°C
• **Salinity range**	
• **O_2**	
• **pH range**	6.5-7.5
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Sw, E, Mkl, St, CP, MK (Ref1) Songkram River(ref 5), Pong, Chi, Mun Rivers (Ref 3, 7, 13), Nonghan (ref 39), Chulaporn Reservoir (ref 4)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	FishBase

19. *Clarias batrachus*

Image: http://apps.acesag.auburn.edu/mediamax/pdata/303.png

Code No.	B4
Common name	Walking Catfish
Local name	**Vn:** Cá Tre trang; **Kh:** Trey Andaing roueng; **L:** Pa Dug en; **Th:** Pla Dug daan ()
Latin name	*Clarias batrachus*
Family	*Clariidae*
Description of fish	A bottom dwelling catfish. Upper jaw a little projecting. Spine of pectoral fins rough on its outer edge and serrated on its inner edge. Occipital process more or less triangular, its length about 2 time in its width; distance between dorsal and occipital process 4-5.5 times in distance from tip of snout to end of occipital process. Genital papilla in males is elongated and pointed
Environment	Freshwater; brackish; demersal; potamodromous
Maximum size	Max length: 47.0 cm. 1.2 kg. In general 20–25 cm
Indigenous or Exotic	Indigenous
Breeding season	May to November in Thailand
Used in Aquaculture	Was commercially cultured, in Thailand but now replaced by Clarias Hybrid
Economic Importance	An important food fish that is marketed live, fresh and frozen. Common in the markets
Food security importance	Important fish for rice farmers, as it is commonly found in fields and trao ponds. The Lao use this fish as lap pa or ponne pa.
Preferred Habitat	Floodplains to hill stream. Adults inhabit lowland streams, swamps, ponds, ditches, rice paddies, and pools left in low spots after rivers have been in flood. Usually confined to stagnant, muddy water. Found in medium to large-sized rivers, flooded fields and stagnant water bodies including sluggish flowing canals. Able to survive in damp areas during dry season.
Migration	Undertake lateral Migrations from the Mekong mainstream, or other permanent water bodies, to flooded areas during the flood season and returns to the permanent water bodies at the onset of the dry season. Can live out of water for quite sometime and move short distances over land. Can walk and leave the water to migrate to other water bodies using its auxiliary breathing organs.
Diet	Omnivorous, mainly benthos and plant matters Feed on insect larvae, earthworms, shells, shrimps, small fish, aquatic plants and debris.
Water quality requirements	
• **Temperature range**	10°C to 28°C
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Sw, E, Mkl, St, CP, MK (Ref1) Songkram River (ref 5), Mun River (ref 3, 6, 10, 13), Pong, Chi, Mun Rivers (Ref 7), Hauy-Laung Reservior (ref 8), Nonghan (ref 11, 12, 39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25).
• **Vietnam**	
Trends and Threats	Competition from invasive *Clarias gariepinus*.
IUCN Red List status	Least concern
Sources:	FishBase

20. *Hemibagrus nemurus*

Image: http://www.zipcodezoo.com/hp350/Hemibagrus_nemurus_0.jpg

Code No.	B5
Common name	Red Tailed catfish
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Kod- lueng
Latin name	*Hemibagrus nemurus*
Family	Bagridae
Description of fish	Body color brown often with greenish sheen. Fins gray with violet tint. Pectoral fin spines serrated along the inner edge. Base of adipose fin shorter than that of dorsal fin and about equal to that of anal fin. Barbels four pairs; nasal barbels extending to or beyond eyes, maxillary ones in anal fin, mandibulary ones beyond base of pectoral fins, mental ones 2/3-3/4 the distance between their base and insertion of pectoral fins. Head flattened rather than conical; rugose skull roof; depressed dorsal fin not reaching adipose fin; pectoral fin smooth in front; 9 branched anal rays
Environment	Freshwater; brackish; benthopelagic; potamodromous
Maximum size	Max length: 72 cm (ref 28). In general 20–25 cm TL
Indigenous or Exotic	Indigenous
Breeding season	All year round but high peak of spawning period depend on location and weather for example February–October in Chao praya River, May to November in the Southern of Thailand.
Used in Aquaculture	Yes. Both in cage and pond culture
Economic Importance	A highly priced aquarium fish.
Food security importance	Usually marketed fresh. High in nutritive values especially omega-3 fatty acids (EPA, DHA)
Preferred Habitat	Occurs in most habitat types, but most frequent in large muddy rivers, with slow current and soft bottom. Enters flooded forest.
Migration	Does not migrate long distances. Moves into flooded forests to spawn and the young are usually first seen in August. In Tonlé Sap (Cambodia), maximum numbers are found as it returns to rivers in November and December. Resides in deep pools in mainstream and trivbutaries during the dry season.
Diet	Feeds on exogenous insects, aquatic insect larvae, shrimps, other crustaceans and fishes.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	7.0-8.2
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	E, Mkl, St, CP, MK (Ref1), Pong, Chi, Mun Rivers (Ref 3, 6, 7, 10, 13), Hauy-Laung Reservior (ref 8), Nonghan (ref 12, 39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25). Widespread distribution in the country (Ref 32).
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	FishBase

21. *Penaeus monodon*

Image: http://nas.er.usgs.gov/XIMAGESERVERX/2008/20081204171904.jpg

Code No.	E1
Common name	Black Tiger Shrimp
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Kung Kuladum
Latin name	*Penaeus monodon*
Family	
Description of fish	*Penaeus monodon*, the giant tiger prawn is a marine crustacean widely reared for food.
Environment	Marine and brackish water environments.
Maximum size	Females can reach approximately 33 cm long, but are typically 25–30 cm long and weight 200–320 grams; males are slightly smaller at 20-25 cm (8–10 in) long and weighing 100–170 g (3.5–6.0 oz)
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	*Penaeus monodon* is the most widely cultured prawn species in the world, although it is gradually losing ground to the whiteleg shrimp, *Litopenaeus vannamei* Globally, in 2009, 770,000 tonnes was produced, with a total value of US$3,650,000,000.
Economic Importance	High but declining due to production problems with this species.
Food security importance	Indirect. Many poor households are engaged in shrimp farming in the Mekong Delta. By-catches from ponds probably more important.
Preferred Habitat	Mangrove areas.
Migration	Migrates to breed in deep offshore areas. Post larvae and juveniles migrates to mangrove fringes as nursery grounds.
Diet	
Water quality requirements	
• **Temperature range**	24°C to 34°C
• **Salinity range**	15–20 ppt (optimum for aquaculture)
• **O_2**	>5 ppm to saturation point (optimum for aquaculture))
• **pH range**	7.5–8.5 (optimum for aquaculture)
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Thai coast both in Andaman sea and Gulf of Thailand.
• **Vietnam**	
Trends and Threats	In 2010, Greenpeace added *Penaeus monodon* to its seafood red list—"a list of fish that are commonly sold in supermarkets around the world, and which have a very high risk of being sourced from unsustainable fisheries" The reasons given by Greenpeace were "destruction of vast areas of mangroves in several countries, over-fishing of juvenile shrimp from the wild to supply farms, and significant human rights abuses.
IUCN Red List status	
Sources:	Wikipedia.

22. *Anadara granosa*

Image: http://noeyeddeer.com/fish/images/anadara-granosa-1b.jpg

Code No.	E2
Common name	Blood cockle
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Hoi Klang
Latin name	*Anadara granosa*
Family	
Description of fish	A species of ark clam known as the **blood cockle** due to the red haemoglobin liquid inside. Shell equivalve, thick and solid, ovate, strongly inflated, slightly longer than high and feebly inequilateral. Umbones strongly protruding, cardinal area rather large. About 18 radial ribs (15 to 20) with wide interstices at each valve. Ribs stout and distinctly rugose, bearing regular, often rectangular nodules. Periostracum rather thin and smooth. Internal margins with strong crenulations corresponding with the external radial ribs. No byssal gape. Outside of shell white under the yellowish brown periostracum. Inner side white, often tinged light yellow towards the umbonal cavity.
Environment	
Maximum size	9 cm long. In general 6 cm.
Indigenous or Exotic	Indigenous
Breeding season	*A. granosa* reproduces from August to February of the next year and begins to be mature at the age of 1+ – 2+. One female can produce 518,400–2,313,200 eggs.
Used in Aquaculture	*A. granosa* are a popular species in Thailand. Cockles are usually cultivated on mud in the intertidal zone with a water salinity of around 10-32 ppt. The production was of around 20 to 21 thousands of tons per year in 1996/7.
Economic Importance	It has a high economic value as food,
Food security importance	It is served steamed, boiled, roasted, or traditionally raw. In Thailand, cockle consumption exceeds local production every year, requiring imports.
Preferred Habitat	It lives mainly in the intertidal zone in one to two metres water depth, burrowed down into sand or mud. *A. granosa* can live in 20m water depth but concentrates in the littoral area *A. granosa* is a typically intertidal species which naturally lives in an area of silty bottom with relatively low salinity and some time of desiccation every day.
Migration	Larvae migrate with tides and currents. Adults sedentary.
Diet	Shallow Burrower.Filter Feeder. Their feeding habit is related to the bottom feed where they live. Their important nutrient components are organic detritus (98% were found in cockle's intestine), phytoplankton and unicellular algae.
Water quality requirements	
• **Temperature range**	Optimum temperature ranging from 20°C to 30°C.
• **Salinity range**	Tolerate salinities of 14–30 ppt
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Found in Thai coast such as Petchaburi, Chonburi, Samutsongkram, Sumutsakorn, Samutprakan, Suratthani and Chumporn Bays. (ref 29)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	
Sources:	FAO Fisheries Department

23. *Lates calcarifer*

Image: http://helifish.com.au/sites/default/files/2010/Barramundi_Lates%20calcarifer.jpg

Code No.	E3
Common name	Sea Bass , Giant sea perch, barramundi
Local name	**Vn:** Cá Chiem; **Kh:** Trey Spong; **Th:** Pla Kapong khao ()
Latin name	*Lates calcarifer*
Family	Centropomidae
Description of fish	An oblong body perch-like with mouth large; slightly oblique, upper jaw extending behind the eye. Dusky or olive silver body; fins dusky. Juveniles with pale mid-dorsal stripe on dark body. Body elongate; mouth large, slightly oblique, upper jaw extending behind the eye. Lower edge of preopercle serrated, with strong spine at its angle; opercle with a small spine and with a serrated flap above the origin of the lateral line. Caudal fin rounded.
Environment	Marine; freshwater; brackish; demersal; catadromous
Maximum size	Max length : 200 cm. 60kg
Indigenous or Exotic	Indigenous
Breeding season	A protandrous hermaphrodite.
Used in Aquaculture	Presently used for aquaculture in Thailand, Indonesia and Australia. They reach 1,500-3,000 g in one year under optimum conditions. Commonly grown in cages in river mouths.
Economic Importance	Sold fresh and frozen; consumed steamed, pan-fried, broiled and baked A very popular and sought-after fish of very considerable economic importance. Common in the markets.
Food security importance	Limited but an important cash crop for poor fishing households in coastal areas.
Preferred Habitat	Found in coastal waters, estuaries and lagoons, in clear to turbid water. Larvae and young juveniles live in brackish temporary swamps associated with estuaries, and older juveniles inhabit the upper reaches of rivers. Have preference for cover on undercut banks, submerged logs and overhanging vegetation
Migration	A diadromous fish, inhabiting rivers before returning to the estuaries to spawn.
Diet	Carnivorous, fishes and shellfishes. Feed on fishes and crustaceans. Juveniles also eat insects
Water quality requirements	
• **Temperature range**	15°C to 28°C
• **Salinity range**	
• **O_2**	Requires at least 3 mg/l
• **pH range**	6.8-8.5 (ref 34)
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Central Indo West-Pacific () Common found in estuarine and coasts of Thailand both Andaman and Gulf of Thailand.
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Not evaluated
Sources:	FishBase

24. *Pseudapocryptes elongatus*

Image: http://www.mudskipper.it/SpeciesPages/elon01.jpg

Code No.	E4
Common name	Elongated mudskipper, Slender mudskipper ()
Local name	**Vn:** Cá Bong lan; **Th:** Pla Kuea. ()
Latin name	*Pseudapocryptes elongatus*
Family	Gobiidae
Description of fish	Body depth less than 14% of standard length. Olive grey body with 6-8 dark bars running obliquely from dorsum to lateral midline, small spots on cheeks, opercula and nape, but not on body
Environment	Amphibious air-breather; brackish water areas.
Maximum size	Max length : 20.0 cm
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	Now cultured in Mekong Delta, using juveniles caught from the wild.
Economic Importance	
Food security importance	Locally common in the markets
Preferred Habitat	Estuaries and mudflat. Found in mudflats of estuaries and the freshwater tidal zone of rivers
Migration	
Diet	Carnivorous, benthos.
Water quality requirements	
• **Temperature range**	23°C to 28°C
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Indo-West Pacific
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Least concern
Sources:	FishBase

25. *Pangasius krempfi*

Image: http://2.bp.blogspot.com/_6e5MQQGb7yQ/TMUdFcGJtTI/AAAAAAAAAH0/jUJXaEzx98o/s1600/Pangasius+Krempfi.jpg

Code No.	E5
Common name	Sea pangasiid
Local name	**Vn:** Cá Bong lao; **Kh:** Trey Bong lao; **L:** Pa Suay sor; **Th:** Pla Suay Sor ()
Latin name	*Pangasius krempfi*
Family	Pangasiidae
Description of fish	Body dark blackish gray on top and sides, silver gray on abdomen and fins lightly yellow. caudal-fin stripes absent; no humeral spot; 18-22 gill rakers in first arch.
Environment	Marine; freshwater; brackish; benthopelagic; Anadromous
Maximum size	Max length : 120 cm 14kg
Indigenous or Exotic	Indigenous
Breeding season	
Used in Aquaculture	
Economic Importance	Commercial
Food security importance	Locally uncommon in the markets of middle Mekong, more common in the Delta
Preferred Habitat	Mainstreams, seasonally long distant migrate; juveniles nursing in estuaries and coastal areas. Unique among pangasiid species in the Mekong in spending a major part of its life in marine coastal waters but details unclear. Stays in deep pools within the mainstream during the dry season.
Migration	Migrates into the Mekong River (but not into any other rivers) in order to breed. It was hypothesized that at least two populations in the Mekong undertake Migration. One population migrates during May-September from just south of Khone Falls upstream to spawning grounds along the mainstream Mekong all the way to Chiang Khong near the Lao-Thai-Myanmar border. The other population migrates downstream from around Stung Treng to unknown spawning grounds somewhere between Stung Treng and Kompong Cham in Cambodia during the spawning season between May and August. When water level starts to fall in October, the fish moves back to the main river to initiate an upstream dispersal Migration, reaching the stretch just below the Khone Falls.
Diet	Carnivorous, mainly crustacean
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	MK (Ref1)
• **Vietnam**	
Trends and Threats	
IUCN Red List status	Vulnerable and Mekong endemic
Sources:	FishBase

26. *Oreochromis niloticus*

Image: http://el.erdc.usace.army.mil/ansrp/ANSIS/image/oreochromis_niloticus.jpg

Code No.	X1
Common name	Nile Tilapia
Local name	**Vn:** Cá Ro phi van; **Kh:** Trey Tilapia; **L:** Pa Nil; **Th:** Pla Nil ()
Latin name	*Oreochromis niloticus*
Family	Cichlidae
Description of fish	Most distinguishing characteristic is the presence of regular vertical stripes throughout depth of caudal fin Jaws of mature male not greatly enlarge (length of lower jaw 29% to 37% of head length); genital papilla of breeding male not tassellated. Body olive or dark grey with regular vertical stripes throughout the depth; margin of dorsal fin grey or black, caudal fin with numerous black bars, vertical bars in caudal fin 7-1.
Environment	Freshwater; brackish; benthopelagic; potamodromous
Maximum size	Max length: 60.0 cm 4.3 kg. In general 25-35 cm.
Indigenous or Exotic	Exotic
Breeding	Oviparous. Mouth brooding by females. Spawning 3-4 times a year. Hatching period 8 days at 27°C water temp.
Used in Aquaculture	Highly commercial. Common and popular in aquaculture. Stocked in reservoirs supporting important fisheries.
Economic Importance	Important farmed species. Marketed fresh and frozen.
Food security importance	Important
Preferred Habitat	Occur in a wide variety of freshwater habitats like rivers, lakes, sewage canals and irrigation channels. Mainly diurnal. Adaptive to all types of freshwaters, sometimes estuaries.
Migration	None
Diet	Omnivorous, algae, detritus and benthos. Feed mainly on phytoplankton or benthic algae.
Water quality requirements	
• **Temperature range**	11°C to 42 °C
• **Salinity range**	0-20 ppt (ref 16,17) and 5-10 ppt for optimum growth rate
• **O_2**	Not less than 4 mg/l. If DO <3 mg/l, fish begin to die.
• **pH range**	6.5-8.0
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Introduced to Thailand since 1965. Originate in Africa, globally introduced. Commonly found in water bodies in Thailand such as Kwan Phayao (ref 2), Songkram River (ref 5), Mun River (ref 3, 6, 10, 13), Pong, Chi, Mun Rivers (Ref 7), Nonghan (ref 11, 12, 39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25).
• **Vietnam**	
Trends and Threats	Does not flourish in the mainstream Mekong but can be found in some tributaries. A potential threat to native species
IUCN Red List status	Not evaluated
Sources:	FishBase

27. *Cyprinus carpio*

Image: http://nematode.unl.edu/carpio.jpg

Code No.	X2
Common name	Common Carp
Local name	**Vn:** Cá Chep; **Kh:** Trey Carp samahn; **L:** Pa Nai; **Th:** Pla Nai ()
Latin name	*Cyprinus carpio* Linnaeus(1758)
Family	*Cyprinidae*
Description of fish	Diagnosed from other cyprinid species in Europe by having the following characters: 2 pairs of barbels; dorsal fin with 15-20½ branched rays; caudal fin deeply emarginate (Ref. 59043). Pharyngeal teeth 1, 1, 3:3, 1,1, robust, molar-like with crown flattened or somewhat furrowed. Scales large and thick. `Wild carp ' is generally distinguished by its less stocky build with height of body 1:3.2-4.8 in standard length. Very variable in form, proportions, squamation, development of fins, and color.
Environment	
Maximum size	Max length : 110 cm, 40 kg
Indigenous or Exotic	Exotic
Breeding season	Spawns during January–April in Thailand. Adult mature about 6 months and 25 cm TL
Used in Aquaculture	In pond and cage polycultures.
Economic Importance	Commercial. Utilized fresh and frozen. Aquarium keeping. Forms the major part of some reservoir fisheries. E.g. Nam Theun II
Food security importance	Common in aquaculture and markets of the Delta.
Preferred Habitat	Mainly in ponds or impounded waters. . Adults inhabit warm, deep, slow-flowing and still waters such as lowland rivers and large, well vegetated lakes. Hardy and tolerant of a wide variety of conditions but generally favor large water bodies with slow flowing or standing water and soft bottom sediments. Thrive in large turbid rivers. Most active at dusk and dawn. Spawns along shores or in backwaters. Larvae survive only in very warm water among shallow submerged vegetation. East Asian congeners and their hybrids have caused continuous decline of wild populations.
Migration	Adults often undertake considerable spawning Migration to suitable backwaters and flooded meadows
Diet	Omnivorous, plant matters, benthos. Both adults and juveniles feed on a variety of benthic organisms and plant material.
Water quality requirements	
• **Temperature range**	3°C to 35°C
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Introduced, origin from China (). Widespread in rivers and wetlands such as Songkram River (ref 5), Mun River (ref 3, 6, 10, 13), Pong, Chi, Mun Rivers (Ref 7), Nonghan (ref 39), Chulaporn Reservoir (ref 4), Nong Bong Khai_Chiangsaen (Ref 25).
• **Vietnam**	
Trends and Threats	Established in the Mekong river and some tributaries. A threat to native species
IUCN Red List status	
Sources:	Fishbase

28. *Labeo rohita*

Image: http://parisaramahiti.kar.nic.in/Gallery%20new/Photo%20Gallery/Albums/Album3/Large/Labeo_rohita.jpg

Code No.	X3
Common name	Rohu
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Yee Sok Ted
Latin name	*Labeo rohita*
Family	*Cyprinidae*
Description of fish	Large scaled carp. Dorsal fin with 12-14 1/2 branched rays; lower profile of head conspicuously arched; short dorsal fin with anterior branched rays shorter than head; 12-16 predorsal scales ; snout without lateral lobe
Environment	Freshwater; brackish; benthopelagic; potamodromous
Maximum size	Max length : 200 cm 45kg In general 60-80 cm
Indigenous or Exotic	Exotic. Widely introduced outside its native range for stocking reservoirs and aquaculture.
Breeding season	Spawning season generally coincides with the southwest monsoon. Spawning occurs in flooded rivers. Fecundity varies from 226,000 to 2,794,000 depending upon the length and weight of the fish and weight of the ovary.
Used in Aquaculture	Yes. Common in polycultures with other carps.
Economic Importance	Medium. Utilized fresh
Food security importance	Medium
Preferred Habitat	Adults inhabit rivers. Are diurnal species and usually solitary. They burrow occasionally.
Migration	
Diet	Feed on plants and plankton growing on emergent vegetation.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Introduce from India since 1968 and wide spread in country.such as Mun River, Nonghan Chulaporn Reservoir Nong Bong Khai_Chiangsaen.
• **Vietnam**	
Trends and Threats	Established in the mainstream Mekong in the Delta, A potential threat to indigeneous species.
IUCN Red List status	Least concern
Sources:	FishBase

29. *Colossoma macropomum*

Image: http://upload.wikimedia.org/wikipedia/commons/1/15/Colossoma_macropomum_01.jpg

Code No.	X4
Common name	Pachu
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Pla Paku
Latin name	*Colossoma macropomum*
Family	
Description of fish	It is similar in shape to the pirhana and is sometimes confused with the carnivorous fish; the *pacu* is tall and laterally compressed with large eyes and a slightly arched back. Body color is basic black to gray with spots and blemishes in its mid body. All the fins are black and the pectoral fins are small.
Environment	
Maximum size	
Indigenous or Exotic	Exotic
Breeding season	
Used in Aquaculture	Ponds and cages. Also in aquarium trade
Economic Importance	Commercial
Food security importance	Limited
Preferred Habitat	Young and juveniles live in black waters of flood plains.
Migration	
Diet	This species is usually solitary. Adults stay in flooded forests during the first 5 months of flooding and consume fruits and grains.
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	
• **Vietnam**	
Trends and Threats	Escape from cages inevitable and could pose a threat to indigenous species.
IUCN Red List status	
Sources:	Wikipedia

30. *Pomacea canaliculata*

Image: http://www.applesnail.net/content/photographs/pomacea_can_walking.jpg

Code No.	X5
Common name	Golden Apple Snail
Local name	**Vn:** ; **Kh:** ; **L:** ; **Th:** Hoi Cherry
Latin name	*Pomacea canaliculata*
Family	
Description of fish	Large freshwater snail with gills and an operculum, an aquatic gastropod mollusk in the family Ampullariidae, the apple snails. South American in origin, The shells of these applesnails are globular in shape. Normal coloration typically includes bands of brown, black, and yellowish-tan; color patterns are extremely variable. Albino and gold color variations exist
Environment	Freshwater
Maximum size	The size of the shell is up to 150 mm in length
Indigenous or Exotic	Exotic. This species is considered to be in the top 100 of the "World's Worst Invasive Alien Species"
Breeding season	In tropical areas reproduction is continuous. The duration of the reproductive period of *P. canaliculata* decreases with latitude, to a minimum of six months in the southern limit of its natural distribution.[6]
Used in Aquaculture	Introduction into the world probably a result from aquacultire, which was initially encouraged in some areas. It is no longer farmed commercially.
Economic Importance	Limited
Food security importance	In Northeast Thailand, these snails are collected and consumed. They are picked by hand or with a handnet from canals, swamps, ponds and flooded rice paddy fields during the rainy season. During the dry season when these snails are concealed under dried mud, collectors use a spade to scrape the mud in order to find them. The snails are usually collected by women and children. [17] After collection, the snails are cleaned and parboiled. They are then taken out of their shells, cut, and cleaned in salted water. After rinsing with water, they are mixed with roasted rice, dried chili, lime juice, and fish sauce, and then eaten. In China and Southeast Asia, consumption of raw or undercooked snails of *Pomacea canaliculata* and other snails is the primary route of infection with *Angiostrongylus cantonensis* causing angiostrongyliasis.
Preferred Habitat	Small ponds and ricefields.
Migration	None
Diet	*Pomacea canaliculata* is extremely polyphagous, feeding on vegetal (primarily macrophytophagous, feeding on floating or submersed higher plants), detrital, and animal matter. Diet may vary with age, with younger smaller individuals feeding on algae and detritus, and older, bigger (15mm and above) individuals later shifting to higher plants
Water quality requirements	
• **Temperature range**	
• **Salinity range**	
• **O_2**	
• **pH range**	
Distribution:	
• **Cambodia**	
• **Lao PDR**	
• **Thailand**	Widespread in paddy field
• **Vietnam**	
Trends and Threats	This species negatively impacts rice and taro agriculture worldwide where it has been introduced.
IUCN Red List status	
Sources:	

ANNEX 4 – CAM VULNERABILITY ASSESSMENT TABLES

1.1. CHIANG RAI SUMMARY

Capture Fisheries

Species	Threat	Vulnerability
1. Tor tambroides UPLAND FISH, SOME MIGRATION, IMPORTANT FOR FOOD SECURITY IN SOME AREAS	Increase in temperature	very high
	Increase in precipitation	medium
	Decrease in precipitation	high
	Decrease in water availability	medium-
	increase in water availability	-
	Drought	medium
	Flooding	-
	Storms and Flash floods	high
	sea level rise	-
	increasing salinity	-
2. Cyclocheilichthys enoplos MIGRATORY, MEDIUM, WHITE FISH IMPORTANT FOR FOOD SECURITY	Increase in temperature	Very high
	Increase in precipitation	medium
	Decrease in precipitation	high
	Decrease in water availability	medium
	Increase in water availability	-
	Drought	medium
	Flooding	-
	Storms and Flash floods	medium
	sea level rise	-
	increasing salinity	-
3. Trichogaster pectoralis NON MIGRATORY, SMALL BLACK FISH, IMPORTANT FOR FOOD SECURITY.	Increase in Temperature	medium
	Increase in precipitation	medium
	Decrease in precipitation	low
	Decrease in water availability	medium
	increase in water availability	-
	Drought	medium
	flooding	-
	Storms and Flash floods	medium
	sea level rise	-
	increasing salinity	-

Aquaculture

System & species	Threat	Vulnerability
INTENSIVE POND MONOCULTURE OF CLARIAS CATFISH	Increase in temperature	high
	Increase in precipitation	low
	Decrease in precipitation	medium
	Decrease in water availability	very high
	Increase in water availability	-
	Drought	very high
	Flooding	very high
	Storms and Flash floods	high
	sea level rise	-
	increasing salinity	-
SEMI-INTENSIVE POND POLYCULTURE OF TILAPIA, SILVER BARB AND CARPS	Increase in temperature	high
	Increase in precipitation	medium
	Decrease in precipitation	very high
	Decrease in water availability	medium
	increase in water availability	-
	Drought	high
	Flooding	very high
	Storms and Flash floods	high
	sea level rise	-
	increasing salinity	-
EXTENSIVE POND POLYCULTURE OF CARPS & TILAPIA	Increase in temperature	medium
	Increase in precipitation	low
	Decrease in precipitation	medium
	Decrease in water availability	high
	Increase in water availability	
	Drought	high
	Flooding	high
	Storms and Flash floods	medium
	sea level rise	
	increasing salinity	

1.2. CHIANG RAI CAPTURE FISHERIES

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
1. Tor tambroides UPLAND FISH, SOME MIGRATION, IMPORTANT FOR FOOD SECURITY IN SOME AREAS	Increase in temperature	Maximum temperatures Increases of up to 10% in the wet season. 5-7% during other seasons. Even higher relative changes in minimum temps 3-27%, highest in the cool season.	Very High	very high	very high	This upland fish favours cooler waters. Increased temps may result in its disappearance from some lower stream reaches.This species spawns during November and December. Temperature increases at this time may result in changes in reproductive success. May also affect fish biology (maturation,hatching periods, etc)	low	very high
	Increase in precipitation	Increased precipitation in the period March-December, highest in the months of Aug & Sept and Oct. Highest perceptage increase in precipitation occurs in December (40%).	medium	high	medium	This fish favours clear flowing waters and spawns on gravel substrates. Increased turbidity will not favour this fish and may result in the siltation of spawning grounds. High turbidity may impact to availabilty of natural food for fry as well.	low	medium
	Decrease in precipitation	Decreases in precipitation are projected to occur duing the months of Jan & Feb, (although these are low rainfall months they are not the driest months).	high	medium	high	Affects on movement of stocks between pools, compounded by increase in temperature. Lower survival of fish during drier months.Lower stream flows. Affect to their habitats (streams in the mountain) during Jan & Feb affecting, availability of food. Lost connectivity of stream pools	low	high
	Decrease in water availability	Reduced soil water availability in period Feb-May and Aug & Sept. The dry season decrease may affect stream water flows.	low	high	medium	Reduced capacity of fish to move from pool to pool and onto floodplain. Availability of food.Reduced access to food. Increased fishing pressure.	low-	medium-
	increase in water availability	No negative effect.	-	-	-	-	-	-
	Drought	Droughts (>60% of years for 6 months) resulting in poorer water quality, increased fishing pressure in refuge areas. Negative effects compounded by temperature increase.	low	high	low	Reduced survival. Increased fishing pressure on stocks trapped in pools.	very low	medium
	Flooding	No negative effects anticipated	-	-	-			
	Storms and Flash floods	Increase in the number of days with daily precipitation above 100 mm, from 7-10 days. Increase in the highest single daily precipitation; 160mm	medium	medium	high	Possible effect on migration patterns. Poor water quality from erosion and pesticide from agricultural area nearby. Reduced survival of juveniles. Negative effecst on food availablity. Physical damage to adults.	medium	high
	sea level rise	n/a	-	-	-	-		
	increasing salinity	n/a	-	-	-	-		

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
2. Cyclocheilichthys enoplos MIGRATORY, MEDIUM, WHITE FISH IMPORTANT FOR FOOD SECURITY	Increase in temperature	Maximum temperatures Increases of up to 10% in the wet season. 5-7% during other seasons. Even higher relative changes in minimum temps 3-27%, highest in the cool season.	Very High	High	Very High	Reduced oxygen levels. Increased disease virulence. Effects on biology and behaviour of fish. Feeding behaviour, maturation, breeding, egg development, hatching, larvae survival affected	low	Very high
	Increase in precipitation	Increased precipitation in the period March-December, highest in the months of Aug & Sept and Oct. Highest perceptage increase in precipitation occurs in December (40%).	medium	Low	medium	Increased turbidity may affect feeding, breeding behaviour.	high	medium
	Decrease in precipitation	Decreases in precipitation are projected to occur duing the months of Jan & Feb, (although these are low rainfall months they are not the driest months).	high	high	high	Poorer water quality in pools may affect fish survival during dry season.	low	high
	Decrease in water availability	Reduced soil water availability in period Feb-May and Aug & Sept. The dry season decrease may affect stream water flows.	low	very high	medium	loss connectivity of reep pools, river courses and tributaries and floodplains. Poorer water quality in refuge areas, less food, increased competition, increased fishing pressure. Increased stress	low	medium
	Increase in water availability	No negative effect.	-	-	-	Increased connectivity, reduced competition, reduced fishing pressure. Easier migration movement.	-	-
	Drought	Droughts (>60% of years for 6 months) resulting in poorer water quality, increased fishing pressure in refuge areas. Negative effects compounded by temperature increase.	low	very high	medium	Deep pool areas and river course will loss connectivity with its tributeries and even itself and obstruct this species migrates. Adult normally found in the deep pool water only.	low	medium
	Flooding	No negative effects anticipated	-	-	-			
	Storms and Flash floods	Increase in the number of days with daily precipitation above 100 mm, from 7-10 days. Increase in the highest single daily precipitation; 160mm	medium	medium	medium	Possible effect on migration patterns. Poor water quality from run off from upstream reservoirs, erosion and pesticides from agricultural area nearby.	medium	medium
	sea level rise	n/a	-	-	-	-		
	increasing salinity	n/a	-	-	-	-		

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
3. Trichogaster pectoralis NON MIGRATORY, SMALL BLACK FISH, IMPORTANT FOR FOOD SECURITY.	Increase in Temperature	Maximum temperatures Increases of up to 10% in the wet season. 5-7% during other seasons. Even higher relative changes in minimum temps 3-27%, highest in the cool season.	Very High	low	high	Known to be tolerant of warm water and wide temperature variations. (optimum 23-28oC)	high	medium
	Increase in precipitation	Increased precipitation in the period March-December, highest in the months of Aug & Sept and Oct. Highest perceptage increase in precipitation occurs in December (40%).	high	very low	medium	Generally beneficial but poorer water quality may affect growth and maturation.	high	medium
	Decrease in precipitation	Decreases in precipitation are projected to occur duing the months of Jan & Feb, (although these are low rainfall months they are not the driest months).	medium	low	low	Resilient'black fish' species able to survive low Reduced rainfall in jan & feb will result in poorer dry season refuge enviornments water conditions. Decrease in rainfall does not happen at the driest time of year.	high	low
	Decrease in water availability	Reduced soil water availability in period Feb-May and Aug & Sept. The dry season decrease may affect stream water flows.	medium	low	medium	Loss habitats and connectivity. Poorer water quality, less food, increased competition, increased fishing pressure. Increased stress. Migration behaviour affected. Compounded by temperature increase.	low	medium
	increase in water availability	No negative effect.	-	-	-			
	Drought	Droughts (>60% of years for 6 months) resulting in poorer water quality, increased fishing pressure in refuge areas. Negative effects compounded by temperature increase.	low	very low	low	Loss habitats and connectivity. Poorer water quality, less food, increased competition, increased fishing pressure. Increased stress. Compounded by temperature increase.	medium	medium
	flooding	No negative effects anticipated	-	-	-			
	Storms and Flash floods	Increase in the number of days with daily precipitation above 100 mm, from 7-10 days. Increase in the highest single daily precipitation; 160mm	medium	medium	medium	Not expected to have significant impact on this species	high	medium
	sea level rise	n/a	-	-	-	-		
	increasing salinity	n/a	-	-	-	-		

1.3. CHIANG RAI AQUACULTURE

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
SEMI INTENSIVE POND POLYCULTURE OF TILAPIA, SILVER BARB AND CARPS	Increase in temperature	Maximum temperatures increases of up to 10% in the wet season. 5-7% during other seasons. Even higher relative changes in minimum temps 3-27%, highest in the cool season.	high	high	high	Reduced oxygen levels. Poorer water quality. Disease incidence.Reduced survival rate and growth rate of fish	low	high
	Increase in precipitation	Increased precipitation in the period March-December, highest in the months of Aug & Sept and Oct. Highest perceptage increase in precipitation occurs in December (40%).	medium	low	medium	Reduced water quality through turbidity Reduced productivity of pond and growth of fish	high	medium
	Decrease in precipitation	Decreases in precipitation are projected to occur duing the months of Jan & Feb, (although these are low rainfall months they are not the driest months).	medium	very high	high	Stagnation of pond water. Ammonia accumulation. Water column stratification Potential die offs	very low	very high
	Decrease in water availability	Reduced soil water availability in period Feb-May and Aug & Sept. The dry season decrease may affect stream water flows.	low	medium	medium	Accumulation of wastes in pond. Poorer water quality. Capacity to fill ponds.Reduced survival and growth of stock	medium	medium
	Increase in water availability	No negative effect.	-	-				
	Drought	Droughts (>60% of years for 6 months) resulting in poorer water quality, increased fishing pressure in refuge areas. Negative effects compounded by temperature increase.	medium	very high	high	Difficulty in maintaining pond water levels. StrataficationReduced survival and growth of stock	low	high
	Flooding	No negative effects anticipated	high	very high	very high	Control of pond water levels. Maintainence of pond fertility Loss of stock from pond	medium	very high
	Storms and Flash floods	Increase in the number of days with daily precipitation above 100 mm, from 7-10 days. Increase in the highest single daily precipitation; 160mm	medium	very high	high	Control of pond water. Maintenance of pond fertility in pond. Loss of stock from pond. Damage to pond infrastructure	low	high
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
INTENSIVE POND MONOCULTURE OF CLARIAS CATFISH	Increase in temperature	Maximum temperatures Increases of up to 10% in the wet season. 5-7% during other seasons. Even higher relative changes in minimum temps 3-27%, highest in the cool season.	high	high	high	Increased Disease incidence.Reduced survival rate and growth rate of fish	low	**high**
	Increase in precipitation	Increased precipitation in the period March-December, highest in the months of Aug & Sept and Oct. Highest perceptage increase in precipitation occurs in December (40%).	medium	low	medium	Reduced water quality through turbidity Fish tolerant of high trubidity Limited impact.	very high	low
	Decrease in precipitation	Decreases in precipitation are projected to occur duing the months of Jan & Feb, (although these are low rainfall months they are not the driest months).	medium	medium	medium	Stagnation of pond water. Water column stratification Fish tolerant of poor water quality Limited impact.	low	medium
	Decrease in water availability	Reduced soil water availability in period Feb-May and Aug & Sept. The dry season decrease may affect stream water flows.	medium	very high	high	Accumulation of wastes in pond. Poorer water quality. Capacity to fill ponds.Reduced survival and growth of stock	very low	very high
	Increase in water availability	No negative effect.	-					
	Drought	Droughts (>60% of years for 6 months) resulting in poorer water quality, increased fishing pressure in refuge areas. Negative effects compounded by temperature increase.	medium	very high	high	Maintaining pond water levels. Stratafication Reduced survival and growth of stock	very low	very high
	Flooding	No negative effects anticipated	high	very high	very high	Control of pond water levels. Maintainence of pond fertiliity Loss of stock from pond	low	very high
	Storms and Flash floods	Increase in the number of days with daily precipitation above 100 mm, from 7-10 days. Increase in the highest single daily precipitation; 160mm	medium	very high	high	Control of pond water. Maintenance of pond fertility in pond. Damage to pond infrastructure Loss of stock from pond. Damage to pond infrastructure	low	**high**
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
EXTENSIVE POND POLYCULTURE OF CARPS & TILAPIA	Increase in temperature	Maximum temperatures Increases of up to 10% in the wet season. 5-7% during other seasons. Even higher relative changes in minimum temps 3-27%, highest in the cool season.	high	low	medium	Increased Disease incidence. Low stress environment survival rate and growth rate of fish should not be affected.	low	medium
	Increase in precipitation	Increased precipitation in the period March-December, highest in the months of Aug & Sept and Oct. Highest perceptage increase in precipitation occurs in December (40%).	medium	low	medium	Reduced water quality through turbidity Fish tolerant of high trubidity Limited impact.	very high	low
	Decrease in precipitation	Decreases in precipitation are projected to occur duing the months of Jan & Feb, (although these are low rainfall months they are not the driest months).	medium	low	medium	Stagnation of pond water. Water column stratification Less fertile ponds, less suceptaple to turn-over	low	medium
	Decrease in water availability	Reduced soil water availability in period Feb-May and Aug & Sept. The dry season decrease may affect stream water flows.	medium	medium	medium	Accumulation of wastes in pond. Poorer water quality. Capacity to fill ponds. Less accumulation of wastes.	very low	**high**
	Increase in water availability	No negative effect.	-					
	Drought	Droughts (>60% of years for 6 months) resulting in poorer water quality, increased fishing pressure in refuge areas. Negative effects compounded by temperature increase.	medium	low	medium	Maintaining pond water levels. Stratafication Pond harvested if water levels are too low	very low	**high**
	Flooding	No negative effects anticipated	high	medium	high	Control of pond water levels. Maintainence of pond fertility Cultured fish lost, partially replaced by fish from wild.	low	**high**
	Storms and Flash floods	Increase in the number of days with daily precipitation above 100 mm, from 7-10 days. Increase in the highest single daily precipitation; 160mm	medium	medium	medium	Control of pond water. Maintenance of pond fertility in pond. Damage to pond infrastructure Loss of stock. Damage to pond infrastructure	low	medium
	sea level rise	n/a						
	increasing salinity	n/a						

2.1. GIA LAI SUMMARY

SUMMARY OF CAM ANALYSIS OF PROXY SPECIES IN GIA LAI, VIETNAM.

Capture Fisheries

Species	Threat	Gai lai
1. Channa Striatus	Increase in temperature	**low**
	Increase in precipitation	low
	Decrease in precipitation	**medium**
	Decrease in water availability	medium
	increase in water availability	low
	Drought	medium
	Flooding	low
	Storms and Flash floods	medium
	sea level rise	-
	increasing salinity	-
3. Tor tambrodies	Increase in Temperature	**very high**
	Increase in precipitation	medium
	Decrease in precipitation	**high**
	Decrease in water availability	medium-
	increase in water availability	low
	Drought	medium
	flooding	low
	Storms and Flash floods	**medium**
	sea level rise	-
	increasing salinity	-

Aquaculture

System & species	Threat	Gai Lai
Clarias Batrachus. INTENSIVE POND CULTURE	Increase in temperature	**medium**
	Increase in precipitation	low
	Decrease in precipitation	**medium**
	Decrease in water availability	**medium**
	Increase in water availability	low
	Drought	**medium**
	Flooding	**high**
	Storms and Flash floods	**high**
	sea level rise	-
	increasing salinity	-
Cyprinus carpio. CAGE AQUACULTURE	Increase in temperature	**medium**
	Increase in precipitation	medium
	Decrease in precipitation	medium
	Decrease in water availability	**medium**
	Increase in water availability	medium
	Drought	**medium**
	Flooding	medium
	Storms and Flash floods	**very high**
	sea level rise	
	increasing salinity	

2.2. GIA LAI FISHERIES

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
1. Channa striatus. A BLACK FISH FOUND IN A WIDE RANGE OF WETLAND ENVIRONMENTS INCLUDING, RICEFIELDS, RESERVOIRS, CANALS.	Increase in temperature	Increase in temperature for Gai Lai will be greatest in Jul & Aug; up to 18% increase. Maximum temperatires in the dry season will peak at 40oC with 36oC as the GCM average.	high	low	medium	Projected temperatures are well within the tolerable range for this species. Air breathing fish so DO levels unimportant. Populations may become more prolific in upland areas, currently below optimum for this species	very high	**low**
	Increase in precipitation	Monthly average rainfall will increase in the period Apr-Nov by 4-13%. October is projected to show the highest increase in rainfall.	medium	low	medium	incresaed precipitation should allow easier access to the floodplains and will benefit this species. Fish is tolerant of turbid waters	very high	low
	Decrease in precipitation	Rainfall will decrease in the dry season months of Dec-Mar by between 4-10%, with Feb showing the higest percentage reduction.	medium	high	medium	Reduced rainfall during the cold season months, coupled with increased temperatures will result in the faster drying of refuge areas, allowing for increased predation and hunting.	medium	**medium**
	Decrease in water availability	Although rainfall decreases in the period Dec-Mar, these are low rainfall months and therefore the volume of water lost from the system does not appear to be hugely significant.	medium	high	medium	Reduced water levels in dry season refuge areas, allowing for increased predation and hunting.	medium	medium
	increase in water availability	Increases in rainfall during the months from Apr-Nov, is more significant and will result in higher flows in the small rivers and streams of this province. E.g Projected rainfall for Aug in a typical year, is 429 mm.	high	low	medium	Fish will benefit from increased water availability, particularly in areas with floodplains and lowland rice grwoing areas.	very high	low
	Drought	The drought situation in the valleys of this region is not expected to change significantly during the time period studied.	low	medium	medium	No significant affect expected for this species	high	medium
	Flooding	Flooding will become increasingly common and some months may have as much as 900mm of rain per month, in some years. Incresaed rainfall in throughput the period Apr-Nov. will result in waterlogged soils and faster run off of rainwater.	high	very low	medium	Fish will benefit from increased water availability, particularly in areas with floodplains and lowland rice grwoing areas.	very high	low
	Storms and Flash floods	Maximum daily rainfall will increase slightly with as much as 150mm falling on some days, and 20 days a year with in excess of 80mm of rainfall.	high	very low	medium	Flash flooding may affect survival of juveniles in exposed areas.	medium	medium
	sea level rise	n/a	-	-	-	-		
	increasing salinity	n/a	-	-	-	-		

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		refer to table		written explanation of what the impact is, and why it was scored (high, med, low)	refer to table	refer to table
Tor tambroides	Increase in Temperature	Increase in temperature for Gai Lai will be greatest in Jul & Aug; up to 18% increase. Maximum temperatires in the dry season will peak at 40oC with 36oC as the GCM average.	Very High	very high	very high	This upland fish favours cooler waters. Increased temps may result in its disappearance from some lower stream reaches. This species spawns during November and December. Temperature increases at this time may result in changes in reproductive success.	low	very high
	Increase in precipitation	Monthly average rainfall will increase in the period Apr-Nov by 4-13%. October is projected to show the highest increase in rainfall.	medium	high	medium	This fish favours clear flowing waters and spawns on gravel substrates. Increased turbidity will not favour this fish and may result in the siltation of spawning grounds. High turbidity may impact to availabilty of natural food for fry as well.	low	medium
	Decrease in precipitation	Rainfall will decrease in the dry season months of Dec-Mar by between 4-10%, with Feb showing the higest percentage reduction.	high	medium	high	Affects on movement of stocks between pools, compounded by increase in temperature. Lower survival of fish during drier months.	low	high
	Decrease in water availability	Although rainfall decreases in the period Dec-Mar, these are low rainfall months and therefore the volume of water lost from the system does not appear to be hugely significant.	low	high	medium	Reduced capacity of fish to move from pool to pool and onto floodplain. Reduced access to food. Increased fishing pressure.	low-	medium-
	increase in water availability	Increases in rainfall during the months from Apr-Nov, is more significant and will result in higher flows in the small rivers and streams of this province. E.g Projected rainfall for Aug in a typical year, is 429 mm.	high	low	medium	This fish is unlikely to be adversely affected by increases in water availability resulting from rainfall.	very high	low
	Drought	The drought situation in the valleys of this region is not expected to change significantly during the time period studied.	low	high	low	Reduced survival. Increased fishing pressure on stocks trapped in pools.	very low	medium
	flooding	Flooding will become increasingly common and some months may have as much as 900mm of rain per month, in some years. Incresaed rainfall in throughput the period Apr-Nov. will result in waterlogged soils and faster run off of rainwater.	high	very low	medium	Flooding unlikely to adversely affect this species, as it is used to living in fast flowing water bodies. Juveniles will benefit from small floodplain areas.as nursery feeding grounds, as a rtesult	very high	low
	Storms and Flash floods	Maximum daily rainfall will increase slightly with as much as 150mm falling on some days, and 20 days a year with in excess of 80mm of rainfall.	medium	medium	medium	Reduced survival of juveniles. Negative effecst on food availablity. Physical damage to adults.	medium	**medium**
	sea level rise	n/a	-	-	-	-		
	increasing salinity	n/a	-	-	-	-		

2.3. GIA LAI AQUACULTURE

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
Clarias Batrachus. INTENSIVE EARTHEN POND AQUACULTURE	Increase in temperature	Increase in temperature for Gai Lai will be greatest in Jul & Aug; up to 18% increase. Maximum temperatires in the dry season will peak at 40oC with 36oC as the GCM average	high	low	medium	Projected temperatires well within the tolerable range for this species. Culture of this species may become more vialble in cooler upland areas	high	**medium**
	Increase in precipitation	Monthly average rainfall will increase in the period Apr-Nov by 4-13%. October is projected to show the highest increase in rainfall	high	low	medium	Culture of this fish should not be affceted by increased rainfall during the wet season. C. batrachus is tolerant of high turbidity and low DO conditions	very high	low
	Decrease in precipitation	Rainfall will decrease in the dry season months of Dec-Mar by between 4-10%, with Feb showing the higest percentage reduction	medium	high	medium	The intensive culture of this fish requires regular water exchange. Reduced precipitation will result in slightly less water available for this purpose during the drier months. However, the fish is able to survive in poor water quality conditions	medium	**medium**
	Decrease in water availability	Although rainfall decreases in the period Dec-Mar, these are low rainfall months and therefore the volume of water lost from the system does not appear to be hugely significant	medium	high	medium	The intensive culture of this fish requires regular water exchange. Less water available as a result of reduced rainfall, and increased evaporation from temepretaure increases may limit the scope for culturing this species, during the drier months. However, the fish is able to survive in poor water quality conditions	medium	**medium**
	Increase in water availability	Increases in rainfall during the months from Apr-Nov, is more significant and will result in higher flows in the small rivers and streams of this province. E.g Projected rainfall for Aug in a typical year, is 429 mm.	high	low	medium	Increased water availability will benefit the culture of this species, unless water levels allow for the fish to walk out of the ponds	very high	low
	Drought	The drought situation in the valleys of this region is not expected to change significantly during the time period studied	medium	high	medium	In intensive systems, the lack of freshwater for pond exchange might affect the viability of culturing this fish.	low	**medium**
	Flooding	Flooding will become increasingly common and some months may have as much as 900mm of rain per month, in some years. Incresaed rainfall in throughput the period Apr-Nov. will result in waterlogged soils and faster run off of rainwater	high	high	high	This fish is difficult to retain in ponds if water levels are high, as it is able to walk overland, for short distances.	low	**high**
	Storms and Flash floods	Maximum daily rainfall will increase slightly with as much as 150mm falling on some days, and 20 days a year with in excess of 80mm of rainfall	high	high	high	The steep slopes of this province may mean that many sites cannot be used for pond aquaculture, due to the difficulties of protection against flash flodding	low	**high**
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
***Cyprinus carpio*. CAGE CULTURE IN RESERVOIRS**	Increase in temperature	Increase in temperature for Gai Lai will be greatest in Jul & Aug; up to 18% increase. Maximum temperatires in the dry season will peak at 40oC with 36oC as the GCM average.	high	high	high	growth of this species but stratification or water columns and then turnover, in deeper waters may affect cage culture of this fish. Aeration may become necessary	high	**medium**
	Increase in precipitation	Monthly average rainfall will increase in the period Apr-Nov by 4-13%. October is projected to show the highest increase in rainfall.	high	low	medium	unlikely to affect cage farming of this species	high	medium
	Decrease in precipitation	Rainfall will decrease in the dry season months of Dec-Mar by between 4-10%, with Feb showing the higest percentage reduction.	medium	low	medium	unlikely to affect cage farming of this species	high	medium
	Decrease in water availability	Although rainfall decreases in the period Dec-Mar, these are low rainfall months and therefore the volume of water lost from the system does not appear to be hugely significant.	medium	high	medium	reduced water levels through increased competition for dry season water, could affect the viability of this enterprise	low	**medium**
	Increase in water availability	Increases in rainfall during the months from Apr-Nov, is more significant and will result in higher flows in the small rivers and streams of this province. E.g Projected rainfall for Aug in a typical year, is 429 mm.	high	low	medium	unlikely to affect cage farming of this species	high	medium
	Drought	The drought situation in the valleys of this region is not expected to change significantly during the time period studied.	medium	high	medium	reduced water levels through increased competition for dry season water, could affect the viability of this enterprise	low	**medium**
	Flooding	Flooding will become increasingly common and some months may have as much as 900mm of rain per month, in some years. Incresaed rainfall in throughput the period Apr-Nov. will result in waterlogged soils and faster run off of rainwater.	high	low	medium	unlikely to affect cage farming of this species, as floating cages will rise and fall with water levels.	high	medium
	Storms and Flash floods	Maximum daily rainfall will increase slightly with as much as 150mm falling on some days, and 20 days a year with in excess of 80mm of rainfall.	high	very high	very high	cage culture in exposed water bodies are vulnerable to storms wihich can damage infrastructure and cause the escape of fish.	low	very high
	sea level rise	n/a						
	increasing salinity	n/a						

3.1. KHAMMOUAN SUMMARY

SUMMARY OF CAM ANALYSIS OF PROXY SPECIES IN KHAMMOUNE, LAOS PDR

Capture Fisheries

Species	Threat	Khammoune
1. Hemibagrus nemurus	Increase in temperature	medium
	Increase in precipitation	medium
	Decrease in precipitation	medium
	Decrease in water availability	medium
	increase in water availability	medium
	Drought	medium
	Flooding	low
	Storms and Flash floods	low
	sea level rise	
	increasing salinity	
2. Pangasius krempfi	Increase in temperature	high
	Increase in precipitation	low
	Decrease in precipitation	low
	Decrease in water availability	low
	Increase in water availability	low
	Drought	low
	Flooding	low
	Storms and Flash floods	low
	sea level rise	
	increasing salinity	
3. Mastocmbalus armatus	Increase in Temperature	medium
	Increase in precipitation	low
	Decrease in precipitation	medium
	Decrease in water availability	medium
	increase in water availability	low
	Drought	medium
	flooding	low
	Storms and Flash floods	low
	sea level rise	
	increasing salinity	

Aquaculture

System & species	Threat	Khammoune
***Barbonymus gonionotus* EXTENSIVE POND AQUACULTURE**	Increase in temperature	**high**
	Increase in precipitation	medium
	Decrease in precipitation	**medium**
	Decrease in water availability	very high
	Increase in water availability	low
	Drought	**high**
	Flooding	**very high**
	Storms and Flash floods	**very high**
	sea level rise	
	increasing salinity	
***Oreochromis niloticus* EXTENSIVE POND AQUACULTURE**	Increase in temperature	**medium**
	Increase in precipitation	medium
	Decrease in precipitation	medium
	Decrease in water availability	**medium**
	Increase in water availability	medium
	Drought	**low**
	Flooding	**medium**
	Storms and Flash floods	**high**
	sea level rise	
	increasing salinity	
***Pangasius pangasius* SEMI INTENSIVE POND CULTURE**	Increase in temperature	**medium**
	Increase in precipitation	medium
	Decrease in precipitation	medium
	Decrease in water availability	**high**
	Increase in water availability	medium
	Drought	**medium**
	Flooding	**high**
	Storms and Flash floods	**high**
	sea level rise	
	increasing salinity	

3.2. KHAMMOUAN FISHERIES

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
1. ***Hemibogrus nemurus***	Increase in temperature	At least 6% incresae in maximum temperatures, with as high as 16% in the Jul and 10% in Aug. Higehst prijected temp 460C Minimum temps increasing most during the cooler months 10% Dec, 8% Jan & Feb. Minimum temps in wet season 5-6.5% increase over baseline	high	medium	high	THis species occurs across a wide range of environments from slow flowing rivers to flooded forests. It does not appear to be adversely affected by the projected temperature increases.	high	medium
	Increase in precipitation	Increased precipitation from Mar- December, resulting in significant changes to monsoon month water flows in streams and rivers. Highest % increase in April 25%, (a low rainfall month)	high	low	medium	Incresaed river flows are likley to benefit this species, which is well adapted to muddy slow flowing waters.	high	medium
	Decrease in precipitation	Decreases in Jan & Feb will reduce dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	medium	medium	medium	this fish resides in deep pools during the dry aseason, when the projected reductions in rainfall are projected.	medium	medium
	Decrease in water availability	Reduced dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	low	high	medium	this fish resides in deep pools during the dry aseason. Reduced flow rates may not adversely affect this fish, during this period.	high	medium
	increase in water availability	Significant increases in wet season flows peaking in Aug with 703 mm	high	very low	medium	Incresaed river flows are likley to benefit this species, which is well adapted to muddy slow flowing waters.	high	medium
	Drought	No significant increase in drought conditions predicted.	low	medium	medium	Drought conditions unlikely to affect river or stream flows.	low	medium
	Flooding	Increased incidence of flooding due to increases in precipitation, (see above)	high	very low	medium	Increased flooding will increase fishs excess to floodplain	very high	low
	Storms and Flash floods	Increase in days where more than 100cm of rain falls, (from 11 days a year to 14 days a year	medium	low	medium	Unlikely to affect this species due to its tolerance of highly turbid waters.	very high	low
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
Pangasius krempfi	Increase in temperature	At least 6% incresae in maximum temperatures, with as high as 16% in the Jul and 10% in Aug. Higehst projected temp 460C Minimum temps increasing most during the cooler months 10% Dec, 8% Jan & Feb. Minimum temps in wet season 5-6.5% increase over baseline.	high	medium	high	This highly migratory species is found in Khammoune during the wet season, when projected temperatire increases are at their highest. The effect of these elevated temps on this fish is uncertain.	medium	**high**
	Increase in precipitation	Increased precipitation from Mar- December, resulting in significant changes to monsoon month water flows in streams and rivers. Highest % increase in April 25%, (a low rainfall month)	high	very low	medium	The increased river flows that result from higher precipitation levels may aid this fish in its migration, during which it has to ascend the Kone Falls.	very high	low
	Decrease in precipitation	Decreases in Jan & Feb will reduce dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	medium	very low	low	THis fish is largely absent in Khammoune, during the drier months when the projected decrease in precopitation is likely to occur.	high	low
	Decrease in water availability	Reduced dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	very low	low	low	This fish is largely absent in Khammoune, during the drier months when the projected decreased water avaialbility may exist	high	low
	Increase in water availability	Significant increases in wet season flows peaking in Aug with 703 mm	high	low	medium	The increased river flows that result from higher precipitation levels may aid this fish in its migration, during which it has to ascend the Kone Falls, suggesting it is able to tolerate extreme river flow conditions.	very high	low
	Drought	No significant increase in drought conditions predicted.	very low	low	low	No impact	high	low
	Flooding	Increased risk due to increases in precipitation, (see above)	high	low	medium	No impact, or positive.	very high	low
	Storms and Flash floods	Increase in days where more than 100cm of rain falls, (from 11 days a year to 14 days a year.	medium	very low	low	no impact	high	low
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
Mastocembalus armatus	Increase in Temperature	At least 6% increase in maximum temperatures, with as high as 16% in the Jul and 10% in Aug. Higehst prijected temp 460C Minimum temps increasing most during the cooler months 10% Dec, 8% Jan & Feb. Minimum temps in wet season 5-6.5% increase over baseline.	high	low	medium	this species is tolerant of a very warm low DO conditions. The projected temperatures should not affect this fish very much. Its upland range may be expanded. Increased evaporation of dry season water bodies could affect survival of brood stocks.	high	medium
	Increase in precipitation	Increased precipitation from Mar- December, resulting in significant changes to monsoon month water flows in streams and rivers. Highest % increase in April 25%, (a low rainfall month)	medium	very low	low	As one of the black fish group, this species is adapted to live in wetland environments that fluctuate between flood and drought. Tolerant of turbid waters. Increases in precipitation are unlikely to affect this species in a negative way.	very high	low
	Decrease in precipitation	Decreases in Jan & Feb will reduce dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	medium	medium	medium	Small changes in precipitation during the dry season could affect water levels in dry season refuge areas and thereby affect the capacity of this fish to survive until the first rains.	medium	medium
	Decrease in water availability	Reduced dry season flows in rivers and streams, although these are low rainfall months, so overall change in flows may not be significant	low	medium	medium	Lower water levels in dry season refuge areas and thereby affect the capacity of this fish to survive until the first rains.	low	medium
	increase in water availability	Significant increases in wet season flows peaking in Aug with 703 mm	medium	very low	low	No negative effect foreseen	very high	low
	Drought	No significant increase in drought conditions predicted.	low	medium	medium	Harsher dry seasons could compromise this fish's capcity to survive in shallow wetlands, during the dry season	low	medium
	flooding	Increased risk due to increases in precipitation, (see above)	high	low	medium	No negative effect foreseen	very high	low
	Storms and Flash floods	Increase in days where more than 100cm of rain falls, (from 11 days a year to 14 days a year.	medium	low	medium	No negative effect foreseen	very high	low
	sea level rise	n/a						
	increasing salinity	n/a						

3.3. KHAMMOUAN AQUACULTURE

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
EARTHERN POND CULTURE OF Barbonymus gonionotus	Increase in temperature	At least 6% incresae in maximum temperatures, with as high as 16% in the Jul and 10% in Aug. Higehst prijected temp 460C Minimum temps increasing most during the cooler months 10% Dec, 8% Jan & Feb Minimum temps in wet season 5-6.5% increase over baseline.	high	high	high	This fish is sensitive to low DO levels, associated with higher water temperatures. Increased evaporation rates will work result in pond levels dropping quickly in the cool and dry seasons.	low	**high**
	Increase in precipitation	Increased precipitation from Mar- December, resulting in significant changes to monsoon month water flows in streams and rivers. Highest % increase in April 25%, (a low rainfall month)	medium	low	medium	This species can tolerate turbid water conditions. Increased precipitaion will improve some pond conditions for this fish.	high	medium
	Decrease in precipitation	Decreases in Jan & Feb will reduce pond water levels, although these are low raifall months, so overall change may not be significant	medium	high	medium	Reduced dry season rainfall will work together with Increased evaporation rates resulting in pond levels droppingmore quickly in the dry seasons.	low	**medium**
	Decrease in water availability	Reduced dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	high	very high	very high	Reduced water availability will affect the viability of culturing this species, which is not tolerant of very warm, low DO conditions	low	very high
	Increase in water availability	Significant increases in wet season flows peaking in Aug with 703 mm	medium	very low	low	Increased water availability will enable farmers tomaintain wtare levels for this fish.	very high	low
	Drought	No significant increase in drought conditions predicted.	low	very high	medium	Reduced water availability will affect the viability of culturing this species, which is not tolerant of very warm, low DO conditions	very low	**high**
	Flooding	Increased risk due to increases in precipitation, (see above)	high	very high	very high	This fish has the tendency to leave flooded ponds very easily, once embankments are topped.	very low	**very high**
	Storms and Flash floods	Increase in days where more than 100cm of rain falls, (from 11 days a year to 14 days a year.	high	very high	very high	Ponds in hill areas and small valleys will be especially affected by these conditions	very low	**very high**
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
Oreochromis niloticus	Increase in temperature	At least 6% increase in maximum temperatures, with as high as 16% in the Jul and 10% in Aug. Highest prijected temp 460C Minimum temps increasing most during the cooler months 10% Dec, 8% Jan & Feb	high	low	medium	This fish is not sensitive to low DO levels, associated with higher water temperatures. Increased evaporation rates will work result in pond levels dropping quickly in the cool and dry seasons	high	**medium**
	Increase in precipitation	Increased precipitation from Mar- December, resulting in significant changes to monsoon month water flows in streams and rivers. Highest % increase in April 25%, (a low rainfall month)	medium	high	medium	This species can tolerate turbid water conditions. Increased precipitaion will improve some pond conditions for this fish.	high	medium
	Decrease in precipitation	Decreases in Jan & Feb will reduce dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	medium	low	medium	Reduced dry season rainfall will work together with increased evaporation rates resulting in pond levels dropping more quickly in the dry seasons	medium	medium
	Decrease in water availability	Reduced dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	high	low	medium	Reduced water availability could affect the viability of culturing this species, although it is tolerant of very warm, low DO conditions	medium	**medium**
	Increase in water availability	Significant increases in wet season flows peaking in Aug with 703 mm	medium	high	medium	Increased water availability will enable farmers to maintain wtare levels for this fish	high	medium
	Drought	No significant increase in drought conditions predicted	low	low	low	Reduced water availability will not affect the viability of culturing this species	high	**low**
	Flooding	Increased risk due to increases in precipitation, (see above)	high	low	medium	This fish will readily leave ponds that are flooded.	medium	**medium**
	Storms and Flash floods	Increase in days where more than 100cm of rain falls, (from 11 days a year to 14 days a year	high	very low	medium	Ponds in hill areas and small valleys will be especially affected by these conditions	very low	**high**
	sea level rise	n/a						
	increasing salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
Intensive pond culture of Pangasius pangasius	Increase in temperature	At least 6% incresae in maximum temperatures, with as high as 16% in the Jul and 10% in Aug. Higehst prijected temp 460C Minimum temps increasing most during the cooler months 10% Dec, 8% Jan & Feb.	high	medium	high	This fish is able to breathe atmospheric air which makes it less vulnerable to DO levels, associated with higher temperatires. However, increased temps might affect its growth rate and make it more susceptible to diseases.	medium	**medium**
	Increase in precipitation	Increased precipitation from Mar- December, resulting in significant changes to monsoon month water flows in streams and rivers. Highest % increase in April 25%, (a low rainfall month)	medium	low	medium	No negative affects foreseen	high	medium
	Decrease in precipitation	Decreases in Jan & Feb will reduce dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	medium	medium	medium	Reduced dry season rainfall and lower flows in streams will reduce the farmer's capcity to draw water for their ponds, in order to replace evaporation losses and refresh conditions.	medium	medium
	Decrease in water availability	Reduced dry season flows in rivers and streams, although these are low raifall months, so overall change in flows may not be significant	high	medium	high	Lower flows in streams will reduce the farmer's capcity to draw water for their ponds, in order to replace evaporation losses and refresh conditions.	medium	**high**
	Increase in water availability	Significant increases in wet season flows peaking in Aug with 703 mm	medium	low	medium	No negative affects foreseen	high	medium
	Drought	No significant increase in drought conditions predicted.	low	low	low	No negative affects foreseen	high	**medium**
	Flooding	Increased risk due to increases in precipitation, (see above)	high	high	high	No negative affects foreseen	medium	**high**
	Storms and Flash floods	Increase in days where more than 100cm of rain falls, (from 11 days a year to 14 days a year.	high	high	high	No negative affects foreseen	low	**high**
	sea level rise	n/a						
	increasing salinity	n/a						

4.1. KIEN GIANG SUMMARY

SUMMARY OF CAM ANALYSIS OF PROXY SPECIES IN KIENG GIANG, VIETNAM

Capture Fisheries

Species	Threat	Kieng Giang
1. Anadosa Granosa. 'BLOOD COCKLE' ESTUARINE BIVALVE IMPORTANT FOR RURAL LIVELIHOODS	Increase in temperature	very high
	Increase in precipitation	medium
	Decrease in precipitation	medium
	Decrease in water availability	low
	increase in water availability	medium
	Drought	low
	Flooding	
	Storms and Flash floods	high
	sea level rise	medium
	increasing salinity	medium
2. Lates calcarifer. SEA BASS, ESTUARINE FISH IMPORTANT FOR COMMERCIAL FISHING. ALSO USED IN AQUACULTURE	Increase in temperature	high
	Increase in precipitation	medium
	Decrease in precipitation	medium
	Decrease in water availability	medium
	Increase in water availability	medium
	Drought	medium
	Flooding	
	Storms and Flash floods	low
	sea level rise	medium
	increasing salinity	medium
3. Pomacea canaliculata. THE GOLDEN APPLE SNAIL. INVASIVE PEST OF RICEFIELDS	Increase in Temperature	Very high
	Increase in precipitation	medium
	Decrease in precipitation	low
	Decrease in water availability	low
	increase in water availability	high
	Drought	medium
	flooding	high
	Storms and Flash floods	medium
	sea level rise	medium
	increasing salinity	medium

Aquaculture

System & species	Threat	Kieng Giang
INLAND POND AQUACULTURE OF GIANT FRESHWATER PRAWN, Macrobrachium rosenbergii	Increase in temperature	very high
	Increase in precipitation	high
	Decrease in precipitation	low
	Decrease in water availability	very high
	Increase in water availability	medium
	Drought	very high
	Flooding	medium
	Storms and Flash floods	medium
	sea level rise	medium
	increasing salinity	medium
SEMI INTENSIVE COASTAL POND AQUACULTURE OF TIGER SHRIMP, Peneaus monodon.	Increase in temperature	very high
	Increase in precipitation	very high
	Decrease in precipitation	medium
	Decrease in water availability	medium
	Increase in water availability	medium
	Drought	medium
	Flooding	medium
	Storms and Flash floods	high
	sea level rise	high
	increasing salinity	medium

* NOTE: WITH INVASIVE SPECIES, VULNERABILITY REFERS TO THE ECOSYSTEM, NOT THE INVASIVE SPECIES.
SO A VERY HIGH RANKING MEANS THAT THE ECOSYSTEM WILL HAVE INCREASED VULNERABLE TO THE INVASIVE SPECIES.

4.2. KIEN GIANG FISHERIES

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity (this is inverted for invasive species	Vulnerability of ecosystem,(not invasive species)
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
1. Anadosa Granosa. 'BLOOD COCKLE' ESTUARINE BIVALVE IMPORTANT FOR RURAL LIVELIHOODS	Increase in temperature	Projected increases in temperature for Kieng Giang will extend well above this fish's preferred range. GCM max temperatures may reach as high as 42.	very High	high	very high	This organism is found in shallow estuarine waters which, at low tide are fully exposed. The lethal temperature for this species is 41.5 oC. Spawning is reported to happened between 22-28.5 oC.	low	very high
	Increase in precipitation	Increased precipitation May-November (5-15% per month). may result in increased erosion and turdibity of coastal waters.	medium	low	medium	Estuarine waters are typically turbid, and this organism has a high tolerance to turbid waters. Increased runoff from rivers will threaten this species if salinities drop below 12 ppt.	medium	medium
	Decrease in precipitation	Slight reduction in precipitation for KG in the low rainfall period; Dec-Apr, may result in reduced freshwater flows and higher coastal salinities.	medium	low	medium	This orgamism can live in full strength seawater, as no threat perceived.	high	medium
	Decrease in water availability	Decreased water availability through reduced precipitation in period Dec-April.	low	very low	low	No negative effects anticipated.	high	low
	increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	high	medium	high	Freshening of coastal waters may result in clam areas shifting away from areas of high freshwater discharge.-	high	medium
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	low	low	low	Unlikely to affect survival and growth of the clam	high	low
	Flooding	n/a	-	-	-	n/a		
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall.	medium	medium	high	Limited affect on this organism as it is sheltered beneath mud surface	high	high
	sea level rise	Sea level rise will result in some areas no longer being exposed, at low tide.	high	high	high	This organism lives in areas that are flooded and then exposed at low tide. Sea level will result in clam populations shifting from deepening waters	high	medium
	increasing salinity	Increased salinities during the dry season, may result from reduced freshater flows.	medium	low	medium	This species is tolerant of full-strength sea water.. No negative effect anticipated.	high	medium

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity (this is inverted for invasive species	Vulnerability of ecosystem,(not invasive species)
		written description of how the threat relates to the system component		refer to table		written explanation of what the impact is, and why it was scored (high, med, low)	refer to table	refer to table
2. Lates calcarifer. SEA BASS, ESTUARINE FISH IMPORTANT FOR COMMERCIAL FISHING. ALSO USED IN AQUACULTU	Increase in temperature	Projected increases in temperature for Kieng Giang will extend well above this fish's preferred range. GCM max temperatures may reach as high as 42.	High	High	High	Feeding behaviour, maturation, breeding, egg development, hatching, larvae survival affected	medium	**high**
	Increase in precipitation	Increased precipitation May-November (5-15% per month); may result in increased erosion and turdibity of coastal waters.	medium	Low	medium	Increased turbidity may affect feeding, breeding behaviour.	high	medium
	Decrease in precipitation	Slight reduction in precipitation for KG in the low rainfall period; Dec-Apr, may result in reduced freshwater flows and higher coastal salinities.	high	low	medium	Sea Bass are highly mobile and tolerant of a wide range of salinities so little impact anticipated	high	**medium**
	Decrease in water availability	Decreased freshwater availability through reduced precipitation in period Dec-April.	low	low	low	Sea Bass are highly mobile antolerant of a wide range ofd salinities so little impact anticipated	high	medium
	Increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	medium	low	medium	Sea Bass are highly mobile and tolerant of a wide range of salinities so little impact anticipated	high	medium
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	low	low	low	Sea Bass are highly mobile and tolerant of a wide range of salinities so little impact anticipated	high	medium
	Flooding	n/a	-	-	-			
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall.	medium	very low	low	no effect anticipated	high	low
	sea level rise	Sea level rise will result in some areas no longer being exposed, at low tide.	high	low	medium	Sea Bass are highly mobile and likley to colonise new areas as sea levels increase. Mangrove environments important for juveniles.	high	medium
	increasing salinity	Increased salinities during the dry season, may result from reduced freshater flows.	high	low	medium	Sea Bass are tolerant of a wide range of salinities so little impact anticipated	high	medium

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity (this is inverted for invasive species	Vulnerability of ecosystem,(not invasive species)
		written description of how the threat relates to the system component		refer to table		written explanation of what the impact is, and why it was scored (high, med, low)	refer to table	refer to table
3. Pomacea canaliculata. THE GOLDEN APPLE SNAIL. INVASIVE PEST OF RICEFIELDS	Increase in Temperature	Projected increases in temperature for Kieng Giang will extend well above this fish's preferred range. GCM max temperatures may reach as high as 42.	High	low	high	Temparture range tolerance 15.2- 36.6oC New upland areas will be colonised by theis animal	very 'low'	Very high
	Increase in precipitation	Increased precipitation May-November (5-15% per month). may result in increased erosion and turdibity.	high	very low	medium	GAS are not espcially sensitive to turbidity. Egg development happens above the water surface so not affected by water quality.	low'	medium
	Decrease in precipitation	Slight reduction in precipitation for KG in the low rainfall period; Dec-Apr, may result in reduced freshwater flows and higher coastal salinities.	medium	low	low	Capacity to survive the dry season in some water bodies, will be reduced.	high	low
	Decrease in water availability	Decreased freshwater availability through reduced precipitation in period Dec-April.	medium	low	low	Capacity to survive the dry season in some water bodies, will be reduced.	high	low
	increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	high	low	medium	will allow the GAS to repopulate areas more quickly	very low	high
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	low	very low	low	Capacity to survive the dry season in some water bodies, will be reduced.Increased harvesting for food.	medium	medium
	flooding	Increased incodence of flooding	high	very low	medium	GAS will benefot from increased flooding and floodied areas	very low	high
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall.	medium	medium	medium	Not expected to have significant impact on this species	high	medium
	sea level rise	Sea level rise will result in some areas no longer being exposed, at low tide.	medium	very high	high	This species does not tolerate salinities above 6.8 ppt. So will be lost from some areas	high	medium
	increasing salinity	Increased salinities during the dry season, may result from reduced freshater flows.	medium	very high	high	This species does not tolerate salinities above 6.8 ppt. So will be under increased prsssure in some areas.	high	medium

4.3. KIEN GIANG AQUACULTURE

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
SEMI-INTENSIVE POND AQUACULTURE OF TIGER SHRIMP, Peneaus monodon.	Increase in temperature	Projected increases in temperature for Kieng Giang will extend well above this fish's preferred range. GCM max temperatures may reach as high as 42	very high	very high	very high	Higher incidence of disease.Incresaed stress, reduced DO. Leading to reduced survival rates and growth rate of shrimp	low	very high
	Increase in precipitation	Increased precipitation May-November (5-15% per month), may result in increased erosion and turdibity	high	very high	very high	Rapidly changing salinities in ponds may lead to higher incidence of diseases e.g. WSSV and reduced survival of shrimp	low	very high
	Decrease in precipitation	Slight reduction in precipitation for KG in the low rainfall period; Dec-Apr, may result in reduced freshwater flows and higher coastal salinities.	low	low	low	Limited impact on shrimp	medium	medium
	Decrease in water availability	Decreased freshwater availability through reduced precipitation in period Dec-April.	low	medium	medium	Farmers unable to manage salinities in ponds, so well.	medium	medium
	Increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	medium	medium	medium	Lower salinities in the wet season, may result in higher disease incidence.	medium	medium
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	medium	medium	medium	Farmers unable to manage salinities in ponds, so well	low	medium
	Flooding	Increased incodence of flooding	high	medium	high	Loss of stock from pond	high	**medium**
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall.	medium	high	medium	Sudden changes in water quality causing stress and disease problems. Loss of stock from pond. Damage to pond infrastructure	very low	**high**
	sea level rise	Sea level rise will result in some areas no longer being exposed, at low tide.	high	high	high	Loss of stock from pond. Damage to pond infrastructure.	low	high
	increasing salinity	Increased salinities during the dry season, may result from reduced freshater flows.	high	medium	high	Farmers unable to manage salinities in ponds, so well.	high	medium

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
EXTENSIVE POND AQUACULTURE OF GIANT FRESHWATER PRAWN, Macrobrachium rosenbergii.	Increase in temperature	Projected increases in temperature for Kieng Giang will extend well above this fish's preferred range. GCM max temperatures may reach as high as 42.	very high	very high	very high	Higher incidence of disease.Incresaed stress, reduced DO. Leading to reduced survival rates and growth rate of prawns	low	very high
	Increase in precipitation	Increased precipitation May-November (5-15% per month) may result in increased erosion and turdibity.	high	high	high	Water quality (DO) problems during early wet season, due to pond turnover.	medium	high
	Decrease in precipitation	Slight reduction in precipitation for KG in the low rainfall period, Dec-Apr, may result in reduced freshwater flows and higher coastal salinities.	low	low	low	No direct impact forseen.	high	low
	Decrease in water availability	Decreased freshwater availability through reduced precipitation in period Dec-April.	high	very high	very high	May become difficult to maintain water levels in ponds	very low	very high
	Increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	high	low	medium	No direct impact forseen.	haigh	medium
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	high	very high	very high	Incresaed competition for freshwater supplies for prawn farms.	very low	very high
	Flooding	Increased incodence of flooding	medium	medium	medium	Loss of stock from pond	high	medium
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall.	medium	medium	medium	Loss of stock from pond. Damage to pond infrastructure.	medium	medium
	sea level rise	Sea level rise will result in some areas no longer being exposed, at low tide.	medium	medium	medium	Loss of stock from pond. Damage to pond infrastructure.	medium	medium
	increasing salinity	Increased salinities during the dry season, may result from reduced freshwater flows.	medium	medium	medium	Some prawn growing areas areas may have to change to marine shrimp or fish	medium	medium

5.1. MONDULKIRI SUMMARY

SUMMARY OF CAM ANALYSIS OF 3 PROXY SPECIES IN MONDOLKIRI PROVINCE, CAMBODIA

Capture Fisheries

Species	Threat	MDK	CR
1. Channa lucius, FOREST STREAM FISH BUT ALSO FOUND ON FLOODPLAINS LIMITED MIGRATION	Increase in temperature		high
	Increase in precipitation		high
	Decrease in precipitation		medium
	Decrease in water availability		medium
	increase in water availability		low
	Drought		medium
	Flooding		low
	Storms and Flash floods		medium
	sea level rise		-
	increasing salinity		-
2. Probarbus jullieni MIGRATORY, MEDIUM, WHITE FISH. ENDANGERED	Increase in temperature		Very high
	Increase in precipitation		medium
	Decrease in precipitation		very high
	Decrease in water availability		medium
	Increase in water availability		low
	Drought		medium
	Flooding		low
	Storms and Flash floods		medium
	sea level rise		-
	increasing salinity		-
3. Clarias batrachus NON MIGRATORY, BLACK FISH, IMPORTANT FOR FOOD SECURITY.	Increase in Temperature		low
	Increase in precipitation		medium
	Decrease in precipitation		low
	Decrease in water availability		medium
	increase in water availability		low
	Drought		medium
	flooding		medium
	Storms and Flash floods		medium
	sea level rise		-
	increasing salinity		-

Aquaculture

System & species	Threat	mdk	CR
SEMI -INTENSIVE POND MONOCULTURE OF CLARIAS CATFISH	Increase in temperature		medium
	Increase in precipitation		medium
	Decrease in precipitation		medium
	Decrease in water availability		medium
	Increase in water availability		low
	Drought		medium
	Flooding		very high
	Storms and Flash floods		very high
	sea level rise		-
	increasing salinity		-
EXTENSIVE POND POLYCULTURE OF CARPS & TILAPIA	Increase in temperature		high
	Increase in precipitation		medium
	Decrease in precipitation		medium
	Decrease in water availability		very high
	Increase in water availability		low
	Drought		high
	Flooding		high
	Storms and Flash floods		very high
	sea level rise		
	increasing salinity		

5.2. MONDULKIRI FISHERIES

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
1. Channa lucius, FOREST STREAM FISH BUT ALSO FOUND ON FLOODPLAINS LIMITED MIGRATION	Increase in temperature	Projected increases in temperature for MDK will extend well above this fish's preferred range, particularly in April, (39°C) GCM average). This may be more of a factor in exposed lowland areas, than in forested streams.	Very High	medium	high	This fish appears to bequite tolerant of the projected increases in temperature for MDK.	medium	**high**
	Increase in precipitation	Increased precipitation May-November (5-15% per month). may result in increased erosion and turdibity of water bodies.	high	high	high	This fish hunts its food by sight. High turbidity may impact to availabilty of natural food for fry as well.	low	high
	Decrease in precipitation	Slight reduction in precipitation for MDK in the low rainfall period; Dec-Apr, mayresult in reduce flows in upland streams..	medium	medium	medium	Lost connectivity of stream pools will make this fish more vulnerable to predation and reduced hunting opportunities. Lower survival of fish during drier months, expected.	low	medium
	Decrease in water availability	Decreased water availability through reduced precipitation in period Dec-April.	medium	high	medium	Reduced capacity of fish to move from pool to pool. Reduced access to food. Increased fishing pressure.	low-	medium
	increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	medium	very low	low	No negative impacts expected through increased water availability	very high	low
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	medium	high	medium	Reduced survival. Increased fishing pressure on stocks trapped in pools.	very low	medium
	Flooding	Increased water velocities and innundation of floodplains caused by flooding in period Aug - Oct.	medium	very low	low	This species has the ability to live on floodplains as well as in streams. Increased Flooding incidence should favour this species.	high	low
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall will result in increased indicence of flash flooding.	medium	low	medium	This fish is found in forest streams, it will be tolerant of sudden changes in water velocity, quality and flash flooding.	high	**medium**
	sea level rise	N/a						
	increasing salinity	N/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
***2. Probarbus jullieni* MIGRATORY, MEDIUM, WHITE FISH. ENDANGERED**	Increase in temperature	Projected increases in temperature for MDK will extend well above this fish's preferred range, particularly in April, (39°C) GCM average). This may be more of a factor in exposed lowland areas, than in forested streams.	Very High	High	Very High	Feeding behaviour, maturation, breeding, egg development, hatching, larvae survival affected. May impact on egg hatching success,(optimum 23 oC) increased disease incidence.	very low	Very high
	Increase in precipitation	Increased precipitation May-November (5-15% per month). may result in increased erosion and turdibity of water bodies.	medium	Low	medium	Increased turbidity may affect feeding, breeding behaviour.	high	medium
	Decrease in precipitation	Slight reduction in precipitation for MDK in the low rainfall period; Dec-Apr, mayresult in reduce flows in upland streams..	high	very high	very high	This fish is a cool season breeder. Reduced flows in the dry season may affect this fish's capacity for reproduction. Poorer water quality in pools may affect fish survival during dry season. Siltation of gravel spawning beds may compromise breeding success.	low	very high
	Decrease in water availability	Decreased water availability through reduced precipitation in period Dec-April.	low	very high	medium	loss connectivity of reep pools, river courses and tributaries and floodplains. Poorer water quality in refuge areas, less food, increased competition, increased fishing pressure. Increased stress.	low	medium
	Increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	medium	very low	low	No negative impacts expected through increased water availability	very high	low
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	medium	very high	high	Drought conditions coincide with breeding season for this species. Deep pool areas and river course will loss connectivity with tributeries and obstruct this species' migration.	low	medium
	Flooding	Increased water velocities and innundation of floodplains caused by flooding in period Aug - Oct.	medium	very low	low	Increased flooding incidence should favour juveniles of this species that migrate onto floodplains to feed.	high	low
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall will result in increased indicence of flash flooding.	medium	low	medium	Flash flooding during breeding season may affect reproductive success.	medium	medium
	sea level rise	N/a	-	-	-	-		
	increasing salinity	N/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
3. Clarias batrachus NON MIGRATORY, BLACK FISH, IMPORTANT FOR FOOD SECURITY.	Increase in Temperature	Projected increases in temperature for MDK will extend well above this fish's preferred range, particularly in April, (39°C) GCM average). This may be more of a factor in exposed lowland areas, than in forested streams.	High	very low	medium	Known to be tolerant of warm water and wide temperature variations. Able to survive dry season in damp ponds despite high temperatures.	very high	low
	Increase in precipitation	Increased precipitation May-November (5-15% per month), may result in increased erosion and turdibity of water bodies.	high	very low	medium	C. batrachus able to tolerate very turbid waters although poorer water quality may affect growth and maturation.	high	medium
	Decrease in precipitation	Slight reduction in precipitation for MDK in the low rainfall period; Dec-Apr, mayresult in reduce flows in upland streams..	medium	low	low	Looks unlikley to affect dry season refuge areas, utilised by this fish.	high	low
	Decrease in water availability	Decreased water availability through reduced precipitation in period Dec-April.	medium	low	medium	Onr of the most mobile of the black fish species, able to migrate over wet surfaces, not needing inundation.	high	medium
	increase in water availability	Increases in water availability through increased precipitation in period May-Nov.	medium	very low	low	This fish likely to benefit from increased water availability	very high	low
	Drought	Increases in drought conditions in Dec, Apr, May & Jun	low	medium	medium	Looks unlikley to affect dry season refuge areas, utilised by this fish.	low	medium
	flooding	Increased water velocities and innundation of floodplains caused by flooding in period Aug - Oct.	medium	low	medium	Fish is very adaptable and can tilerate a wide range of water conditions	high	medium
	Storms and Flash floods	Increased number of days with greater than 100 mm of rainfall will result in increased indicence of flash flooding.	medium	medium	medium	Not expected to have significant impact on this species	high	medium
	sea level rise	N/a	-	-	-	-		
	increasing salinity	N/a	-	-	-	-		

5.3. MONDULKIRI AQUACULTURE

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
SEMI -INTENSIVE POND MONOCULTURE OF CLARIAS CATFISH	Projected increases in temperature for MDK will be well above this species optimum range in April, (39°C) GCM average).	Higher pond water evaporation rates. Increaed disease incidence. Lower DO levels	high	low	medium	Reduced survival rate and growth rate of fish. However number of days with su- optimum temperatures, (<25oC) reduced, which will favour fish growth during the cool season.	medium	medium
	Increased precipitation May-November (5-15% per month).	Reduced water quality through turbidity. Erosion of pond embankments.	medium	low	medium	Reduced growth of fish	medium	medium
	Slight reduction in precipitation for MDK in the low rainfall period; Dec-Apr,	Stagnation of pond water. Ammonia accumulation. Water column stratification. Reduced capacity to refill ponds.	low	medium	medium	Potential die offs	low	medium
	Decreased water availability through reduced precipitation in period Dec-April.	Accumulation of wastes in pond. Poorer water quality. Capacity to fill ponds.	low	medium	medium	Reduced survival and growth of stock	medium	medium
	Increases in water availability through increased precipitation in period May-Nov.	No negative effects forseen	high	very low	medium	no negative impact foreseen	very high	low
	Increases in drought conditions in Dec, Apr, May & Jun	Maintaining pond water levels. Stratafication of water column	medium	low	medium	Reduced survival and growth of stock	medium	medium
	Increased water velocities and innundation of floodplains caused by flooding in period Aug - Oct.	Control of pond water levels. Flooding of ponds	high	very high	very high	Loss of stock from pond. THis species is extremely mobile over land.	low	very high
	Increased number of days with greater than 100 mm of rainfall will result in increased indicence of flash flooding.	Control of pond water levels. Loss of stick through flash flooding	high	very high	very high	Loss of stock from pond. Damage to pond infrastructure	very low	very high
	Sea level rise	n/a						
	Salinity	n/a						

System component or assets	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
EXTENSIVE POND POLYCULTURE OF CARPS & TILAPIA	Projected increases in temperature for MDK will be well above this species optimum range in April, (39°C) GCM average).	Water temperatures will rise above optimum growing conditions for these speces, resulting in reduced growth rates, higher disease risk and potential die offs from reduced oxygen levels and water column turnovers.	high	high	high	Reduced survival rate and growth rate of fish. However number of days with sub optimum temperatures, (, 25oC) reduced, which will favour fish growth during the cool season.	low	high
	Increased precipitation May-November (5-15% per month).	Reduced pond fertility through increased turbidity. Reduced sunlight for photosynthesis during wet season.	medium	low	medium	Reduced growth due to increased pond turbidity	low	medium
	Slight reduction in precipitation for MDK in the low rainfall period; Dec-Apr,	Stagnation of pond water. Water column stratification. Creating dangerous pre-storm conditions.	low	medium	medium	Fish tolerant of poor water quality Limited impact	very low	medium
	Decreased water availability through reduced precipitation in period Dec-April.	Accumulation of wastes in pond. Poorer water quality. Capacity to fill ponds.	medium	very high	high	Reduced survival and growth of stock	very low	very high
	Increases in water availability through increased precipitation in period May-Nov.	No negative effects anticipated.	high	very low	medium	No negative effects foerseen	very high	low
	Increases in drought conditions in Dec, Apr, May & Jun	Difficulties in maintaining pond water levels. Increased water column stratafication	medium	very high	high	Reduced survival and growth of stock	low	high
	Increased water velocities and innundation of floodplains caused by flooding in period Aug - Oct.	Control of pond water levels.	high	high	high	Loss of stock from pond	low	high
	Increased number of days with greater than 100 mm of rainfall will result in increased indicence of flash flooding.	Loss of stock through flash flooding, particularly in ponds sited near to streams. Damage to pond infrastructure	high	very high	very high	Loss of stock from pond. Damage to pond infrastructure	low	very high
	Sea level rise	n/a						
	Salinity	n/a						

6. 1. STUNG TRENG HYDROLOGY CAM

Capture Fisheries

Species	Threat	Stung Treng
1. Bagana behri	Hydro-biological seasons	medium
	Flow	medium
	Water level	medium
2. Henicorychus siamensis	Hydro-biological seasons	low
	Flow	low
	Water level	low
3. *Pangasius pangasius*	Hydro-biological seasons	medium
	Flow	medium
	Water level	medium

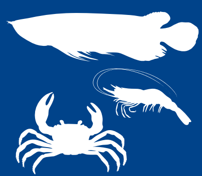
6.2. STUNG TRENG FISHERIES

Species	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
1. Bagana behri A LARGE MIGRATORY RIVER FISH	Hydro-biological seasons	7 day delay in the onset of the dry season, 7 day advance of the onset of the monsoon. 5 day shortening of the dry season. 10 day increase in the duration of the flood season	medium	low	medium	The extended wet season is likely to benefit this fish species. Its spwaning migration may be brought forward by the earlier rises in water level and flows	high	medium
	Flow	Increased dry season and wet season flows anticipated, with the highest flows and increases over baseline appearing in September and the highest relative change occuring in May.	low	low	low	Increased flows will benefit this fish, particularly its migration through the Khone falls.	high	medium
	Water level	Increased water levels throughout the year, with the greatest increases through the wet season, peaking in September.	low	low	low	Increased water levels are likely to benefit this fish, particularly its migration through the Khone falls.	high	medium

Species	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
2. Henicorychus siamensis. A VERY IMPORTANT FISH FOR FOOD SECURITY OF THE MEKONG PEOPLE	Hydro-biological seasons	7 day delay in the onset of the dry season, 7 day advance of the onset of the monsoon. 5 day shortening of the dry season. 10 day increase in the duration of the flood season	medium	low	low	The extended wet season is likely to benefit this fish species. Its migratory patterns may nkt be affected as its downstream migrations is influenced by lunar cycles rather than water conditions.	very high	low
	Flow	Increased dry season and wet season flows anticipated, with the highest flows and increases over baseline appearing in September and the highest relative change occuring in May.	low	low	low	Whilst this fish benefits from extended wet sesons, being of a small size, it is unclear how increased flows might affect the behaviour and survival of this fish species and its young.	very high	low
	Water level	Increased water levels throughout the year, with the greatest increases through the wet season, peaking in September.	low	low	low	Evidence from the Tonle Sap suggests that the growth and productivity of this fish is closley related to the extent of the wet season.	very high	low

Species	Threat	Intrepretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
		written description of how the threat relates to the system component		*refer to table*		*written explanation of what the impact is, and why it was scored (high, med, low)*	*refer to table*	*refer to table*
3. ***Pangasius pangasius. A COMMERCIALLY IMPORTANT MIGRATORY BLACK FISH,.***	Hydro-biological seasons	7 day delay in the onset of the dry season, 7 day advance of the onset of the monsoon. 5 day shortening of the dry season. 10 day increase in the duration of the flood season	medium	low	low	The extended wet season is likely to benefit this fish species. Its spwaning migration may be brought forward by the earlier rises in water level and flows.	high	medium
	Flow	Increased dry season and wet season flows anticipated, with the highest flows and increases over baseline appearing in September and the highest relative change occuring in May.	low	low	low	Increased flows will likely benefit this fish, particularly its migration through the Khone falls.	high	medium
	Water level	Increased water levels throughout the year, with the greatest increases through the wet season, peaking in September.	low	low	low	Increased water levels are likely to benefit this fish, particularly its migration through the Khone falls.	high	medium

"Black Tiger Shrimps are commonly sold in Ho Chi Minh City fish markets." *by Donald Bason*



"Aquaculture and associated infrastructure will be vulnerable to increasing frequency and intensity of flood events throughout the LMB, and aquaculture stocks will experience increasing disease induced by the more extreme temperatures and corresponding lower dissolved oxygen levels."
– Headlines: USAID Mekong ARCC Climate Study for the Lower Mekong Basin

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