Climate Change Vulnerability Assessment Boueng Chhmar Ramsar Site, Cambodia

Peter-John Meynell, Kimsreng Kong, Pheakdey Sorn and Vanny Lou

Mekong WET: Building Resilience of Wetlands in the Lower Mekong Region

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

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ACRONYMS

BCRS	Boeung Chhmar Ramsar Site
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CFi	Community Fisheries
CPA	Community Protected Area
DoCDL	Department of Community Development and Livelihood
DoFWC	Department of Freshwater Wetlands Conservation
DoMCC	Department of Marin and Coastal Conservation
EU	European Union
FCA	Fish Conservation Area
FiA	Fisheries Administration
GDANCP	General Department of Administration for Nature Conservation and Protection
GHG	Green House Gas
ha	Hectare
IBBRI	Indo-Burma Ramsar Regional Initiative
ICEM	International Centre for Environmental Management
IKI	International Climate Initiative
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
LI	Learning Institute
km	Kilometre
m	Metre
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoE	Ministry of Environment
NGO	Non-Governmental Organisation
NSBSAP	National Biodiversity Strategies and Action Plan
PDoAFF	Provincial Department of Agriculture, Forestry and Fisheries
PDoE	Provincial Department of Environment
P/PET	Balance between precipitation (P) and potential evapotranspiration (PET)
TSBR	Tonle Sap Biosphere Reserve
TSCP	Tonle Sap Conservation Project
USAID	United States Agency for International Development
VA	Vulnerability Assessment

ACKNOWLEDGEMENTS

The climate change vulnerability assessment (VA) was conducted under the project “Mekong WET: Building Resilience of Wetlands in the Lower Mekong Region” (2017-2020). The Boeung Chhmar Ramsar Site (BCRS) was selected as one of the wetland sites for building climate resilience and conserving, managing and restoring natural ecosystems in collaboration with local communities and stakeholders, with the VA being a first step towards adaptation planning.

The assessment was carried out by the International Union for Conservation of Nature (IUCN) in cooperation with the Indo-Burma Ramsar Regional Initiative (IBRRI) national focal point from the Department of Freshwater Wetlands Conservation (DoFWC), and the Department of Marine and Coastal Conservation (DoMCC) of the Ministry of Environment (MoE) in Cambodia. From the start, it was decided to summarize and update the extensive assessment led by Mr. P.J. Meynell and his team in 2014.

We like to express our gratitude to the project partners, especially provincial and local authorities from Kampong Thom Province and Peam Bang Commune and local community representatives. Thanks also to the VA team in Cambodia, in particular: Mr. Pen Thearath, Deputy Director of the Department of Environment of Kampong Thom Province, Mr. Sorn Pikphat, Director of BCRS, and Mr. Pen Vannarith from the Fisheries Administration. Special thanks go to Mr. Sun Visal, IBRRI national focal point of MoE and local MoE Rangers for their technical support and participation. Special appreciation for Dr. Srey Sunleang, Director of DoFWC and Chairman of IBRRI of the MoE, for supporting the Mekong WET and nominating officers to join the assessment team.

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EXECUTIVE SUMMARY

Boeung Chhmar Ramsar Site (BCRS) is one of the three core zones of the Tonle Sap Biosphere Reserve (TSBR) in Cambodia. BCRS covers a total area of 28,000 hectares and includes a permanent open water body of 3,800 hectares called Boeung Tonle Chhmar, surrounded by a complex creek system and flood plains, with flooded forests fringing the shores of the Tonle Sap.

The area's climate is dominated by tropical monsoons, leading to a wet season from June to November and dry season from December to May. Two rivers, the Stung Staung and Stung Chikreng, and the interaction with the adjacent Tonle Sap Great Lake largely determine the hydrology of the site. Key species found in the Ramsar site include black fish (residents), grey fish (opportunists), and white fish species (migrants). Eels have been considered separately because of their importance to the fishery. Invertebrates include molluscs and crustaceans. BCRS is famous for large water birds, including greater adjutant (*Leptoptilos dubius), lesser adjutant (Leptoptilos javanicus)*, spot-billed pelican (*Pelecanus philippensis)*, painted stork (*Mycteria leucocephala)* and milky stork (*Mycteria cinerea)*, black-headed ibis (*Threskiornis melanocephalus)*, oriental darter (*Anhinga melanogaster)* and Indian cormorant (*Phalacrocorax fuscicollis)*, that visit to feed during the late dry season. The wetland is also an important breeding area for water snakes and turtles.

There are five villages in BCRS. In 2017, they comprised 611 households and a population of 3,500; 55% were poor and highly dependent upon fisheries as the main source of food and livelihood. They have no agricultural fields, though some have small livestock and aquaculture cages. In BCRS both men and women play important roles in the fisheries sector by engaging in fishing, post-harvest fisheries activities, repairing fishing gear, and fish trading. Despite this, little attention has been paid to women's roles in the fishery sector (FiA 2015).

Non-climate threats to the wetland include: the depletion of water levels in the lake due to dry season rice farming in St. Staung upstream of the site; outsiders coming in to fish during the dry season; illegal fishing using techniques such as electric fishing and bag nets; and invasion by *Mimosa pigra* and water hyacinth. The abolition of commercial fishing lots has reduced the pressure on fish populations in Boeung Chhmar.

Climate change projections for 2050 indicate that in the dry season, the maximum temperature will rise steadily from 32ºC to 35ºC, and the main part of the dry season will become drier. This may lead to drying out and water stress on the wetlands. Monsoon season is expected to start earlier, and maximum temperatures are expected to increase from 27.5ºC to over 31ºC. The annual rainfall is expected to increase from 1,250 to 1,380 mm (+10.6%). There is likely to be an increase in frequency and intensity of heavy rainstorms. Hydropower dams may counterbalance the impact of climate change on water levels.

These changes directly affect the wetlands' main habitats. Open water habitat in BCRS shows high vulnerability to climate change. Changes in climate are likely to affect both the extent of open water during the flood season and the depth and water quality of the open water in the dry season. Shallow waters in dry season will become hotter due to increased temperatures under climate change. Strong winds late in the dry season will lead to the mixing of poor quality water from the bottom layers of the lake, causing fish mortality.

Gallery forests are vulnerable to changes in water levels in the wet season and the depth and duration of the flood. Under climate change, it is likely that the wet season flooded area will increase slightly, but this may be moderated by infrastructure development. The extent of the dry season flooded area under climate change is likely to be reduced but will expand with infrastructure development. Throughout BCRS, there will be an overall increase in open water and loss of flooded forest, except for a few fringing areas along the shorelines and levees. Flooded forests are further at risk of fires in the dry season.

Shrubland habitats able to adapt to changes in water levels and seasonal drying out, making them relatively resilient to climate change. One of the main shrubs in the area*, Sesbania sesban,* has low vulnerability to climate change, although the invasion into these areas by *Mimosa pigra* may increase with climate change. Seasonally inundated grassland habitats are resilient to changes in climate; the highest temperatures occur when the grasses have matured and seeded. There may be changes in the extent of grassland areas, especially at the deeper flooded grasslands, which may evolve into flooded shrublands. Increased risk of fires in the dry season is part of the natural grassland cycle and may reduce conversion to shrubland.

Black fish are less vulnerable to climate change because they can survive in poor water quality. They can withstand harsh dry season environments and their limited migratory habits make them more resilient to wetlands fragmentation. White fish species require higher water quality conditions and are more vulnerable to increased temperatures and decreases in water availability in the dry season. Eels are generally very hardy species, tolerant to drought and poor water quality and able to move overland to other areas. Increased rainfall in the wet season, and increased flooding are likely to be beneficial for the species.

Rice-field shrimp are tolerant of adverse water quality, although they are vulnerable to the drying out of shallow floodplain pools in the dry season. Climate change may enhance the invasiveness of *Pomacea canaliculate* (golden apple snail), but compared to the native *Pila scutata,* both seem well adapted to hotter and drier dry seasons and can take advantage of increased rains and larger wetland areas in the rainy season. Reptiles are more vulnerable. Rising temperature will affect the sex ratio of turtles, while the shrinking wetland habitats during the dry season will make them susceptible to collection. Forest fires also threaten turtles. Rising temperatures may encourage water snakes to aestivate more in the late dry season, making them vulnerable to collection. Large water birds' vulnerabilities depend on climatic conditions at the time of breeding and incubation. Most birds come in large numbers in March and April to feed. Low water levels at that time of year make fish, snails and other aquatic animals easier to catch, which is important for juvenile bird development. If these food sources decline due to climate change, large water bird populations are likely to decline as well.

An analysis of livelihood vulnerability is based on climate impacts on key wetland resources. Black fish are the least vulnerable, with the exception of fish kills late in the dry season due to poor water quality. White fish are more sensitive to poor water quality but are not resident to BCRS. Climate change threats elsewhere may alter breeding habitats and influence their populations. Caged fish are more vulnerable to temperature extremes and poor water quality than fish in their native habitat; they are also more susceptible to disease outbreaks. If fish stocks decline, it will affect fish processing and marketing, boat and engine maintenance, equipment supply and other industries dependent on healthy fisheries. Fish declines may increase pressure on other wetland resources, especially water snakes and turtles. If large water bird populations decline, the potential of the area as a tourism site will also decrease. The availability of drinking water also threatens local communities, especially late in the dry season.

One of the key factors in effectively managing and protecting BCRS is ensuring adequate dry season flows of the Stung Staung and Stung Chikreng to maintain a positive inflow into the site, especially into open waters, to reduce the risk of poor water quality leading to massive fish kills. Reducing tree cutting in gallery forests and planting new trees in the areas bordering Tonle Sap can increase resilience and provide habitat for wildlife such as snakes and turtles that locals harvest. Managers should also consider methods to reduce the spread of alien species such as *Mimosa pigra* and golden apple snail; protecting predator species such as open bill storks can naturally control the latter.

Future planning should involve working with the local community to strengthen capacity and community-based approaches on fisheries management and sustainable financing mechanisms such as ecotourism, mini-trust funds, marketing wetlands products, and women's savings groups. Ensuring the provision of good quality drinking water for the communities, so that they are not directly reliant upon water from the creeks and open water, is also essential. To address and implement these issues, it will be critical to update the current management plan, preferably supported by a co-management approach with relevant stakeholders.

1 GENERAL INTRODUCTION

1.1 Building resilience of wetlands to climate change in the Lower Mekong Region

Wetlands, such as marshes, rivers, mangroves, coral reefs, and other coastal and inland habitats, have many important functions. They regulate water flows, provide clean water, store carbon and reduce disaster risk by acting as natural buffers against erosion and the impact of floods, tsunamis and landslides. In the Lower Mekong Region, millions of people rely on wetlands for their survival. In recent decades, however, infrastructure developments, deforestation, the expansion of irrigated agriculture and increasing urbanisation have led to dramatic declines in the region's wetlands. Impacts on habitats, species and livelihoods are further intensified by climate change. Conserving, managing and restoring natural ecosystems in collaboration with local communities and stakeholders, is increasingly recognised as critically important to maintain these unique environments.

"Mekong WET: Building Resilience of Wetlands in the Lower Mekong Region"[1] (2017-2020) aims to build climate resilience by harnessing the benefits of wetlands in Cambodia, Lao PDR, Thailand, and Vietnam. The project is funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). Mekong WET will help the four countries to address their commitments to the Ramsar Convention, an international treaty for the conservation and sustainable use of wetlands, and to achieve the Aichi Biodiversity Targets. Through its focus on wetland ecosystems, the project also supports governments in implementing National Biodiversity Strategies and Action Plans (NSBSAPs) under the Convention of Biological Diversity and pursuing their commitments on climate change adaptation and mitigation under the United Nations Framework on Climate Change.

Vulnerability Assessments (VAs) were conducted in ten Ramsar sites/wetland sites in the four countries as the first step of a participatory adaptation planning process. The approach combined scientific assessments with participatory appraisals and dialogues with communities living at the sites and the authorities in charge of site management. For Cambodia, three sites were selected: Koh Kapik Ramsar site in Koh Kong Province, Boeung Chmar Ramsar Site located in Kampong Thom Province and Boeung Prek Lapouv Protected Landscape situated in Takeo Province. This report focusses on the VA for Boeung Chhmar Ramsar Site, further referred to as BCRS.

1.2 Objective and setup of the study

The main objectives of the assessment were:

- To assess the vulnerability of ecosystems and livelihoods to the impacts of climate change.
- To identify options to address vulnerabilities and increase the resilience of wetlands and livelihoods to the impacts of climate change.

The assessment consisted of two parts: a baseline description of the current situation of the wetland and an assessment of the climate change vulnerability of wetland habitats, species and livelihoods.

IUCN previously conducted a VA assessment for BCRS in 2014. Therefore, it was decided to summarize and update the original report with recent data and information. The original assessment was based on a similar conceptual framework as the one used for the other sites in the Mekong WET project (see Box 1.1), however, the study in 2014 elaborated more on the

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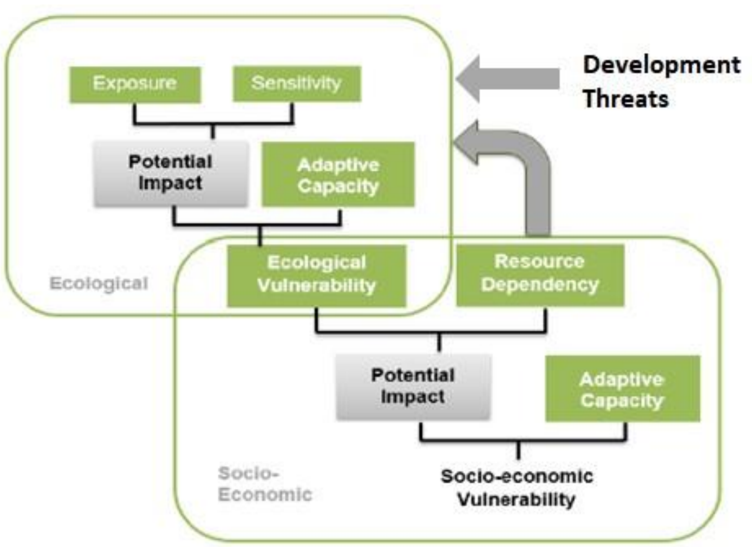
[1]See https://www.iucn.org/regions/asia/our-work/regional-projects/mekong-wet

specific processes and impacts, with a strong emphasis on the literature review and expert opinions. IUCN synthesized and verified key findings, while complementing them with recent data and information from a participatory appraisal with communities living at the sites and authorities in charge of site management.[2]

The VA covered the wetland and adjacent villages that rely on its resources for their livelihoods. It assessed how these are affected by climate change and non-climate threats, including those from outside the wetland boundary. In this updated report, special attention was paid to the needs and perspectives of women, because women may use wetland resources in different ways than men do, and women may have different knowledge and perspectives of wetland resources than men. The report will be used as input for meetings with villagers and other relevant stakeholders to discuss the results and develop adaptation plans.

Box 1: Conceptual framework Vulnerability Assessment (after Marshall, 2009; GIZ/ISPONRE/ICEM, 2016)

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), vulnerability is defined as the degree to which something (a species, an ecosystem or habitat, a group of people, etc.) is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is further explained as a function of the character, magnitude, and rate of climate variation to which a system/species is exposed, the system/species' sensitivity, and the system/species' adaptive capacity.



Exposure is defined as the extent to which a region, resource or community experiences changes in climate. It is characterised by the magnitude, frequency, duration and/or spatial extent of a weather event or pattern.

Sensitivity is defined as the degree to which a system is affected by climate changes.

Together, exposure and sensitivity describe the potential impact of a climate event or change.

This interaction of exposure and sensitivity is moderated by adaptive capacity, which refers to the ability of the system to change in a way that makes it better equipped to manage its exposure and/or sensitivity to a threat.

Within the context of Mekong WET, which is focused on wetlands, the ecological system consists of two elements: species and habitats. The socio-economic system refers to the socio-economic vulnerability (i.e. livelihoods) of the villages or communities that are dependent on resources derived from the wetlands. Socio-economic and ecological information collected during the assessments evaluates how the ecological and socio-economic system interact to determine the overall potential climate change impact.

[2]Since outcomes of the VA should lead to actions and decisions at the local and potentially national levels, members of different institutions at both national and sub-national levels were involved in the appraisal process, i.e.: director of BCRS, and representatives from Provincial Department of Environment (PDoE) and Department of Freshwater Wetlands Conservation (DoFWC) and the Department of Community Development and Livelihood (DoCDL) of the Ministry of Environment (MoE).

2 SITUATION ANALYSIS

2.1 Description of the wetland

Various factors, including the wetland's biophysical and ecological characteristics determine the vulnerability of BCRS to climate change. The description of the wetland is based on geographic, climate, biodiversity and hydrology data described in the vulnerability assessment in 2014. This is followed by an overview of land use patterns, drivers of change, and recent conservation/zoning plans to provide an overview of the current state of the ecological system.

2.1.1 Location and site description

Boeung Chhmar is one of three core areas of the Tonle Sap Biosphere Reserve (TSBR). It is located just northeast of the main constriction in the Tonle Sap Great Lake as shown in Figure 1. The other two core areas are at Prek Toal in the northwest corner of the lake and Lower Stung Sen at the bottom end of the lake.

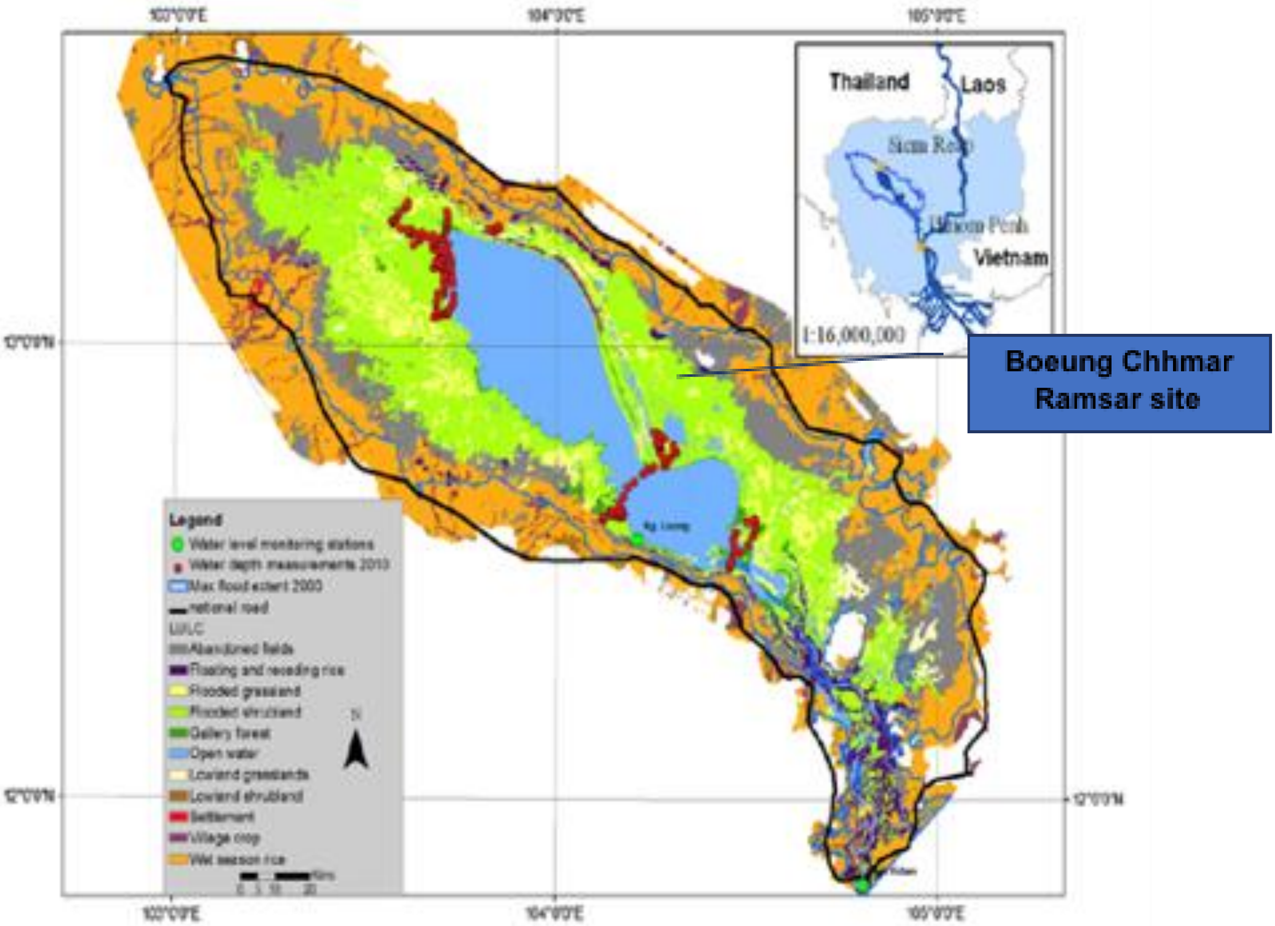


Figure 1: *Overview map of the Tonle Sap with major land use/land cover classes from JICA (1999) below 15 m asl and water depth measurements (source: Arias, 2012)*

The Ramsar site at Boeung Chhmar and associated river system and floodplain covers a total area of 28,000 ha, of which 23,000 ha lie in Kampong Thom Province (the focus of this assessment) and 5,000 ha in Siem Reap Province (Figure 2). The maximum elevation of the site is 10 m above sea level. The site consists of a permanent open water body of about 3,800 ha, surrounded by a complex creek system and flood plains, with flooded forest fringing the shores of the Tonle Sap and parts of the open water lake. The area contains a range of complex wetland habitats including seasonally inundated forests, forest mosaic and woods and bushlands. The nutrient dynamics of the area create a rich ecological diversity.

BCRS supports a large assemblage of plant, fish, reptile, mammal and waterbird species, many of which are vulnerable or endangered. It regularly supports more than 20,000 individuals of large water birds, being one of main feeding grounds for the breeding colonies of birds at Prek Toal, such as Asian open-bill, Oriental darter, spot billed pelican, Indian cormorant, lesser adjutant and greater adjutant. There are also 296 fish species in the Tonle Sap area (43% grey fish, 40% white fish and 17% black fish species); of which 17 are threatened species. When inundated, the Boeung Chhmar site provides a rich habitat for fish feeding and breeding.

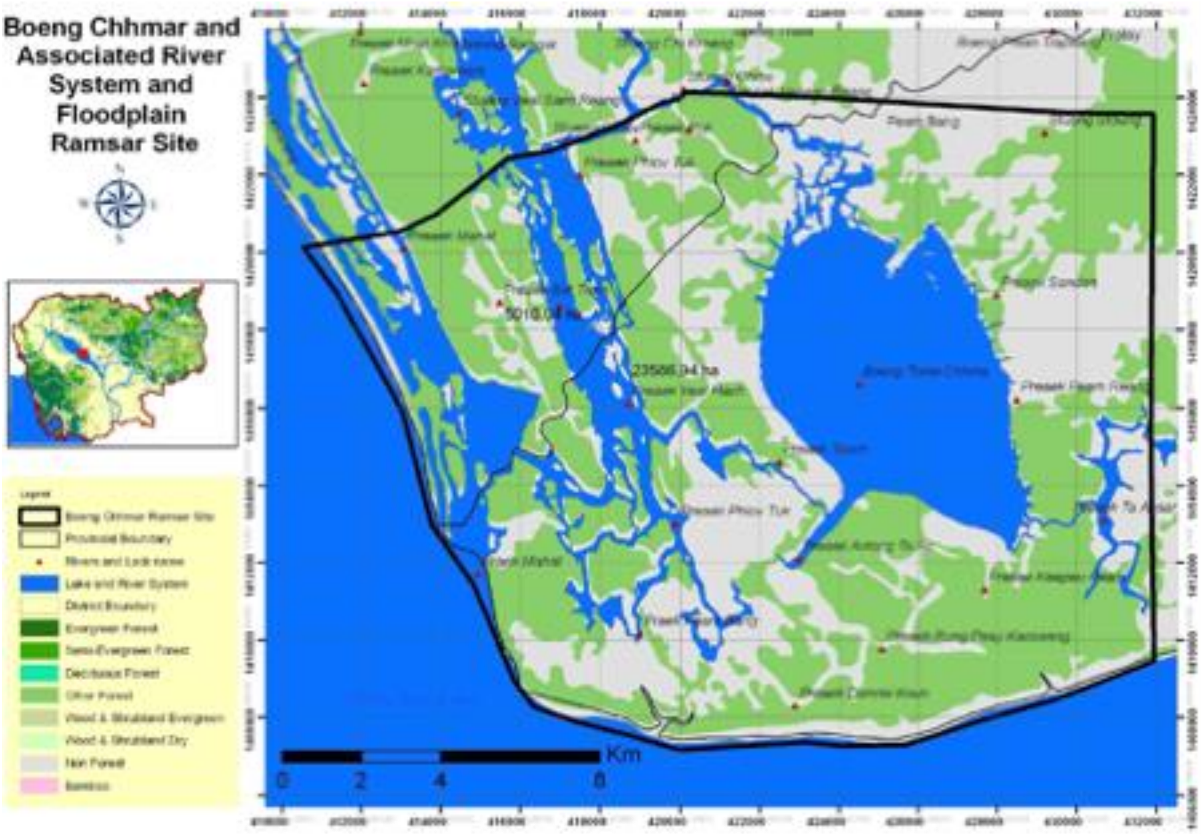


Figure 2: *Map of BCRS (source: Ramsar)*

2.1.2 Current and historic climate

Similar to other parts of Cambodia, the climate of BCRS is dominated by tropical wet and dry monsoons. The southwest monsoon lasts from mid-May to mid-September/early October, while the northeast monsoon's drier and cooler air lasts from early November to March. In BCRS, the period December-May is referred to as the dry season and the period June-November as the wet season.

There is no local weather station at the site, but the average annual temperature measured at Kampong Thom town, about 70 km from the centre of the wetland, shows stable temperatures between 2002 and 2010. The monthly mean maximum temperature between 2002-2010, shows a peak in March/April of about 35ºC, which falls throughout the wet season to about 31ºC from September to December (Figure 3).

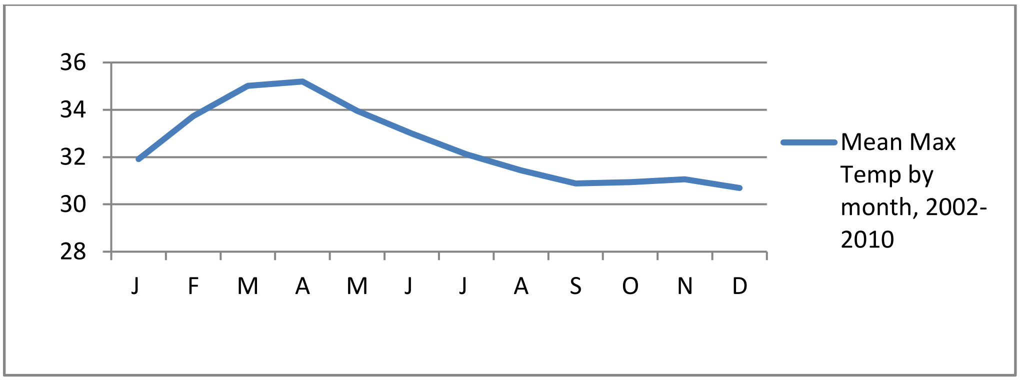


Figure 3: *Monthly mean maximum temperature at Kampong Tom from 2002-2010 (source: Department of Water Resources and Meteorology, Kampong Thom)*

There are 13 stations in Kampong Thom Province that record rainfall data and other meteorological parameters. Average annual rainfall is between 1,300 and 1,900 mm. Three stations (Baray, Kampong Thom and Staung) have recorded rainfall data since 1920, showing an annual average value of 1,481 mm, with a peak of 300 mm in September. December, January, and February are the driest months. The rainfall data at Kampong Thom town from 2000 to 2010, as well as monthly averages, are shown in Figure 4.

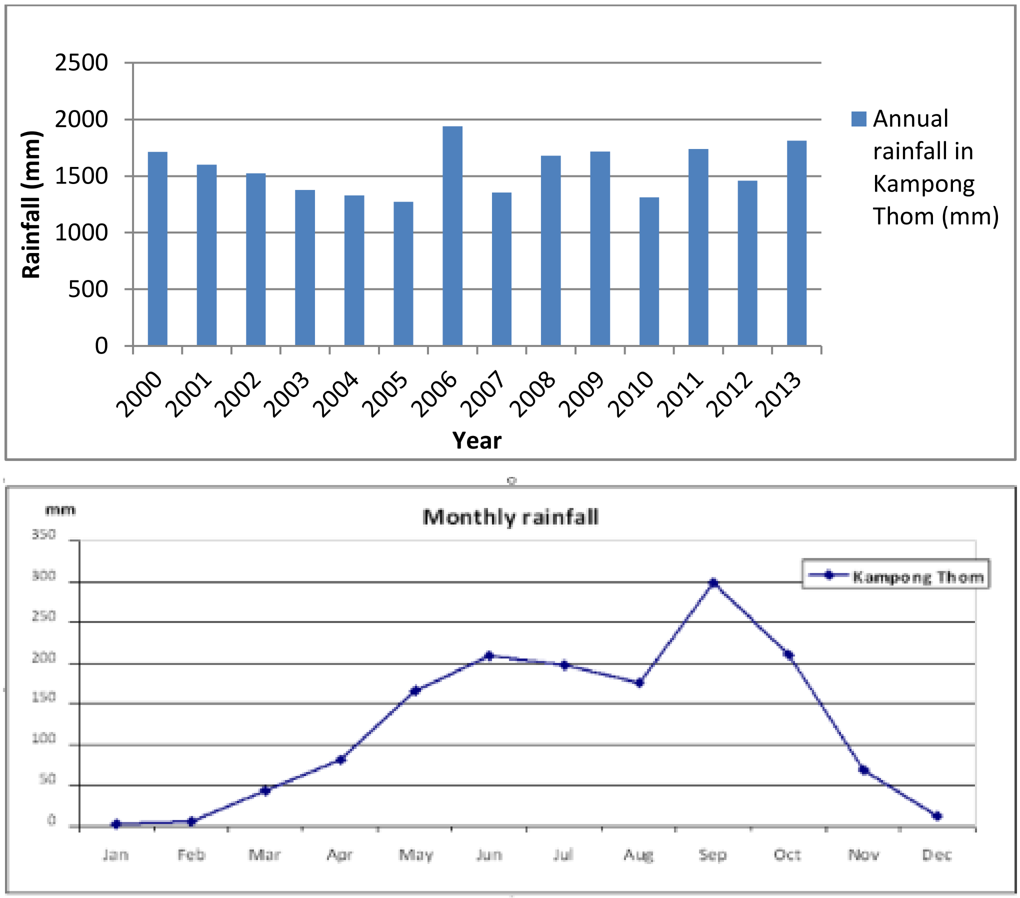


Figure 4: *Annual rainfall and monthly rainfall at Kampong Tom from 2000-2010 (source: Department of Water Resources and Meteorology, Kampong Thom)*

During the assessment in 2014, local villages reported that rainfall had become erratic with wet seasons starting later, until recently when they reported that the rainfall began starting earlier in the season. Locals also noted that rainfall was heavier but lasted for a shorter period. Locals also observed that heavy rainfalls led to flash floods on the rivers. They reported few dry spells in years leading up to 2014. Recently, the onset of the wet season has been unpredictable, with late dry seasons between 2014 and 2016 and with early rains in 2017 and 2018.

2.1.3 Hydrological characteristics

The hydrology of the site is largely determined by two rivers, the Stung Staung and Stung Chikreng, and the interaction with the adjacent Tonle Sap Great Lake. The creek systems are mostly shallow, especially in April, with a maximum depth of about 2 m. The lake in Boeung Chhmar is shallower at 0.5 to 1 m deep, but during inundation the lake may reach a maximum depth of 8 m. The lake in Boeung Chhmar is a natural depression perched slightly higher than the Tonle Sap Great Lake, and so it maintains its water levels even as the waters in the Tonle Sap recede. The creeks flowing into and out of the lake cut through the seasonally inundated floodplains, grasslands and shrublands, with the gallery forests mainly occurring on the outer shoreline of the Tonle Sap.

In the first part of the wet season, the two rivers and local rainfall raise the water levels in the Boueng Chhmar Lake and the other bodies of open water. Later in the wet season the lake will receive water from the Tonle Sap Great Lake as it starts to rise, first due to the inflow from its tributaries, and then in July and August due the back flow from the Mekong during the rainy season. Thus, like the Tonle Sap Great Lake, Boeung Chhmar Lake is subject to three types of inflow:

- Throughout the dry season and in the early wet season – inflow from Stung Staung and Stung Chikreng (in the low water season, a large part of the area around BCRS dries out, with water remaining only in the open water bodies, other scattered pools and watercourses);
- Mid wet season – inflow from rising water levels in the Tonle Sap Great Lake from its tributaries and local rainfall;
- Late wet season – inflow from Mekong River backflows during the rainy season, raising the overall levels of water in the Tonle Sap Great Lake.

In the wet season, the wetland area is completely flooded, with only the tops of emergent trees remaining above water. Changes in water levels influence the size of the lake and the floodplain as well as the exchange between groundwater and surface water. The flooded forest and creek system trap the sediments flowing in from the two rivers, and maintain the fertility of the ecosystem. The flooded forests and shrublands also protect the open bodies of water in BCRS from weather back flow and sediment extremes in the Great Lake during the late wet season.

2.1.4 Wetland habitats and vegetation

The wetland habitats in BCRS are highly dependent upon the varying water levels and lengths of inundation. The species that survive under these conditions are highly adapted, and there is a clear zonation of species dependent upon the elevation, i.e. the length of time that the plants can withstand inundation. This is clearly illustrated in Figure 5, which shows the cross-sectional profiles in the late wet season when the water levels are highest and in the late dry season when the levels are lowest.

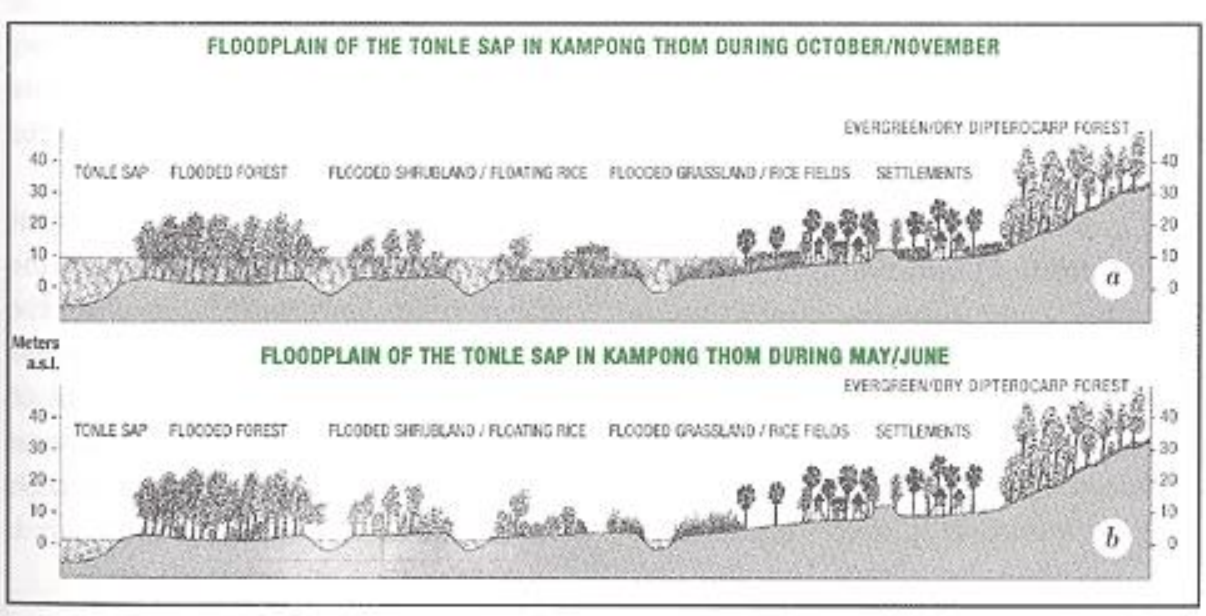


Figure 5: *Cross section of floodplain habitats in Kampong Thom province during a) October/November and b) May/June (Source: Davidson, 2006, quoting Balzer, 2002)*

Common species in the lake and river systems include: non-rooted floating plants (water hyacinth (*Eichhornia crassipes*), *Pistia stratiodes* and *Salvinia* sp.); non-rooted submerged plants (*Utricularia* sp. is present in small amounts); rooted floating leaves (*Trapa natans, Nymphaea* sp.) and creeping species (*Ipomea reptans, Ludwigia adscendens*). Trees such as *Barringtonia acutangula* and *Xanthophyllum glaucum* are very common along the levees of waterways within the floodplain and as scattered groves on the floodplain. *B. acutangula* is a medium sized evergreen tree with traditional medical uses; it is also valued as a timber species. Saplings of *B. acutangula* must survive at least 4 months of complete inundation. The back-swamp areas are lower than the levees. In the dry season the water table may still be at the surface of the soil. The dominant plant forms are extensive thickets of the shrub *Sesbania javanica* and meadows of the low-growing *Polygonum barbatum. Ipomea reptans* is common, creeping over the ground, and there are extensive areas of water hyacinth growing in the moist soil.

Arias et al. (2012) distinguished six habitat groups around the Tonle Sap based on the extent of flooding. These include: open water, flooded for 12 months in an average hydrological year; gallery (swamp) forest, flooded for 9 months; seasonally flooded habitats, flooded for 5-8 months and dominated by shrublands and grasslands; transitional habitats, flooded for 1-5 months and dominated by abandoned agricultural land, receding rice/floating rice and lowland grasslands; and, rainfed habitats, flooded up to 1 month and consisting mainly of wet season rice fields and village crops. Open water, gallery forest, and seasonally flooded habitats (shrublands and grasslands) are present in Boeung Chhmar. Researches used satellite imagery to determine the areas of the different habitats within the site (Figure 6; Table 1).

Table 1: *Habitat type and estimated areas in BCRS based on 2014 satellite data*

Habitat type	Area (ha)	Percentage
Open water lake	3,803	14 %
Open water – rivers and creeks	4,722	17 %
Flooded forest – Gallery (swamp) forest	644	2 %
Short-tree shrubland	16,090	57 %
Floodplain – seasonally inundated grassland	2,749	10 %

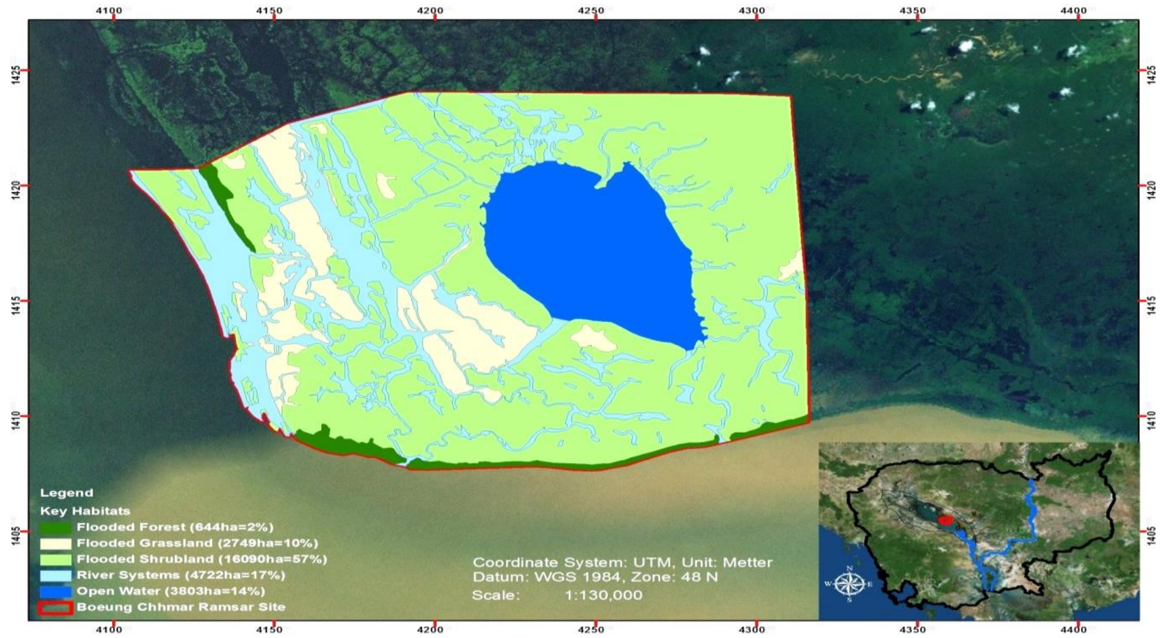


Figure 6: *Map of key habitats in BCRS*

2.1.5 Key Species

BCRS hosts a huge diversity of animas: more than 200 bird species, 100 fish species, over 30 reptile species, 20 mammal species and 5 amphibian species, although biological research is incomplete (Goes, 2005; Davidson, 2006). The whole Tonle Sap area covers hosts even greater biodiversity.

Fish: The fish in the Mekong are generally categorized into three main groups:[3]

- Black fish: Black fish are the main residents in the Tonle Sap. They inhabit waters with decomposed floodplain vegetation, which increases water acidity and depletes oxygen; most black fish species are adapted to such conditions and can breathe air and move overland in search of fresh waterbodies (Hortle et al. 2004). Black fish include the Channidae (Snakeheads), Clariidae, Bagridae (*Mystus* spp.) and Anabantidae (Baran 2004).
- Grey fish or opportunists: Opportunists are small, fast-growing species, able to make maximum use of the flood period for prolific reproduction and/or growth. This group (also classified as white fish) comprises mainly cyprinids, which are harvested in large quantities for the manufacture of fish sauce (*prahoc*), and food for caged fish. *Henicorhynchus* spp. (*Trey Riel*) are the most common species (van Zalinge et al. 1999).
- White fish: White fish are mainly associated with the main channels and streams, and exhibit strong lateral and longitudinal migrations, including into floodplains. They move into the Tonle Sap as the flood rises in the early wet season (from May), remaining there to feed and reproduce, until the waters begin to recede (from November), when they return to the turbid ("white") waters of the Tonle Sap and Mekong Rivers (e.g., Nao 1997, Hortle et al. 2004). White fish include many cyprinids, *Pangasius* sp., Siluridae and Notopteridae (Baran 2004).

[3] Fish group descriptions quoted from Davidson, 2006

Eels: There is one species of true eel (*Anguilla marmorata*) and two species of swamp eel (*Mastacembelus armatus* and *Monopterus albus*) found in the Tonle Sap ecosystem. They are separated from fish because of their seasonal dormancy behaviour and importance as a fishery in Boeung Chhmar. Adults inhabit streams, ponds, canals, drains, and rice fields, in both clear and turbid water. They are nocturnal and carnivorous. They are facultative air-breathers.

Invertebrates: Invertebrates include molluscs and crustaceans.

- Molluscs. The Mekong Basin, including in the Tonle Sap, exhibits an extremely high diversity of molluscs (snails and mussels) (Rainboth 1996). *Pila scutata* is one of the most common snails collected in Boeung Chhmar. The species is ambhibious abd found in calm freshwater habitats. They usually climb on the aquatic grass/plants using their muscular foot. It can aestivate and tolerates drying out. *Pomacea gigas* (apple snail), which feeds on the growing basal stems of aquatic plants, has had a major impact on aquatic habitats and agro-ecosystems throughout Southeast Asia, degrading natural vegetation and severely reducing rice yields (Welcomme and Vidayathon 2003). The fish populations of affected habitats are heavily impacted, and the introduced snails compete with native species such as *Pila* spp.
- Crustacea. All rice field crabs in Tonle Sap belong to the same genus *Somanniathelphusa*. These crabs are rice pests (Balzer *et al*. 2002) and are collected from June to December, but only eaten in times of food scarcity. The local shrimp (*Macrobrachium lanchesteri*) (Mogensen in Balzer *et al*. 2002), is abundant between September and December, when it is harvested for food. *M. lanchesteri* is a relatively small species but can form a large proportion of the habitat's biomass due to its large numbers.

Large water birds: There are more than 200 species of birds within the wider Tonle Sap, of which more than 25 species are of globally and/or regionally significant populations, 17 of which are IUCN Red-Listed. These most significant species and populations are:

- Globally significant colonies of greater and lesser adjutants, spot-billed pelicans, painted and milky storks, black-headed ibises, darters and Indian cormorants that breed in seasonally inundated swamp forest in the Prek Toal core area;
- One of the largest known breeding populations of grey-headed fish eagles (*Icthyophaga ichthyaetus)*;
- A unique bird community in one of the largest remnant tract of seasonally inundated grasslands and agro-ecosystems in Southeast Asia;
- During the dry season one of the world's largest breeding population of Bengal florican (*Houbaropsis bengalensis)*;
- The largest known wintering population of Manchurian reed warbler;
- Very small numbers of white-shouldered ibis;
- Regionally important populations of greater spotted and imperial eagles;
- Post-breeding aggregations of greater and lesser adjutants and black-headed ibises during the wet season

Resident water birds in BCRS include Oriental darters, cormorants and Asian openbills (*Anastomus oscitans)*. Visitor species from mid-January to July include painted storks, lesser and greater adjutants, and spot-billed pelicans. Peak numbers occur from March to May when the water level in Boeung Chhmar becomes lower, providing greater availability of food sources.

Mammals: Relatively few mammal species occur in the Tonle Sap reserve considering that it is a tropical lowland ecosystem. These include six IUCN Red Listed species, each of which inhabits the seasonally inundated swamp forests and short-tree shrublands. Populations that are potentially of global or regional conservation significance are: long-tailed macaques (widespread and locally common, probably one of the larger populations in Southeast Asia); Germain's silver leaf monkeys (*Trachypithecus villosus germaini*) (poorly known but certainly important globally); smooth coated otter (*Lutrogale perspicillata)* and hairy-nosed otter (*Lutra sumatrana)* (poorly known, especially the latter, but important in Southeast Asia), and fishing cats (*Prionailurus viverrinus)* (poorly known but important in Southeast Asia)

Reptiles: There are 23 reptile species, including three python species of conservation importance: the blood python (*Python curtus*), the rock python (*P. melurus bivittatus*) and the reticulated python (*P. reticulatus*). Locals target them for their skin, meat and blood. They are also sold on domestic and international markets. Boeung Chhmar is also an important breeding area for Tonle Sap water snakes and turtles.

- Water snakes. Since the late-1990s, snakes have become one of the main protein sources for captive-bred crocodiles in the burgeoning number of crocodile farms around the lake; an estimated 3.8 million snakes were harvested between June 2004 and January 2005 (Brooks et al. 2007). This harvest principally targets species in the sub-family Homalopsinae (*Homalopsine watersnakes*). These species are also targeted for their skins, while a proportion is also used for human consumption (Stuart et al. 2000, Brooks et al. 2007).
- Turtles. Turtle populations of lowland wetland habitats in Cambodia have plummeted due to over-harvesting, chiefly for both legal and illegal export to China and Vietnam for use in traditional medicine and as food, and for domestic consumption (Walston 2005). Eight species globally threatened species are reported to occur in the Tonle Sap reserve. The most commonly found species in the Tonle Sap include: the Asian box turtle (*Cuora amboinensis*), the black marsh turtle (*Siebenrockiella crassicollis*); the yellow-headed temple turtle (*Hieremys annandalii*), the giant Asian pond turtle (*Heosemys grandis*), the Malayan snail-eating turtle (*Malayemys subtrijuga*), and the Asiatic softshell turtle (*Amyda cartilaginea).*

2.1.6 Land use

The major areas are the Tonle Sap's open water and the vast inundated floodplain. In the Boeung Chhmar region of the flood plain there are numerous creeks, and there are scattered pools over the floodplain area. Some open water areas are managed as community fisheries (CFi) and as Fish Conservation Areas (FCA). The flood plain is a food source for large water birds and other animals, while people use it to collect other wetland resources.

People in the commune have been allocated farmland in an area that was formerly grassland and is now used for dry season rice production. This 600-ha area, 5 km from Pov Vouey, was a "gift" from the government to compensate for declining fish stocks pre-2012 (as result of privatization of fishing grounds), but there has not yet been an official approval for the allocated land from the government.

2.1.7 Drivers of change

Several factors have driven the changes in land-use and the wetland:

- In recent years, the sourcing of irrigation water from the Stung Staung and Stung Chikreng has almost stopped the flow of water reaching Boeung Chhmar during the dry season and early wet season. There are concerns that this shortage of the natural inflow during the dry season is changing the hydrology and ecology of the wetland.
- The region is beginning to feel the impact of climate change through rising temperatures, rainfall patterns and storms. These impacts are already affecting hydrological and ecological processes in Boeung Chhmar. Some of the effects in terms of water flows are mitigated by upstream infrastructure (hydropower dams).

2.1.8 Conservation and zoning

There is currently one Community Protected Area (CPA) in BCRS. The CPA in Balot village (Peam Bang Commune) was formed from 2006-2007 through the UNDP Tonle Sap Conservation Project (TSCP); it initially covered 27 hectares, including a 5-hectare FCA – classified for strict protection. The creation of the CPA emerged from village protests over the privatisation of fishing grounds by local authorities, reflecting a strong community will to protect the area. After a short period in which the CPA was not functioning, it was revived by MoE with technical and financial support of EU-NSA IUCN project (2013-2016). The CPA and FCA were enlarged (to 65 ha and 8 ha, respectively) and have since been managed by elected community committees using ecosystem-based approaches; as result, the fish stock has increased, local livelihoods have been enhanced, and the engagement, capacity and confidence of key actors has improved (IUCN, 2016).

In 2012, 37 fishing lots in and around the Tonle Sap Lake, including Fishing lot 6 in Boeung Chhmar, were permanently abolished and handed back to fishermen's families for their daily livelihood. Following this decision, three Community Fisheries (CFi) sites (including small FCAs with strict protection) were established in Peam Bang Commune, inside BCRS. These CFi sites are in the floating villages of Pov Veuy (2676 ha), Doun Sdeung (445 ha), and Peam Bang (209 ha). The CFi sites fall under the jurisdiction of the Ministry of Agriculture, Forests and Fisheries (MAFF) and are managed by elected committees under coordination of the Fisheries Administration (FiA). The decision to abandon the fishing lots was strongly supported by most fishermen who expected to get more benefit from fisheries resources. Others were concerned about the potential increase of illegal fishing, due to the limitations of law enforcement of FiA and local authorities, within and around the lake where fish crimes are still rampant.

2.2 Communities and wetland livelihoods

Baseline information from the 2014 vulnerability assessment was updated with more recent data about the current state of local interaction with the wetland ecosystem and its components. Data included the livelihoods of people in and near BCRS, their reliance on wetland resources, tenure and resource rights, governance structures and stakeholders, and vulnerable groups and perceived threats.

2.2.1 Communities and population

Peam Bang Commune in BCRS consists of five villages. The commune statistics of 2017 show that the villages include 611 households with a total population of about 3,500 people, of which 52% are women (see Table 2). There has been minimal change since 2013. In 2017, the poverty level was 55%, a slight reduction compared to the rate of 60% in 2013; the provincial poverty rate for Kampong Thom in 2015 was 24.5%, suggesting that communities in and around BCRS are relatively poor compared to other parts of the province.[4]

Table 2: *Demographic data for villages in and around BCRS (source: Commune Data Base)*

	Year 2013				Year 2017			
	Household	Population	Women	Poverty	Household	Population	Women	Poverty
Pov Veuy	166	902	51 %	60 %	166	935	51 %	57 %
Doun Sdeung	144	791	52 %	55 %	144	832	51 %	50 %
Peam Bang	176	982	53 %	60 %	176	988	53 %	55 %
Pecharei	71	372	54 %	65 %	71	376	54 %	65 %
Balot	54	361	54 %	60 %	54	367	54 %	50 %
Total	*611*	*3,408*	*52 %*	*60 %*	*611*	*3498*	*52 %*	*55 %*

[4]Statistics provided by the Commune Data Base management by the Ministry of Planning showed that the national poverty rate decreased from 30.7 % in 2007 to 18.8 % in 2015.

Note: Poverty rate reflects the percentage of households falling into category I (very poor) or category II (poor), based on several criteria

2.2.2 Key livelihood activities

The communities are highly dependent upon fisheries as the main source of livelihood, both as source of income and for their own consumption. They have no agricultural fields, though some have some small livestock and aquaculture cages.

There are three kinds of fishing people on the Tonle Sap Lake:

- Permanent residents living in floating villages;
- Permanent residents of villages that are on land for six months and on water for six months;
- Transient fishers who live on the land and come to fish after the onset of the dry season and the rice harvests in November.

Fishing livelihoods are finely tuned and highly seasonal. Fishers must make decisions about how to invest their effort in response to myriad risks, trade-offs, and opportunities (Marschke and Berkes 2006). On average, poorer families spend 2-3 hours fishing per day and can catch 5-10 kg of fish or more if they are lucky. Villagers keep some fish for their own consumption and sell the rest of their catch immediately. Some families are also involved in fish processing, such as making fermented fish paste (*prahoc*) and smoking fish, to sell to more wealthy families and traders. Previously, FiA rangers prohibited raising fish, because people mainly kept invasive species, but since April 2016, raising fish in Tonle Sap has become legal. It requires registration with the FiA and is an important activity for people in Boeung Chhmar to complement their income.

There are 4-5 middlemen who regularly come to the centrally located Peam Bang Village to buy fish, which they transport to Kampong Lourng in Pursat or Stoung in Kampong Thom depending on the season. The price depends on the market and the middlemen. Fishermen have relatively little bargaining power because: (i) they must sell their fish immediately before it spoils, and (ii) the distance from Boeung Chhmar to other markets is prohibitive for one family to travel alone to sell 10-20 kg of fish. The middlemen coordinate with each other so that they all offer the same price to villagers.

2.2.3 Use of wetland resources

The main wetland resource used by locals is fish. Some of the catch is used as food for raising fish (typically snakehead, catfish). Other aquatic plants and animals that are collected include:

- *Sesbania* – flowers collected for food; stems used as floats for fishing gear and house floatation.
- Rice field shrimp – these are collected and provide a valuable source of income.
- Snails - golden apple snails are collected and eaten, but the native species are preferred.
- Water snakes – the water snake populations are declining due to unsustainable harvesting (mainly sold to crocodile farms).
- Turtles – turtles are highly prized, and their populations are under pressure from over collection.

2.2.4 Land tenure and rights

So far, land tenure and land-use rights of communities in BCRS have not been recognized by the government of Cambodia. Many local families live in floating houses, moving from one place to another during the dry and rainy season. Although people can legally fish anywhere in BCRS, a CPA and three CFi areas have been established to protect the fisheries and natural resources. Moreover, under the Protected Area Law or Fisheries Law, in each CFi or CPA, several conservation areas (or FCAs) have been established with strict protection to increase fish stocks.

2.2.5 Governance

In 1999, Boeung Chhmar was designated as a Wetland of International Importance under the Ramsar Convention. Soon thereafter, in 2001, the Tonle Sap Biosphere Reserve (TSBR) was created by the Royal Government of Cambodia, as the most important inland wetland in Southeast Asia. MoE was designated as the authority responsible for managing the Biosphere Reserve's core areas as well as being the Cambodia focal point for the Ramsar Convention.

Both MoE and FiA (which falls under MAFF) play roles in protecting BCRS (see Figure 7). Broadly speaking, MoE protects biodiversity and natural resources like flooded forests and wildlife, while the FiA focuses on fish and prevention of illegal fishing. The Provincial Department of Environment (PDoE) and the Provincial Department of Agriculture, Forestry and Fisheries (PDoAFF) are in regular contact and BCRS rangers and FiA officers work together at the local level.

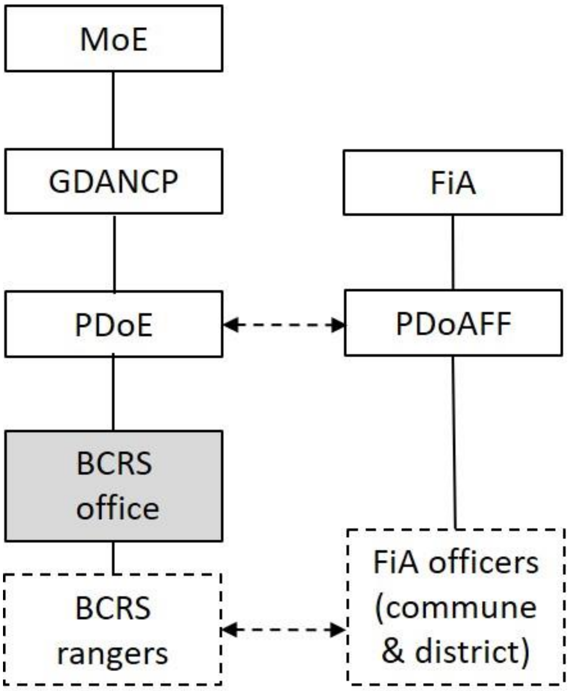


Figure 7: *Governance structure of BCRS*

There is no specific management plan for BCRS. The only existing management plan, was prepared for the Boeung Chhmar Core Area of the TSBR for the period 2008 – 2012, but this plan has not been updated (Tonle Sap Conservation Project, 2007). The Core Area Management Plan did not refer to climate change and adaptation, though the analysis of the issues and problems included the future of commercial fishing in the area, local livelihoods, control of fires, ecotourism development, and management programming, implementation and funding.

2.2.6 Stakeholder analysis

Tonle Sap, including BCRS, is an area where different actors and interests come together. For effective management it is important to acknowledge these interests and involve actors in key decisions. A stakeholder analysis and a Venn-diagram with community members highlights various government actors, NGOs, local community groups and other relevant actors (Table 3).

Table 3: *Relevant stakeholders and their interest/role in BCRS*

Actor	Description	Interest/role (relation with BCRS)
Government	MoE – GDANCP	National coordination to provide policy and technical support on implementation of BCRS management.
	PDoE, Director BCRS	Provincial coordination on implementation of BCRS management
	FiA	Cooperation and contribute inputs for BCRS management at national level
	FiA officers	Cooperation and contribute inputs for BCRS management at commune/district level
Local authorities	Village chief and commune council	Coordination, especially in relation to socio-economic development, and the protection of the environment and natural resources

	Local police	Participation in law enforcement activities in BCRS.
Local community	Community members	Participation in planning, monitoring and evaluating through providing local knowledge/information and feedback for improving overall site management.
	CFi and CPA committees	Coordination and implementation of CFi/CPA operation under the supervision of FiA/MoE, and with support from local and international NGOs.
	Middlemen/fish traders	Willing to share information on the status of fish catches and market prices, may be able to benefit from increased productivity and buying agreements with (organized) community members
NGOs	IUCN	Facilitation role with all stakeholders and provides both technical and financial support to implement the Mekong-WET project in BCRS (2017-2020)
	Learning Institute (LI)	Recently implemented a 2.5- year project (Jan 2017-June 2018) on Sustainable Fisheries Conservation Management in Boeung Chhmar, Kampong Thom Province. LI could possibly remain involved in BCRS in case of new funding.
	Conservation International	Biodiversity research and monitoring in BCRS
	BirdLife International	Promoting awareness and education activities in BCRS
Other	School	Cooperation on awareness and education activities in BCRS
	Health care center	Cooperation on awareness/education on water and sanitation issues in BCRS

2.2.7 Gender and vulnerable groups

Over the past decades, both Cambodian men and women have played important roles in contributing to the development of the fisheries sector by partaking in fishing, post-harvest fisheries activities, repairing fishing gears, and fish trading, among others. These nationwide trends can be seen in BCRS. Little attention has been paid to women's roles in the fisheries sector and their work has been poorly recognized (FiA, 2015). Women often have fewer rights compared to men. At the household level, women are also responsible for domestic work from an early age and they are often deprived of education, particularly in poor households, which are most dependent on natural resources for their livelihoods.

Each village in BCRS has about 10-20 "very poor" families (poverty level I). These families have only wooden rowboats, and they must fish every day to eat, selling most of their catch to buy rice. In 2014, one local leader explained that fish catches had declined in the preceding years and that there were many new seasonal immigrant fishers from other areas competing for fish. Since the abolition of the fishing lots, livelihoods have started to improve slightly. In addition, capacities of communities in Balot CPA have been strengthened to sustainably manage fisheries resources through the EU-NSA project (2013-2016), this could possibly be replicated in other areas (IUCN, 2016). These positive natural resource developments may be compromised if extreme weather events due to climate change increase in frequency.

2.2.8 Perceived threats to wetland habitats and livelihoods

Based on the 2014 VA report, the main non-climate threats to the natural resources of BCRS include:

- Upstream water abstraction for dry season rice farming in St. Staung is depleting water levels in the lake during the late dry season.
- Outsiders coming to fish in BCRS in the dry season, competing with local people for fish.

- Illegal fishing is threatening fish populations in the Tonle Sap Lake and in BCRS (both local and outsider fishers have been involved in unsustainable fishing using fishing techniques such as electric fishing and bag nets).
- Invasion by *Mimosa pigra* and water hyacinth.

The abolishment of fishing lots in 2012 has reduced the pressure on fish populations and the threat to local birds. Fishing lot owners regarded the birds as competitors for the fish, and would shoot them or burn trees containing birds' nests – creating a threat for forest fires in the wetland.

The 2014 issues remain, and the appraisal process raised two additional issues:

- Flooded forest fires have led to reductions in fish catches due to loss of breeding habitats. Fires have also made communities more vulnerable to rainy season storms, as there are fewer trees on which to tie their floating houses. Two factors drive forest fires around the Tonle Sap: accidental fires due to the use of smoke to harvest honey, burning firewood, and leaving cooking fires unattended; and intentional fires started by farmers to convert flooded forest into dry season rice fields, to hunt animals, or to create space for setting long fishing nets (*Sach Daiy*) across fish migration areas.
- Community members also raised the issue of their strong dependency on fish buyers/middlemen who control fish prices.

2.3 Climate projections for the site

This section presents an overview of climate projections up to 2050 for BCRS. The climate change projections presented in Meynell et al. in 2014, were drawn from the 2013 ICEM downscaling of IPPC4 global projections to the region (see ICEM, 2013a). The study utilized a 25-year baseline period of 1980-2005 for all analyses. The assessment focused on a 25-year time period from 2045 to 2069 (referred to as "2050") as a suitably distant and sufficiently clear signal in both the directionality and scale of change in the Mekong hydroclimate system. The study used the IPCC 4 scenario A1b – a moderate emissions scenario representing a world of rapid economic growth, introduction of more efficient technologies, global population peaking by 2050 and a balance between fossil intensive and non-fossil energy sources (scenario A1b is considered a conservative scenario). The study used a statistical downscaling of results from six Global Climate Models (GCM) best suited to the Mekong region and down to a resolution of one square kilometre.

Although there is already evidence that GHG emissions in previous periods have exceeded even the most extreme IPCC scenarios, the projections presented in the original vulnerability assessment report from 2014 are still valid. The models showed some differences in results but were in general agreement regarding trends in temperature and rainfall. The main trends are presented in Table 4.

Table 4: *Main climatic trends up to 2050 (source: Meynell et al., 2014)*

Variable	Climate projections up to 2050
Temperature	- Temperatures in the dry season are expected to increase by up to 3ºC; the baseline maximum temperature in March of 32ºC is likely to increase to 35ºC, with the period of high temperatures extending through into early May. - Temperatures in the wet season are expected to increase by almost 4ºC; the baseline maximum temperature in August is expected to increase from 27.5 ºC to over 31ºC. - A similar, but more moderate pattern is expected for minimum temperatures throughout the year, with the baseline ranging from 19ºC in December-January through to about 24ºC in May to October; with climate change, the minimum temperatures may increase from 21ºC in January to 25ºC through the late dry season and wet season. - Number of hot days (> 35ºC) will increase from 11 days to 51 days per year.
Rainfall	- The total average annual rainfall will increase from 1,249 mm/year to 1,381 mm per year - Rainfall in the wet season will increase from 975 mm to 1,092 mm, an increase of 11.9%

	- Rainfall in the dry season will increase from 274 mm to 290 mm, an increase of 5.9% - The distribution of rainfall in the dry season will be more variable, with small decreases during January and February and a 7.5% decrease in April, counterbalanced by a 13.2% increase in rainfall in May	
Extreme events	- There is likely to be an increase in heavy rainstorms (> 80 mm in a day) from 7 to 11 events per year; storm intensity is also likely to increase, with the greatest rainfall increasing from 170 to 190 mm in a day. - One of the features of the climate in BCRS has been the incidence of sudden strong winds late in the dry season (April/May) which disturbs shallow open water surfaces, causing the release of poor quality water and massive fish kills; such events will increase.	

The projections indicate that there could be a 2-4ºC increase in temperature at different times of the year, which will result in a dramatic increase in number of hot days (> 35ºC). The shift in minimum temperate range is less problematic for habitats and species (due to overlap with baseline temperature variability), than a shift in maximum temperature range (Meynell et al., 2014).

The hydrology is the most fundamental characteristic that defines a wetland and the habitats. Climate change is likely to increase rainfall patterns in both wet and dry seasons, which mirrors an increase in storm frequency and intensity. There is a trend of the earlier start of the monsoon, with the main part of the dry season becoming drier (see Figure 8). The increase in temperature during the late dry season will have implications for the rate of evapotranspiration from open bodies of water and wetlands. Thus, there may be increased drying out and water stress on the wetlands during the later dry season (March/April), making Boeung Tonle Chhmar and surrounding creeks even shallower during the late dry season in 2050 than at present.

As the start of the wet season is more likely to occur in May/June, the first flush of water down the Staung river and Chikreng river is more predictable. Given that there is likely to be less water available for the wetland in the late dry season, the extra rainfall during the early wet season may compensate for the water shortage. Thereafter, the hydrology of BCRS will be influenced more by water levels in the Tonle Sap Great Lake and the backwater flow from the Mekong than the additional rainfall in the locality of the site and its catchment from the Staung river and Chikreng river.

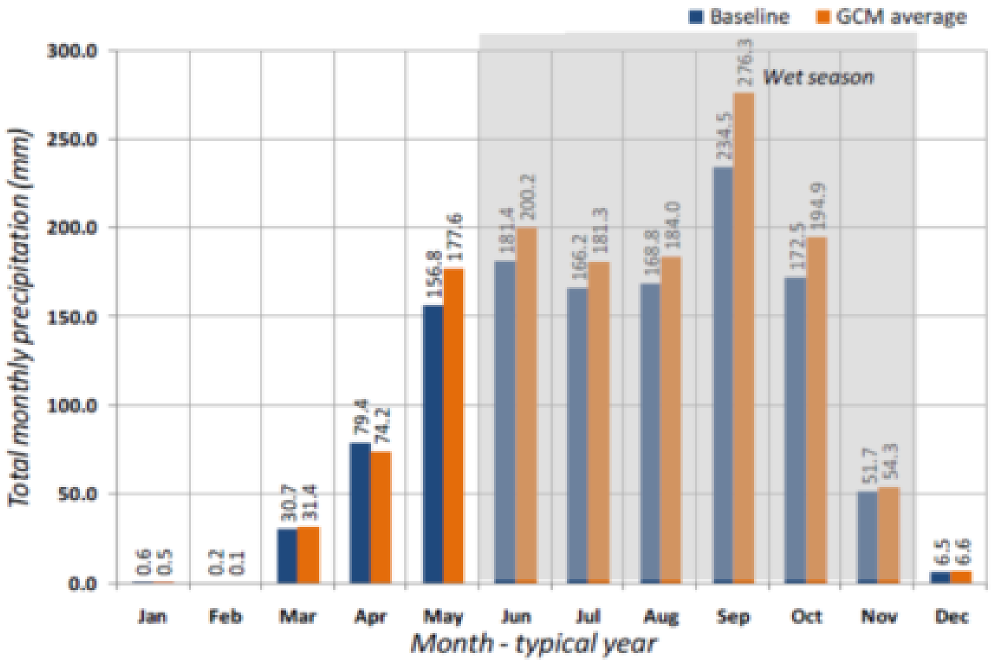


Figure 8: *Average monthly rainfall at BCRS, baseline and future projection (Source: ICEM)*

Arias et al. (2012) have attempted to quantify the changes in flooding and habitats in the Tonle Sap due to hydropower infrastructure and climate change. When the impacts of climate change and development of infrastructure are combined, there are two main impacts upon water levels in the Tonle Sap, which will affect the habitats in BCRS. Hydropower development is likely to increase the water levels in the dry season by up to 80 cm because the infrastructure tends to store water in the wet season and release it in the dry season. In the wet season, the opposite happens. The increased water levels induced by climate change in the wet season are moderated by the storage of water by hydropower plants, thus the overall flooding levels in the wet season will be slightly less than predicted by climate change alone (Sokrith, 2013). When these changes are translated into the extent of flooding in BCRS, there is a marked overall increase in open water and losses of flooded forest, except for a few fringing areas along the shorelines and levees.

3 VULNERABILITY ASSESSMENT

3.1. Habitat Vulnerability

The vulnerability assessment followed the methodology developed by ICEM in earlier studies (see also Section 1, Box 1). Main habitats in BCRS (i.e. open water, gallery forests, shrublands, and seasonally inundated grasslands) were assessed based on their exposure, sensitivity, impact level, and adaptive capacity to climate change.

Open water. BCRS's open water shows high vulnerability to climate change which is likely to affect both the extent of the open water during the flood season and the depth and water quality of the open water in the dry season (Table 5). Due to its shallow depth, especially in the dry season, the water will become much hotter with increased temperatures under climate change. It is particularly vulnerable to the strong winds that occur late in the dry season when the water is overturned, and the bottom poor-quality water layer is mixed into the water column, causing massive fish mortality.

Table 5: *Climate change vulnerability matrix for open water habitats (source: Meynell et al., 2014)*

Threat	Exposure	Sensitivity	Impact Level	Adaptive capacity	Vulnerability
High temperature	VH	VH	VH	L	VH

Increased rainfall in wet season	VH	VH	VH	H	H
More irregular rainfall in dry season	VH	VH	VH	VL	VH
Longer period of dry season	H	H	H	M	H
Decreased P/PET ratio in April[5]	VH	VH	VH	L	VH
Strong winds	VH	VH	VH	VH	VH
Storm events	VH	M	VH	VH	H

Note: Very High (VH); High (H), Medium (M), Low (L), Very Low (VL)

Gallery forests. The gallery forests around BCRS are particularly vulnerable to changes in water levels in the wet season and the depth and duration of the flood (see Table 6). Under climate change it is expected that the wet season flooded area will increase slightly, but this may be moderated by the impacts of infrastructure development which will store water during the wet season. The extent of dry season flooded area under climate change is likely to be reduced, but with infrastructure development, the flooded area extent will increase. This will threaten the survival of much of the flooded forest of BCRS. The gallery forest habitat is less vulnerable to other aspects of climate change, though increased temperature at the time of flowering and fruiting may reduce the fertility of seeds. One of the main species, *Barringtonia acutangula,* is considered to have moderate vulnerability to climate change, principally for this reason, though it can adapt to prolonged inundation.

Table 6: *Climate change vulnerability matrix for gallery forest habitats (source: Meynell et al., 2014)*

Threat	Exposure	Sensitivity	Impact Level	Adaptive capacity	Vulnerability
High temperature	H	M	H	H	M
Increased rainfall in wet season	H	L	M	H	M
Increased wet season water levels	VH	VH	VH	H	VH
More irregular rainfall in dry season	M	L	M	H	L
Longer period of dry season	M	L	M	H	L
Decreased P/PET ratio in April	M	L	M	H	L
Strong winds	H	M	H	H	M
Storm events	H	M	H	H	M

Note: Very High (VH); High (H), Medium (M), Low (L), Very Low (VL)

Shrublands. Shrubland habitats are generally quite resilient to climate changes and able to adapt to changes in water levels, and seasonal drying out.[6] One of the main shrubs in the area*, Sesbania sesban,* has been shown to have low vulnerability to climate change, although the invasion of *Mimosa pigra* into these areas may increase with climate change.

Seasonally inundated grasslands. Grassland habitats appear to be resilient to changes in climate, with the highest temperatures occurring when the grasses and herbs have matured and seeded (Table 7). There may be some changes in the extent of the grassland areas, especially at the deeper flooded grasslands which may tend to evolve into flooded shrublands. Increased risk of fires in the dry season is part of natural grassland cycle and may control conversion to shrubland. There may be changes in the predominant species mix of the grassland, but the habitat will remain.

[5]P/PET is an index of aridity, whereby P refers to average annual precipitation and PET to potential evapotranspiration; PET increases at end of dry season (in the original 2014 report, it said “increased P/PET balance”, but after consultation with J.P. Meynell, the lead author of that report, this was changed to “decreased P/PET ratio”)

[6]No specific table was included for this habitat in the original vulnerability assessment by Meynell et al. in 2014.

Table 7: *Climate change vulnerability matrix for flooded grassland habitats (source: Meynell et al., 2014)*

Threat	Exposure	Sensitivity	Impact Level	Adaptive capacity	Vulnerability
High temperature	M	M	M	H	M
Increased rainfall in wet season	M	L	M	H	M
Increased depth/ duration of inundation	H	H	H	H	M
More irregular rainfall in dry season	L	L	L	H	L
Longer period of dry season	L	L	L	H	L
Decreased P/PET ratio in April	H	L	M	H	M
Strong winds	L	L	L	H	L
Storm events	L	L	L	H	L

Note: Very High (VH); High (H), Medium (M), Low (L), Very Low (VL)

3.2. Species Vulnerability

Fish. Black fish tend to be less vulnerable to climate change because they can survive poor water quality conditions (low dissolved oxygen, low pH, high turbidity and high ammonia). Black fish can withstand harsh dry season environments, including high temperatures and anoxic conditions, and their limited migratory habits make them less vulnerable to wetlands fragmentation. Most white fish species require higher water quality conditions in terms of dissolved oxygen and alkalinity. They are more vulnerable to increased temperatures, especially at maturation and fry stages and more vulnerable to decreases in water availability in the dry season. The response of fish to increased temperatures is likely to be a shift in behaviour and some species may extend their ranges at the expense of others. Because of the higher tolerance of black fish to temperatures compared to white fish, there could be a shift towards greater populations of black fish, although declining populations of small white fish– an important food source for black fish – may affect black fish in the long term.

Eels. These are generally very hardy species, they can tolerate climate extremes of drought and poor water quality and are able to move overland to areas that are more favourable. The USAID Mekong ARCC fisheries study (ICEM, 2013b) carried out a vulnerability assessment of an eel-like fish species, *Mastacembalus armatus*, under climate change. The species is tolerant of high water temperatures and low dissolved oxygen, and the projected increases in temperature are within its tolerance range. The drying out of water bodies during prolonged dry seasons would render *M. armatus*, moderately vulnerable, but the swamp eel can move away to find other bodies of water, and burrow into the mud to survive. It would therefore have low vulnerability. Increased rainfall in the wet season, greater extent of the inundated area and flooding are likely to be beneficial for the species, providing both greater habitat and larger populations of prey.

Rice field shrimp. Rice field shrimp (*Machrobrachium lanchesterii*) appear to be tolerant of adverse water quality conditions and have a relatively prolific and adaptable breeding cycle. Of the various climate change threats, the shrimp populations will be most vulnerable to drought and the drying out of shallow floodplain pools in the dry season. Populations living in the open water bodies will be able to survive drought but may be susceptible to higher temperatures and poor water quality during strong wind events in the late dry season.

Snails. The vulnerability analysis for *Pomacea canaliculata* (golden apple snail) in the Mekong Delta supported the hypothesis that climate change would enhance its invasiveness. However, in comparison to native *Pila scutata,* both appear to be well adapted to cope with a hotter and drier dry season, and both able to take advantage of increased rains and larger wetland areas in the rainy season. The population size of *Pila* may be determined by the habitat requirement for permanent wetland area. The effective invasiveness of *Pomacea* may be due to its higher reproductive capacity and voracious feeding habits, rather than climate change.

Water snakes. Unlike reptiles such as turtles and crocodiles, the gender of water snakes is not dependent on environmental factors such as temperature. The rises in temperature are not expected to be critical but may encourage water snakes to aestivate more in the late dry season, which may make them more vulnerable to collection. The habitat changes induced by climate change are unlikely to affect the breeding of water snakes, although the populations are under severe pressure from hunting, which may increase as dependence upon other livelihood activities are threatened by climate change.

Turtles. The major climate change threat to turtles (e.g., Malaysian snail eating turtle and yellow-headed temple turtle) is increased temperature, especially during the period of nesting and incubation of the eggs which takes place during the dry season, when temperatures are highest. Increased temperatures can affect the sex of the hatchlings and skew the sex ratios of populations, with greater numbers of females being produced at higher temperatures. There is little adaptive capacity available for turtles to adjust to this. Increased temperatures have also been shown to affect the behaviour of turtles, with slower swimming speeds and a tendency of hatchlings incubated at higher temperatures to swim closer to the surface. The lower rainfall and higher evapotranspiration in the dry season are likely to cause a shrinkage of the wetland habitats with smaller wet areas and shallower pools, making the turtles easier to catch; at the same time, they are threatened by forest fires. When the rains come and expand the wet area again, turtles are likely to benefit from the expanded area and higher availability of food sources.

Large water birds. The vulnerabilities of the large water birds, such as the storks, adjutants and Asian open bill will depend on the climatic conditions at the time of breeding and incubation, but this has not been considered because nesting occurs in the bird colonies at Prek Toal, rather than in BCRS. However, these birds are an important part of the ecosystem in BCRS arriving in March and April to feed, taking advantage of the rich food sources at BCRS at the end of the dry season. The low water levels at that time of year make fish, snails and other aquatic animals easier to catch. It is important because the juvenile birds need this source of food to complete their growth to maturity. Thus, the critical time for the ecological relationship between the large water birds and BCRS will be at the end of the dry season. The most important factor is likely to be the impacts of climate change upon food availability at this time. If these food sources decline in the future due to the influence of climate change, then the large water bird populations are likely to decline as well (Milne, 2013).

3.3. Community and livelihoods

Extreme weather events, which are likely to increase under climate change, impact local livelihoods. Recent discussions with village members from the five villages from Peam Bang Commune showed that extreme weather events over the last 10 years have had a measureable impact (Table 8).

Table 8: *Extreme weather events over the last 10 years (2007-2016) and impact*

Extreme Weather event	Year	Impact (on villages and wetland habitats and resources)
High water levels	2011, 2013	Due to increased rainfall. No huge impact since flooded forests are able to withstand and protect people's floating houses
Drought	2010 to 2013, 2015, 2016	Key river systems/cannels dried out (boats could not navigate); local people faced lack of food, because they could not use their boats to go to the market in the central village.
Flooded forest fires (accelerated by droughts/temperature)	2007, 2015, 2016	Droughts and high temperatures accelerated forest fires. In 2015, about 100 ha of flooded forest areas were destroyed. Several wildlife species (monkeys, turtles, snakes) were killed. The destruction of flooded forests has left people without resources to protect their floating houses from rainy season storms.

Storms	2013, 2014, 2015	Mass fish kill in 2013 (25 ton), 2014 (89 ton), and 2015 (176 ton); also, two critically endangered Mekong giant barb fish were killed in 2013.

Droughts in combination with forest fires and storms have had a devastating impact on habitats and species. Although high water levels (floods) have not had much of an impact yet, this may change when habitats of flooded forest decline. To get a better understanding of the impact of climate change on livelihood activities, community members were asked to make a seasonal calendar as part of the recent appraisal process (see Table 9).

Table 9: *Seasonal calendar of livelihoods activities and key climatic threats in Peam Bang Commune*

	Months											
Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fishing	2	2	2	3	3	2	1	1	1	1	2	2
Raised fish	0	0	0	0	0	1	2	2	3	0	0	0
Fish processing	1	2	2	3	3							
Business	2	2	2	3	3	1	1	1	1	2	2	2
Boat fixing	0	0	0	3	3	0	0	0	0	0	0	0
Crop planting		0	0	0	3	3						
Climate threats	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High temperature			2	3	3	3	1					
Cold	3	3									2	2
Irregular rainfall				3	3							
Flood							3	3	2	2		
Storm				1	2	3	3	3	3	2	2	1

Note: 0 = No impact, 1 = Less, 2 = Medium, 3 = Strong

The seasonal calendar shows the main climate threats over a 12-month period, i.e.: high temperatures at the end of the dry season, followed by irregular rainfall in April-May, and floods and storms in the wet season; surprisingly, cold periods – from November to February – were also mentioned, and are mainly problematic for poor vulnerable families, affecting people's health. Main livelihood activities are exposed throughout the year, although fishing, fish processing, business and boat fixing are mainly affected during the dry season (with a peak in April-May) as result of high temperatures and irregular rainfall and storms; this is also the time in BCRS when there is strong competition for fish from outsiders (April-June). Fish raising, instead, is mainly affected in the late wet season, when floods and storms are more common. During the same period, although not necessarily climate related, water hyacinth has been reported to block navigation canals, which is especially a problem during emergency health problems. A few families practice small-scale crop planting at some islands nearby their village, which is sensitive to unpredictable weather during the transition from dry to wet season; these practices are however still very limited, and therefore not yet considered a high priority issue.

The vulnerabilities of main livelihood activities are discussed in more detail below (see also Annex 3):

Fishing: Fishing is the principal livelihood activity for all of the communities living in and around BCRS. The fish catch is used in various ways. A portion is kept as a food source for the fishers families, some is sold either fresh or processed, and some is used as food for fish raising. Processing may include drying, smoking, and fermenting into shrimp paste. The communities have few other income-generating activities, no rice fields, and limited livestock, therefore they are highly dependent upon the fish stocks. Any changes in fish populations and species distributions due of climate change are likely to have a substantial impact upon the livelihoods of these communities.

Black fish, which make up the bulk of the fish stock, are resident throughout the year. They are less vulnerable than the white fish, which come into BCRS to breed in the wet season when water levels are high, and then move out again to dry season refuges. The critical time for black fish species is at the end of the dry season when water levels are low and there is a risk of strong winds churning up the poor quality bottom layers of the open water and mixing it into the water column. Despite their relative resilience to poor quality water, these events result in massive black fish kills. In the short-term these fish kills represent a bonanza for the fishermen, especially now that the commercial fishing lots have been abolished. In the longer term, if climate change results in low water levels and increased frequency of strong winds in April/May, such fish kills may have a significant impact, reducing the overall population size of black fish in BCRS. This would have serious implications for the livelihoods of the fishing families.[7]

The white fish populations mainly visit BCRS during the wet season, therefore the water quality in late dry season has a limited impact on their populations. Increases in water levels and the extent of the flooded area may increase the breeding and growth possibilities for white fish. However, climatic factors elsewhere in the dry season refuges may reduce the population size available to enter BCRS. White fish tend to be more sensitive to poor quality water and increases in temperature than black fish. Habitat changes resulting from climate change (reducing areas of gallery forest and grassland, while increasing areas of shrubland with *Mimosa pigra* invasion) may alter the availability of breeding habitats for some species. Reduced populations of white fish in the wet season will also have a negative impact on people's livelihoods in BCRS.

Fish raising: Some of the fish caught are used as food for fish raising activities. Typically, snakehead and catfish are raised in cages underneath the floating houses. Unlike the natural populations of such fish, which are relatively resilient to climate changes, fish stocked in cages are likely to be more vulnerable. Stocking fish in high density cages increases stress levels and makes them more vulnerable to increases in water temperature and lowered water quality. Increases in temperature also increases the possibility of disease outbreak, which can quickly kill entire fish stocks. Fish raising is also at risk from storms and floods, which may lead to large losses during the wet season.

Fish processing, boat and equipment maintenance and small businesses: There are several livelihood activities that support fishing and fish raising, including fish processing, boat and equipment maintenance and small businesses selling fishing nets, equipment and other household goods. All of these are highly dependent upon the success of the fisheries sector. If the fish stocks decline because of climate change, the fisheries supporting activities will be affected and vulnerable.

Climate change is also expected to have large impacts on the biodiversity of other aquatic plants and animals, such as *Sesbania*, rice field shrimp, snails, water snakes, and turtles (see Box 2).

Box 2: Aquatic plants and animals affected by the impact of climate change
• ***Sesbania:*** Flowers are collected for food, and the stems are used as floats for fishing gear and house floatation. The assessment for *Sesbania* shown above indicates that it has a low vulnerability to climate change, therefore it is likely to remain available in the future • **Rice field shrimp**: These are collected and provide a valuable source of income. The vulnerability assessment indicates the critical time may be at the end of the dry season when the floodplain pools dry out, although the rapid breeding and growth of the species in the wet season may counter any losses. This source is unlikely to be seriously impacted by climate change. • **Snails:** It is expected that there will be a population shift towards greater populations of invasive golden apple snails at the expense of the native apple snails, but this is not directly attributable to climate change. Golden apple snails are collected and eaten, but the native species are preferred. This may increase the spread of

[7]Another recent threat is that of large-scale illegal fishing. During early raining season (June/July) black fish species move to the Tonle Sap Great Lake (with better water quality) but when they return to the flooded forest areas of BCRS for spawning in August, they get caught by long fishing nets (*Robang Sach Dai*) which are blocking the main canals.

the alien species and make the native species become more rare. Both species are considered to be equally resilient to climate change.

- **Water snakes:** The water snake populations are already declining due to unsustainable harvesting. Climate change may increase the physiological and reproductive stress on the water snakes and the combination may destroy the sustainability of the water snake harvest as a livelihood source.
- **Turtles:** Turtles are highly prized, and their populations are already under pressure from over collection. It is expected that climate change, especially increased temperatures during the dry season, when the eggs are laid, may cause gender shifts in the population. Such impacts are likely to have serious implications for the availability of turtles as a livelihood source.

Another precious wetland resource which will be affected is freshwater. Whilst the communities in BCRS are surrounded by water, the supply of drinking water is a concern. Waste from toilets, fish processing, caged fish food and fish excrement are disposed of directly into the water. Traditionally, local people used water directly from the lake for their daily water consumption. Now some households drink boiled water as they are concerned about their family health. In addition, it has been reported that the water used for bathing and washing can give rise to skin diseases, especially early in the wet season. Under climate change projections, the availability of high quality drinking water will continue to be an issue. It is also likely that there will be an increase of water quality issues in the late dry season and early wet season due to higher water temperatures and lower water levels.

Though not yet developed, future opportunities for ecotourism in BCRS will be affected by climate change. The main attractions of the site are the large water birds visiting the wetlands to feed from March to May. If climate change affects the food sources for the large water birds, then the birds may not frequent the site to the same extent but will look elsewhere for their food. The attractiveness of the site to bird watchers will decrease with fewer large water birds and there will be a loss of potential to develop ecotourism.

Despite the impact of climate change, local communities in BCRS have been implementing measures to help themselves. For example, local people have dredged conservation areas for fish in BCRS to maintain permanent water year-round to cope with long droughts. In addition, they started replanting flooded forests at degraded sites as a solution to address the impact of forest fires. They are supported by the management of BCRS, which has prioritized awareness raising on climate change adaption among local communities. The E-NSA project established and strengthened fishing communities (CFi/CPA) in BCRS, aiding them in effectively managing their wetland resources, particularly fisheries. Building on this successful experience, climate risk reduction plans could be integrated in the area, and sustainable financing mechanisms could be explored. Local people realize that actions will only be effective when other, non-climatic, factors (e.g. illegal fishing, forest fires etc.) are also addressed.

4 CONCLUSIONS

4.1. Summary of vulnerabilities

The vulnerability assessment has shown that the habitats and associated species in BCRS demonstrate a very varied response to the projected changes in climate. Some habitats are relatively resilient and may even expand their areas at the expense of less resilient habitats, for example, the shrublands expanding into the grasslands and potentially gallery forests. Some species are particularly resilient especially the shrubs such as *Sesbania* and the invasive *Mimosa pigra.* It is expected that the latter will be one of the winners as climate change progresses.

The black fish species are generally quite resilient to climate change but are expected to become more vulnerable to the poor-quality water releases caused by strong winds over the open water (while at also facing pressure from large scale illegal fishing). The open water habitats are particularly vulnerable at the end of the dry season. The impact of climate change is likely to be exacerbated by continued abstraction of water for dry season rice farming in the upper catchment of the Stung Staung, effectively stopping the flow of water into BCRS in the dry season.

White fish species are less resilient to higher temperatures and poor-quality water but only enter BCRS during the wet season, when there is ample good quality water. However, climate change stresses on the dry season refuges for white fish may be significant, and these may cause declines in white fish populations.

Fishing is the main livelihood activity for the communities living in BCRS resulting in an increased impact on the vulnerability of fish populations. Other species such as water snakes and turtles, which provide a lucrative bonus when they are collected, have been shown to be highly vulnerable, especially because these species are already under severe hunting pressure. Climate change impacts may result in the collection of these species becoming unsustainable as a livelihood.

Climate change may also threaten the main ecotourism draw of BCRS; the arrival of large water birds in March and April. The birds come to feed on fish, snails and other aquatic resources, and if these decline or access becomes difficult for the birds, the birds may go elsewhere, leaving BCRS with fewer potential ecotourism opportunities.

4.2. Adaptation planning

Some of the key features to manage and protect BCRS include:

- Ensuring adequate dry season flows of the Stung Staung and Stung Chikreng, to maintain a positive inflow into the site, and especially into the open waters (and reduce the risks of strong winds churning up poor quality water and inducing massive fish kills).
- Reducing the pressure on the gallery forests, through management of tree cutting, and possibly replanting efforts in the back side of the gallery forest areas bordering the Tonle Sap
- Reducing harvesting pressure on vulnerable groups such as the turtles and water snakes
- Managing the spread of alien species such as *Mimosa pigra* and golden apple snail; for the latter, promoting predator species such as open bill storks could be investigated further.
- Provisioning of good quality drinking water for the communities, so that they are not directly reliant upon water from the creeks and open water bodies.
- Strengthening local capacity and community-based approaches based on previous experiences, e.g. on fishery management; sustainable financing mechanisms should be considered to fund these approaches (e.g. mini-trust fund, ecotourism, wetlands product markets, women saving groups).

To address and implement these issues, it is critical to update the current management plan, preferably supported by a co-management approach with relevant stakeholders.

ANNEX I: SEASONAL CALENDAR OF PHYSICAL AND ECOLOGICAL PROCESS IN THE TONLE SAP

Season	Month(s)	Key Physical, Land- and Human-use Processes	Ecological Processes/Events by Habitat Type			
			Open Lake	Swamp forests	Short-tree shrublands	Grasslands/agro-ecosystems
Early monsoon	May-July	Reversal of Tonle Sap River flow into Tonle Sap Lake - floodpulse begins	In-migration of "white fish" from Mekong via Tonle Sap River	Tree and shrub flowering and fruit production	Tree and shrub flowering and fruit production	Out-migration of terrestrial breeding species (grassland birds and larger mammals) as flood rises
		Deepwater rice crops germinating in outer floodplain		In-migration of "white fish" for feeding, nesting and spawning	In-migration of "white fish" for feeding, nesting and spawning	In-migration of post-breeding large waterbird congregations (storks, ibises, herons and egrets, pelicans)
		Watersnake harvest begins		Lateral migrations of "black fish" to nesting and spawning habitats	Lateral migrations of "black fish" to nesting and spawning habitats	In-migration of wet-season breeding waterbirds (e.g. rails, crakes, bitterns)
				Departure of large waterbird breeding colonies (storks, pelicans, ibises, herons and egrets)		In-migrations of some black and white fish species for nesting, spawning and juvenile growth.
Mid-monsoon	August-October	Expansion of Tonle Sap Lake to max. inundation through reverse flow mechanism and catchment rainfall		Tree and shrub flowering and fruit production	Tree and shrub flowering and fruit production	
		Largest sediment inputs		Deciduous tree leaf fall (underwater)	Deciduous tree leaf fall (underwater)	
		Fishing (outside lot system) in outer floodplain agro-ecosystems		Fish nesting, spawning, feeding and juvenile growth period	Fish nesting, spawning, feeding and juvenile growth period	Fish nesting, spawning, feeding and juvenile growth period
		Deepwater rice crop main growth phase		Cormorants and Darters return to nest colonies and commence breeding		Main phase of deepwater rice growth in the outer floodplain agro-ecosystems
		Watersnake harvest peaks		Watersnake breeding period	Watersnake breeding period	Fish perform function of natural pest regulators in traditional rice agricultural systems
Late monsoon	October-November	Flood water begins to recede as Mekong River level drops and Tonle Sap River reverses flow again and begins draining the lake	Out-migration of "white fish" to Mekong River via Tonle Sap River and floodplains	Leaf flush in all deciduous and evergreen tree species	Leaf flush in all deciduous and evergreen tree species	Continued growth of "floating grasses"
		Large-scale commercial fishing begins in all fishing lots and main waterways draining Tonle Sap lake		Watersnake breeding period	Watersnake breeding period	
		Deepwater rice ripening phase				
Early dry	November-January	Large-scale commercial fishing continues in all fishing lots and main waterways draining Tonle Sap lake	Out-migration of "white fish" to Mekong River via Tonle Sap River and floodplains continues	Cormorants and Darters complete breeding and fledge		In-migration of terrestrial breeding species begins (grassland birds including Bengal Florican) as land reexposed on flood recession
		Flood waters recede increasingly rapidly	Large feeding aggregations of terns and gulls	Large waterbirds (storks, ibises, pelicans, herons and egrets) return to nesting colonies		Large in-migration of Palearctic "winter visitor" bird populations (raptors, chats, hirundines, warblers, pipits, wagtails)
		Second watersnake harvest peak				
		Deepwater rice harvest				
Mid-late dry	January-May	Large-scale commercial fishing begins in all fishing lots and main waterways draining Tonle Sap lake	?Concentration of black fish as surrounding floodplain dries out	Main breeding period for large waterbrids (storks, ibises, pelicans, herons and egrets)		Main breeding period for terrestrial grassland birds (e.g.Bengal Florican, quails and buttonquails)
		Increasingly drought like conditions develop in outer floodplain	Large feeding aggregations of terns and gulls	High concentrations of fish behind fish traps in fishing lots	Black fish concentrated in remaining waterbodies and performing "overland" migrations	Black fish concentrated in remaining waterbodies and performing "overland" migrations
		Extensive burning of grassland and shrubland		Estimated main breeding period for turtles and pythons	Estimated main breeding period for turtles and pythons	Local movements of Palearctic birds in response to availability of key food resources
		Livestock grazing (January-early April)				Domestic livestock may partly fulfil grazing function of extirpated herbivore populations
		Preparation of land for deepwater rice cultivation				

(Source: Davidson 2006)

ANNEX II: CLIMATE CHANGES AND IMPACTS ON KEY PHYSICAL AND ECOLOGICAL PROCESSES IN THE TONLE SAP

Season	Month(s)	Climate change influence		Key Physical, Land- and Human-use Processes	Ecological Processes/Events by Habitat Type			
		Temperature	Rainfall/hydrology		Open Lake	Swamp forests	Short-tree shrublands	Grasslands/agro-ecosystems
Early monsoon	May-July	Mean maximum temperatures follow general pattern decreasing from peak at beginning of May to low in July. Increase in mean daily maximum is of the order 3 - 4 deg C	In May, water levels in B.Chhmar likely to be lower than currently due to hotter dry season	Reversal of Tonle Sap River flow into Tonle Sap Lake - floodpulse begins ***Under CC this is unlikely to be felt immediately in B. Chhmar until later in the year***	In-migration of "white fish" from Mekong via Tonle Sap River ***Will not really affect B. Chhmar***	Tree and shrub flowering and fruit production ***Higher temperatures may speed up process of flowering and fruit production. Very dry conditions in early May could affect flowering, causing flowers to shrivel and dry up before fertilisation***		Out-migration of terrestrial breeding species (grassland birds and larger mammals) as flood rises ***Possible earlier departure as flood water rise earlier in the season***
		Current pattern is 31/32 C in May to 27 C in July,	Monsoon rainfall more likely to start in May in c. 30% of years	Deepwater rice crops germinating in outer floodplain ***Increased temperatures may affect germination of deep water rice***		In-migration of "white fish" for feeding, nesting and spawning ***In migration of white fish would wait until waters start to rise in swamp forests, likely to beearlier rather than later in season***		In-migration of post-breeding large waterbird congregations (storks, ibises, herons and egrets, pelicans) ***Possible earlier arrivals of large water birds to B.Chhmar to take advantage of earlier floods***
		With climate change this mean daily maiximum is increased from 35 C in May declining to 31 C in July	Nearly 11% more rainfall expected in May to July in typical years	Watersnake harvest begins ***Early rains and rising water levels in B.Chhmar may alter the emergence of water snakes from burrows***		Lateral migrations of "black fish" to nesting and spawning habitats ***Spawning habitats likely to be inundated in back swamps earlier in the season***		In-migration of wet-season breeding waterbirds (e.g. rails, crakes, bitterns) ***Possible earlier in-migration to take advange of earlier inundation of grasslands and increase in food supply***
		Partially outside comfort zone in May and as wet season progresses, temperature generally outside comfort zone	Water levels in B. Chhmar likely to increase faster in early wet season due to rainfalling in catchment of S. Staung and S. Chikreng			Departure of large waterbird breeding colonies (storks, pelicans, ibises, herons and egrets) ***Possible earlier arrivals of large water birds to B.Chhmar to take advantage of earlier floods***		In-migrations of some black and white fish species for nesting, spawning and juvenile growth. ***Spawning habitats likely to be inundated in back swamps earlier in the season***

Season	Month(s)	Climate change influence		Key Physical, Land- and Human-use Processes	Ecological Processes/Events by Habitat Type			
		Temperature	Rainfall/hydrology		Open Lake	Swamp forests	Short-tree shrublands	Grasslands/agro-ecosystems
Midmonsoon	August-October	Mean monthly temperature is fairly constant, baseline 26 - 27 C likely to increase to 28 - 29 C (+2deg C)	Rainfall in three months increases from 598 mm to 655.2 mm (+9.5%)	Expansion of Tonle Sap Lake to max. inundation through reverse flow mechanism and catchment rainfall - ***wet season flood extent expected to be higher and longer***		Tree and shrub flowering and fruit production - ***Higher temperatures may speed up process of flowering and fruit production. May lead to lowered fertility of seeds***		
		Mean max temperatures increase from 28-29 C to 31-32C (+3 deg C)	Increased input from St. Staung and St. Chikreng	Largest sediment inputs - ***sediments come mainly from Mekong, will not affect B. Chhmar***		Deciduous tree leaf fall (underwater) - ***unaffected***		
		Wet season comfort zone exceeded by 3 deg C	Increased back flows from Mekong flows into Tonle Sap	Fishing (outside lot system) in outer floodplain agro-ecosystems - ***floodplain likely to be inundated for longer and higher and fishing may be improved***		Fish nesting, spawning, feeding and juvenile growth period - ***higher flood levels will tend to make more breeding sites and food availability. Increased air temperatures unlikely to be reflected in water temperatures because of higher water levels***		Fish nesting, spawning, feeding and juvenile growth period - ***higher flood levels will tend to make more breeding sites and food availability. Increased air temperatures unlikely to be reflected in water temperatures because of higher water levels***
			Water levels in B. Chhmar expected to be higher	Deepwater rice crop main growth phase - ***Increased temperature and availability of water likely to enhance growth***		Cormorants and Darters return to nest colonies and commence breeding - ***higher air temperatures may affect the breeding of these birds in B. Chhmar, earlier hatching***		Main phase of deepwater rice growth in the outer floodplain agro-ecosystems - ***Increased temperature and availability of water likely to enhance growth***
			Possibility of increased intensity storms	Watersnake harvest peaks - ***higher water levels may tend to disperse water snakes more***		Watersnake breeding period - ***Increased water temperatures moderated by high water levels, so increase in temperature may have less effects on water snakes breeding***	Watersnake breeding period - ***Increased water temperatures moderated by high water levels, so increase in temperature may have less effects on water snakes breeding***	Fish perform function of natural pest regulators in traditional rice agricultural systems - ***unaffected***

Season	Month(s)	Climate change influence		Key Physical, Land- and Human-use Processes	Ecological Processes/Events by Habitat Type			
		Temperature	Rainfall/hydrology		Open Lake	Swamp forests	Short-tree shrublands	Grasslands/agro-ecosystems
Late monsoon	October-November	Mean monthly temp falling from 26.5 in early Oct to 25 C in late Nov. This will change from 28 C in early Oct to 27 C in late Nov (+1.5 - 2 Deg	Rainfall shows an overall increase of + 25 mm or 11.2% in these two months with most of increase in October	Flood water begins to recede as Mekong River level drops and Tonle Sap River reverses flow again and begins draining the lake - ***increased rainfall in October could delay recession in B. Chhmar***	Out-migration of "white fish" to Mekong River via Tonle Sap River and floodplains - ***unaffected***	Leaf flush in all deciduous and evergreen tree species - ***Unaffected***		Continued growth of "floating grasses" - ***Unaffected***
		Mean max temperatures fall from 28 to 27 C Oct to Nov. with CC this likely to increase to 32 to 30 C Oct to Nov. Daily peaks could increase from 34 C to	Possibility of increased intensity storms	Large-scale commercial fishing begins in all fishing lots and main waterways draining Tonle Sap lake - ***Unaffected***		Watersnake breeding period - ***increases in temperature could affect water snake breeding and hatching of eggs***		
		Mean minimum temps fall from 23 C in Oct to 20 C in late Nov. With CC this will change to 25 C to 22 C		Deepwater rice ripening phase - ***increased rainfall and delayed recession could delay ripening***				
Early dry	November-January	Mean monthly temperature falls from 25 to 24 C and rises again in Jan. This is likely to increase from 27.5 falling to 26	Rainfall shows slight increase in three months - only 4% increase	Large-scale commercial fishing continues in all fishing lots and main waterways draining Tonle Sap lake - ***Unaffected***	Out-migration of "white fish" to Mekong River via Tonle Sap River and floodplains continues - ***unaffected***	Cormorants and Darters complete breeding and fledge - ***unaffected***		In-migration of terrestrial breeding species begins (grassland birds including Bengal Florican) as land reexposed on flood recession - ***Unaffected***
		Mean max temps go from 28 - 30 C to 30 - 32 C (+2 deg C) Daily peak temperatures, very hot days range from 32 - 35 C increasing to	All of the increase comes in November (51.7 to 54.3 mm) Dec shows slight decrease (6.5 to 6.4 mm) and January 0.6 to 0.5 mm	Flood waters recede increasingly rapidly - ***flood recession rate likely to increase***	Large feeding aggregations of terns and gulls - ***unaffected***	Large waterbirds (storks, ibises, pelicans, herons and egrets) return to nesting colonies - ***unaffected***		Large in-migration of Palearctic "winter visitor" bird populations (raptors, chats, hirundines, warblers, pipits, wagtails) - ***Unaffected***
		Mean min temps range around 19 -21 C baseline increasing to 20 - 23 C	November baseline showed 6% of years when they received more than 200 mm of	Second watersnake harvest peak - ***unaffected***				
		Comfort zone for temperature not exceeded during these three months		Deepwater rice harvest - ***early harvest of deep water rice possible as recession rate increases***				

Season	Month(s)	Climate change influence		Key Physical, Land- and Human-use Processes	Ecological Processes/Events by Habitat Type			
		Temperature	Rainfall/hydrology		Open Lake	Swamp forests	Short-tree shrublands	Grasslands/agro-ecosystems
Mid-late dry	January-May	Mean temp rises from 26 - 28C during period. This will increase by 2 deg C to 28 - 30 C.	Rainfall in Feb to April will **decrease** by - 4.6 mm of -4.2% from 110.3 to 105.7 mm	Large-scale commercial fishing begins in all fishing lots and main waterways draining Tonle Sap lake - ***Rapidly falling water levels in B. Chhmar may affect fishing***	Concentration of black fish as surrounding floodplain dries out - ***black fish likely to congregate in B. Tonle Chhmar***	Main breeding period for large waterbrids (storks, ibises, pelicans, herons and egrets) - ***Less relevant for B. Chhmar (more for Prek Toal), but increases in temperature could affect breeding and fertility of eggs***		Main breeding period for terrestrial grassland birds (e.g.Bengal Florican, quails and buttonquails)
		Mean max temp rises from 30 to 32 C and will increase by 3 deg C to 33 - 35 C.	Rainfall in Feb to May will **increase** by +16.2 mm of +6% from 267.1 to 283.3 mm	Increasingly drought like conditions develop in outer floodplain - ***This is likely to be intensified***	Large feeding aggregations of terns and gulls - ***Shallow water in B. Tonle Chhmar likely to make fishing for gulls etc easier and so may see greater concentrations of gulls and terns***	High concentrations of fish behind fish traps in fishing lots - ***no longer relevant since fishing lots abolished, but lower water levels will mean higher concentrations of fish***	Black fish concentrated in remaining waterbodies and performing "overland" migrations	Black fish concentrated in remaining waterbodies and performing "overland" migrations - ***High water temperatures in exposed small bodies of water, may be over comfort zone even of black fish***
		Peak daily temps in March April range about 37 - 39 C will increase to 40 to 43 C	Decreased rainfall from Jan to April coupled with increased temperatures will increase rate of fall of water levels in B.Chhmar	Extensive burning of grassland and shrubland - ***With increased drought conditions, risk of fire outbreak will increase***		Estimated main breeding period for turtles and pythons - ***Higher temperatures may mean reduced fertility of eggs, especially if nesting sites are exposed. May also change sex ratio in populations of turtles***	Estimated main breeding period for turtles and pythons - ***Higher temperatures may mean reduced fertility of eggs, especially if nesting sites are exposed. May also change sex ratio in populations of turtles***	Local movements of Palearctic birds in response to availability of key food resources - ***patterns of movement may be affected if drought conditions persist***
		Max temp comfort zone will increase from 28 - 33 C to 31 to 35 C, so with CC will be partially outside comfort zone	Also note windstorms in April May when water levels in B. Chhmar are lowest	Livestock grazing (January-early April) - ***Potentially shortage of fodder if drought conditions persist and intensify***				Domestic livestock may partly fulfil grazing function of extirpated herbivore populations - ***generally unaffected but potentially shortage of fodder if drought conditions persist and intensify. Livestock may need to go further into wetland for grazing and browsing, which may damage vegetation.***
		Minimum temps range 22 - 24 C which will increase to 23 - 25 C		Preparation of land for deepwater rice cultivation - ***may be affected if drought conditions persist, but may be alleviated by increased rainfall in May***				

ANNEX III: SUMMARY OF CLIMATE CHANGE VULNERABILITIES IN DRY AND WET SEASON (DS/WS) IN BCRS

Ecosystem component	Climate change threat	Vulnerability DS	Vulnerability WS	Impact	Implications for livelihoods
Habitat					
Open water	• Increased temperature, • Decreased rainfall in dry season and longer dry season • Strong winds at end of dry season	VH	H	At end of longer and drier dry seasons, there will be less water available and the open water will become even shallower. Strong winds at end of dry season likely to become more frequent and cause overturn of open waters and release of poor quality water. This will be made worse if water abstraction in the Stung Staung for dry season irrigation minimizes the flow to the open water	Release of poor quality water at end of dry season likely to cause large fish kills. If this occurs more frequently, this will have a longer term negative impact upon fish populations, and changes in fish species distribution. Communities will harvest the fish killed, and this will be a short-term bonus for the fishers
Gallery forest	• Increased wet season water levels	M	VH	Increased water levels in Tonle Sap tend to put pressure on gallery forests and reduce their area at the water front side. They may be able to expand into flooded shrubland, but not certain. Effects may be compounded by changes in flows in Mekong due to infrastructure development	Gallery forests are important areas for spawning of fish, and for protection of the edges of the Boeung Chhmar against wind. If flooded forest area is reduced, there may be implications for fish populations.
Seasonally flooded grasslands	• Increased temperatures • Increased wet season rainfall • Increased depth and duration of inundation • Decreased P/PET ratio in April • Increased risk of fire	M	M	Grassland habitats are quite resilient. Highest temperatures occur when grasses have seeded. Fires are part of natural cycle for grasslands. May be some redistribution of grassland species Deeper areas may be invaded by shrubs especially *Mimosa pigra*	Little implication for livelihoods
Flooded shrublands	• Low threats	L	L	Least vulnerable of flooded habitats. May be an expansion of shrubland into gallery forests and into grasslands	Little implications for livelihoods
Plants					
Barringtonia acutangula	• Increased wet season water levels • Increased temperatures	L	M	Well adapted to areas that have prolonged inundation and resilient to increased flooding. Increased temperatures during flowering and fruiting may affect fertility of trees.	Little implications for livelihoods
Sesbania sesban	• Low climate threats	L	L	Sesbania is very resilient, because has wide tolerance ranges for heat, inundation and drought	Flowers are collected as vegetable for domestic consumption. Climate change unlikely to affect this
Mimosa pigra	• Low climate threats	L	L	Mimosa is also very resilient. There may be some increased invasion into grasslands and degraded flooded forest areas.	No effective way of using or controlling mimosa has been found. The bushes are difficult to penetrate and have sharp spines that catch fishing gear.

Ecosystem component	Climate change threat	Vulnerabilit y		Impact	Implications for livelihoods
		DS	WS		
					Increased spread of mimosa likely to hinder fishing activities
Animals					
Black fish	• Decreased water availability in dry season, lower water levels • Strong winds churn up open water, decreasing water quality	M	L	There may be large fish kills in the open water due to poor quality water release in late dry season. Black fish more resilient than white fish	Large fish kills may be a bonus for fishers in the short term. More frequent fish kills every year could reduce populations of resident fish
White fish	• Decreased water availability in dry season, lower water levels • Strong winds churn up open water, decreasing water quality • Increased water levels in wet season • Increased temperatures	H	M	White fish less likely to be resident in the dry season, but would be more vulnerable to poor quality water release Wet season water levels increasing would be likely to be favourable for white fish spawning, though temperature increases might become a problem Uncertain about CC impacts on white fish in other parts of river basin in dry season refuges	There may be an increase in white fish coming into the Boeung Chhmar with higher water levels, with larger populations. This would be beneficial for fishers. Any remaining white fish at end of dry season likely to be killed off if poor water quality is released by strong winds
Eels	• Decreased water availability in dry season, lower water levels • Strong winds churn up open water, decreasing water quality	M	L	Eels are very resilient and can move overland to more favourable conditions, and can hibernate in muds till the beginning of wet season	Eel populations will probably remain similar and so there should be no livelihood implications for fishers catching this species
Rice field shrimp	• Irregular rainfall in dry season • Longer period of dry season • Increased temperature • Strong winds	H	L	Rice field shrimps tolerant of adverse water quality, with relatively prolific and adaptable breeding cycle. Drying out of pools in floodplain will be a problem; populations living in open water may be susceptible to strong wind events	Fishers catching rice field shrimps should not be affected, though catches may decrease in early wet season, when the floodplain pools fill up with water again, with fewer stock to replenish the populations
Water snakes	• Increase in temperature during dry season • Increase in temperature during breeding season (wet season)	H	H	Water snakes breeding season is in late wet season. Temperature increases may cause physiological stress. In dry season, water snakes may aestivate more because of higher temperatures and drought	Peak water snake harvest coincides with breeding season. Climate change may add further stress to an already declining population. Unsustainable harvesting of water snakes with climate change is likely to lead to further collapse of populations and this source of livelihoods
Turtles	• Increase in temperature at end of dry season • Irregular rainfall in dry season	VH	L	Increases in temperature may affect the fertility and sex ratio of eggs and hatchlings, leading to increased pressure upon populations already stressed from over-exploitation	Falling populations of turtles, increased time required for hunting and collection. Likely elimination of turtle populations in the long term.
Apple Snails	• Increased temperature, especially in the dry season	M	L	Snails able to avoid hotter and drier conditions through aestivation. Wet season temperatures less of a problem. Rapid growth and breeding leads to	Competition between native and golden apple snail likely to favour the alien species, but probably not related to climate change. Increase in golden apple

Ecosystem component	Climate change threat	Vulnerability		Impact	Implications for livelihoods
		DS	WS		
				population expansion and densities especially for Golden Apple snail.	snail numbers likely to be a problem for rice farmers around Boeung Chhmar, but not in the Ramsar site.
Large water birds	Increased temperatures during the breeding season (at Prek Toal)	M	L	Effects of climate change upon food species for large water birds will be critical, especially in March-May. Increase in golden apple snails will favour Open Bill storks.	If large water bird populations decline and no longer visit Boeung Chhmar, the opportunities for developing ecotourism at the site will diminish.

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