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

Protected Areas

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USAID MEKONG ARCC CLIMATE CHANGE IMPACT AND ADAPTATION STUDY FOR THE LOWER MEKONG BASIN

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

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

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

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

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ABBREVIATIONS

CAM	Climate Change Adaptation and Mitigation
CC	Climate Change
ICEM	International Centre for Environmental Management
IUCN	International Union for Conservation of Nature
LMB	Lower Mekong Basin
NBCA	National Biodiversity Conservation Area
NTFPs	Non-Timber Forest Products
PAs	Protected Areas
WHC	World Heritage Convention

CONTENTS

INTRODUCTION

Few regions demonstrate in such dramatic terms the fundamental links between human and ecosystem welfare as the Lower Mekong Basin (LMB). Around 80 per cent of the population of the LMB is directly dependent on the productive capacity of healthy natural systems. Communities living in and around forested areas in the LMB are generally subject to chronic poverty and low standards of living (ICEM 2003; Sunderlin 2006), intensifying their reliance on natural systems for human welfare.

There is an intimate relationship between healthy natural systems and local, national, and regional economies of the LMB, particularly for the energy, agriculture, and fisheries sectors. The economic, environmental, and social case for effective management of protected areas to safeguard the ecosystem goods and services of the LMB is strong. Well-managed protected areas are an essential development strategy for LMB countries (ICEM 2003). Yet, the region is undergoing a fundamental transformation due to the development of infrastructure, power schemes and agricultural industries, along with population growth (Pech & Sunada 2008). Natural forests, wetlands, and species are under increasing pressure. Protected areas are degrading often irreversibly. The strong interaction between healthy natural ecosystems, sustainable economic development, and human wellbeing is not being appropriately valued and reflected in on-ground conservation investments (WWF 2013).

Climate change exacerbates the impact of development pressures on the basin's natural systems. Yet, protected areas are a foundation stone for adaptation to climate change. They enable adaptation by buffering of local climate, and reducing the risks and impacts from extreme climatic events, and by providing greater flexibility and options for adaptation. Ecosystem services supplied by natural areas reduce the impact of disasters by providing water, food, and public health benefits to local communities, and are of growing importance with climate change (Dudley *et al.* 2010). Degraded protected areas are likely to be sensitive to changes in temperature, precipitation, and hydrological regimes. Building climate resilience into protected areas of the LMB is an essential strategy for building resilience in communities and economies. It will require a thorough understanding of current and future threats and impacts, and a renewed emphasis on protected area and biodiversity conservation management so they continue to provide for ecosystem and human wellbeing. The axiom that well-managed protected areas are an essential development strategy in the LMB has even greater validity with climate change.

This report forms part of a baseline analysis of agricultural and natural systems in the LMB under the USAID Mekong ARCC Climate Change Impact and Adaptation Study. It is linked to the baseline report on NTFPs and Crop Wild Relatives. Here we provide an outline of protected areas (PAs) and biodiversity in the LMB, and an overview of threats to PAs other than climate change, including land concessions, infrastructure development, illegal activities, and agriculture. The threats posed by climate change to PAs are then reviewed, followed by a series of case studies of climate change impacts, vulnerabilities, and adaptation options in four protected areas: 1) Nong Bong Kai Non Hunting Area – Thailand; 2) Nakai Nam Theun - Lao PDR; 3) Phnom Prich Wildlife Sanctuary - Cambodia; and 4) U Minh Thuong National Park – Vietnam.

SECTION 1- BASELINE ASSESSMENT

1 OVERVIEW

1.1 BIODIVERSITY, PROTECTED AREAS AND CLIMATE CHANGE IN THE LOWER MEKONG BASIN

The LMB is extremely rich in biological diversity, recognized as a biodiversity "hotspot" of global significance (Myers *et al.* 2000). The plains of the Lower Mekong still retain some areas of near-primary habitat (Robichaud 2012), with mosaics of open deciduous dipterocarp forest, seasonally inundated wetlands and grasslands, and riverine habitats. These ecosystems support a huge diversity of globally important mammals (Nguyen *et al.* 2001; Sterling *et al.* 2006; Nguyen 2009), birdlife (BI 2001), and more than 250 freshwater fish species in the Lower Mekong River alone (Sterling *et al.* 2006). Upland areas of the LMB are recognized as key biodiversity areas (KBAs), being home to the last remnants of globally important endemic, rare, and endangered species (Robichaud 2005, 2012).

Protected areas (PAs) are the areas of last resort for national and international biodiversity conservation in the LMB. At a regional scale many PAs in the basin act as biodiversity corridors and the last remaining habitats for flagship species, such as elephants, tigers, saolas, bantengs, and gibbons (Foster-Turley *et al.* 1990; Duckworth 1998; BI 2004b; Lynam 2010; Gray *et al.* 2012).

Environmental degradation and habitat fragmentation is common within PAs of the LMB. Despite conservation efforts, some habitats have become seriously degraded, invasive species have been introduced and are now common in many areas, and the populations of many large flagship species have markedly declined (Nekaris *et al.* 2008; Lynam 2010). With over 60 million people living in the region (Sunderland *et al.* 2012), and persistent poverty within communities living in and around natural areas (ICEM 2003; Sunderlin 2006), PAs are exposed to escalating threats. Unsustainable and illegal logging, wildlife trading, rapid industrialization and concessions, shifting cultivation, infrastructure development, and unsustainable tourism all exert negative pressures and impacts on PA systems.

Degraded and isolated protected areas are particularly affected by climate change impacts. Rising temperatures, changes to the volume and seasonality of precipitation, and the increasing frequency and magnitude of droughts and floods will have broad-reaching impacts on ecological systems in the LMB. Many ecosystems are expected to have some ability to adapt naturally to changes in climate (Gitay *et al.* 2001). Yet, adaptive capacity is reduced as areas are stressed and reduced in size and complexity by development pressures. Also, there is limited information regarding critical thresholds for ecosystems. At a global scale, approximately 20 to 30% of plant and animal species are increasingly at risk of extinction due to climate change associated temperature increases (Fischlin *et al.* 2007). Loss of species can have subsequent effects on ecosystem functioning and the maintenance of ecosystem services (Hooper *et al.* 2005), and would limit options for social-ecological system adaptation response.

Climate change adds another layer of complexity to existing protected area management challenges. To fully understand the impact of climate change at the local, or even basin-wide, level it is important to recognize the interactions between climate change and wider development pressures on natural areas. Human actions reduce the resilience of natural systems where they degrade biodiversity; pollute ecosystems; or disrupt natural disturbance regimes (Folke *et al.* 2004). Healthy, connected ecosystems are best placed to respond and adapt to a changing climate (Luck *et al.* 2003). Given that PAs in the LMB are subject to ongoing degradation and fragmentation, there is a clear need to first address the existing conservation management deficit when planning for climate adaptation.

Climate change is expected to exacerbate human pressures on the basin's natural resources. Climate change impacts within the basin will increase reliance on the provision of ecosystem services and products for livelihood support, fisheries and agricultural production, and overall food

security. Adaptation measures developed for PAs will help maintain biodiversity and dependent livelihoods and sectors.

1.2 NATURAL ECOSYSTEMS AND PROTECTED AREAS IN THE BASIN

1.2.1 FORESTS AND WETLANDS OF THE LMB

Forests provide a suite of ecosystem services in the LMB including NTFPs, provision of clean water and healthy aquatic ecosystems, microclimate regulation, protection against floods and landslides, medicines, and carbon sequestration (MEA 2005). However, forests have been significantly impacted by human activities across the Mekong Basin. Few stands of primary forest remain, and the degradation, fragmentation, and conversion of secondary forest to alternate land uses and monoculture forest stands is widespread (Stibig *et al.* 2007; WWF 2013). Between 1973 and 2009, Cambodia lost 22% of its forest cover, 24% was lost in Lao PDR, and 43% in both Vietnam and Thailand (WWF 2013).

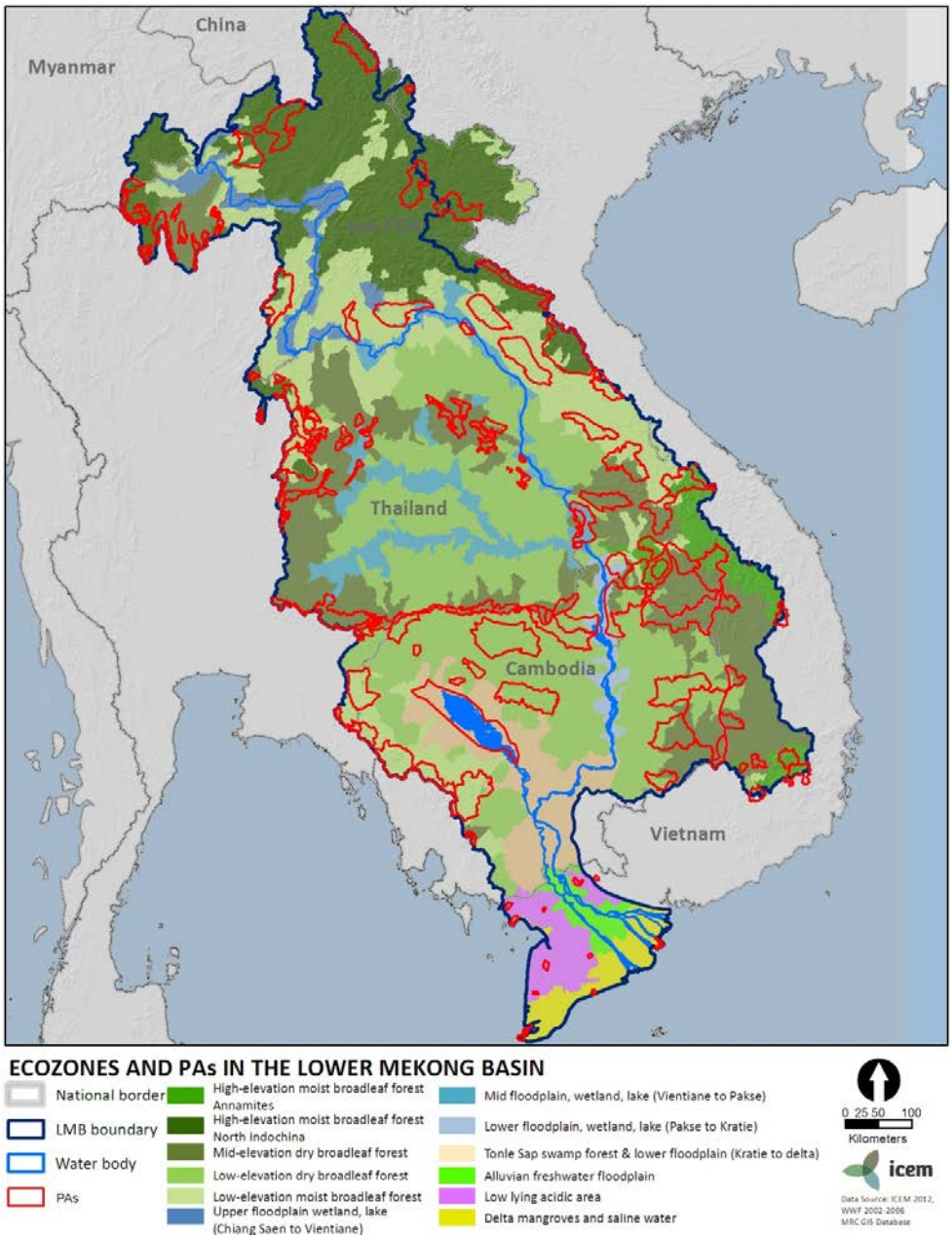
Numerous development impacts place the wetlands of the LMB at risk. Wetlands are seriously underrepresented in the LMB conservation estate, with 0-6% of the six wetland ecozones in the region being held within protected areas (Table 3). Additionally, legal protection against natural resource extraction and other forms of human use within the boundaries of protected areas can offer insufficient protection to wetland ecosystems. The hydrological regimes that are essential to the maintenance of healthy wetland systems are impacted by actions occurring outside PA boundaries (Gopal 2013). Expansion of agriculture and hydropower projects along the Mekong River and tributaries places wetlands under current and future pressure. The Mekong River Commission identified changes in flow, water quality, and flooding patterns in the floodplains as major sources of future impacts on the ecosystems of the Mekong Basin (MRC 2010). Environmental impacts that may result include changes in ecosystem productivity, the provisioning of environmental services, and biodiversity conservation, all of which have both direct and indirect impacts on local livelihoods (MRC 2010). For those reasons, the LMB wetlands are systems under acute pressure.

Climate change is predicted to both exacerbate existing pressures and introduce new threats to forest and wetland ecosystems in the LMB. The cumulative pressure of development and climate change impacts on these ecosystems requires urgent attention to avoid far reaching and permanent losses to the natural systems and livelihoods of the region.

1.2.2 PROTECTED AREAS

The four countries of the LMB—Cambodia, Lao PDR, Thailand, and Vietnam—have established one of the largest protected area systems in the world.[1] Between the four LMB countries, 115 PAs across 9,821,395 ha have been established within the LMB (Table 1). These PAs incorporate up to 16% of the LMB land area. The majority of the significant forests and upper watersheds of the LMB are contained within these areas, making effective conservation of the protected area estate of paramount importance to biodiversity conservation, the regional economy, and the communities of the LMB.

Figure 1: Protected areas and ecozones in the Lower Mekong Basin



[1] As a proportion of national territory.

Table 1 – Number of PAs of the LMB in each country. Source: World Database on Protected Areas (WDPA 2012)

Country	PAs in Mekong Basin		No. of important wetlands
	Number	Area (HA)	
Cambodia	21	3,715,306	24
Lao PDR	27	3,922,359	13
Thailand	46	1,803,063	39
Vietnam	21	380,667	18
Total	**115**	**9,821,395**	94

1.3 COUNTRY PROFILES

This section provides a brief overview of biodiversity and the PA systems of each country - Cambodia, Lao PDR, Thailand, and Vietnam.

1.3.1 CAMBODIA

Cambodia's unique range of plains, river basins, coastline, mountains, and plateaus create the conditions for the country's diverse ecosystems. Tonle Sap is an outstanding feature and is the most influential lake and river system in the LMB. The lake acts as a major regulating force for the seasonal flood pulse of the Mekong River that supports LMB fisheries and the livelihoods of tens of millions of the basin's inhabitants. However, the lake's inundated forests are under increasing pressure due to the demand by households for wood for fuel and handicraft production; expanding fishing-lot operations; and conversion of inundated forest to farming, caused by increasing seasonal migration toward the lake of people looking for income-earning opportunities. Cambodia's forests are also under intense pressure and about 55% of forest area (including 45% of forests in PAs (EU 2012)) is degraded. Illegal and legal logging, agriculture and mining activities, even within protected areas, threaten forested ecosystems in Cambodia (WWF 2013). In coastal areas, extensive infrastructure development is rapidly destroying large areas of mangroves and reducing coastal biodiversity (ICEM 2003a).

The protected area system in Cambodia was established in the 1990s, starting from a low base following war and political upheavals that swept aside any institutional expression of the forest reserves defined under the French administration earlier in the century (IUCN, 2003 #98). Early work by the IUCN divided Cambodia into seven biodiversity conservation regions on the basis of biological resources, geology and soils, and past and present use (IUCN 2003). Cambodia promotes the use of these biodiversity regions through PA clusters, such as the conservation landscapes of the Eastern Plains Landscape in Mondulkiri and Ratanakiri Provinces, or the southwest cluster including Phnom Bokor, Preah Suramarit Kossamak (Kirirom), Preah Sihanouk (Ream), and Kep protected areas. More recently, the country has undergone a series of PA downgrades, with mining and economic land concessions being granted across 346,000 ha of designated conservation areas, representing 10% of PAs administered by the Ministry of Environment (Vrieze & Naren 2012). These actions and the ensuing activities greatly threaten the effectiveness of the conservation measures in place to protect natural systems in Cambodia.

Important initiatives have been made to expand the national PA system with the addition of fisheries and forest conservation areas and the establishment of conservation landscapes. Cambodia's protected areas now cover more than 20% of the country, which is exceptional by international standards.

1.3.2 LAO PDR

Lao PDR supports a relatively high level of biological diversity compared to Vietnam and Thailand (ICEM 2003b). The most biologically distinct ecosystem of the country is the Evergreen Forests of the Annamite Mountains and Foothills. Further important habitats of Lao PDR include the Central Indochina Limestone Karst, Dry Dipterocarp Forests of the Mekong Plain, Bolavens Plateau, Northern Highlands, and rivers and streams of the Mekong River system.

Similar to Cambodia, the Lao PDR PA system was established in the 1990s with substantial international support. This system is one of the youngest and most comprehensive protected area systems in the world. It was designed as an integrated system using scientific principles for biodiversity conservation and habitat connectivity. Only wetlands and lowland forest might be considered to be under-represented across the national biodiversity conservation areas (NBCAs). In addition, there is a growing number of provincial and district-level PAs, restricted use zones, and watershed forest areas. Combined, the protected area system covers more than 21 percent of the country's land area (ICEM 2003b).

The country's steady economic growth has exerted pressure on its biological resources. Both the quality and quantity of forest declined markedly over the last 50 years as a result of population growth, encroachment, slash-and-burn cultivation, illegal trade in wildlife and forest products for food and traditional medicines, excessive timber harvesting, forest fires, and the effects of wartime bombing and chemical defoliation. Between 1940 and 2001 forested land area decreased from 70% to 41%. Since 2001, government policies to protect forested areas have encouraged an increase in forested area up to 52%, with an ultimate goal of forest cover across 70% of the Lao land by 2020.

1.3.3 THAILAND

The range of terrestrial ecosystems in Thailand is extensive, including moist evergreen forests, hill evergreen forests, dry evergreen forests, pine forests, mixed deciduous forest, dry deciduous forest, and grasslands. The country's many freshwater wetlands provide important habitat for a wide range of unique plant and animal species, including nesting and homing grounds for many migratory birds of international importance (ONREPP 2004).

Protected areas in Thailand were provided a legislative foundation in the early 1960s, with technical assistance from IUCN, through promulgation of the Wildlife Act (1960) and National Park Act (1961). The current PA system forms one of the largest systems in the world as a proportion of national territory. The system includes some 81 terrestrial national parks, 21 marine parks, 39 wildlife sanctuaries, 35 forest parks and 17 other PAs of various types.

Thailand's PA system was initially fragmented, with many of the areas too small to sustain their flora and fauna, especially populations of large mammals, including tigers, leopards, elephants, and bears. Efforts to redress deficiencies in coverage of habitat have included the declaration of 19 forest or protected area complexes. Each complex comprises a number of protected areas in a shared geographic region; 17 complexes encompass forest habitats, while two cover marine and coastal habitats (ICEM 2003d).

Similar to other countries in the LMB, many of Thailand's protected areas have been degraded by rapid growth in population, exploitation of timber, land conversion and hydropower, tourism impacts, and residential development. Yet, management and conservation of the national system is the strongest in the region.

1.3.4 VIETNAM

Vietnam also contains extraordinary biodiversity. It is one of the world's 10 most biologically diverse countries and contains about ten percent of the world's species while covering less than one percent of its land area (Bank 2002). Vietnam's natural habitats range from mountainous forest areas to large estuarine and delta systems with immense seasonally flooded plains, extensive mangrove swamps and

tidal mudflats, and *Melaleuca* forests with elaborate networks of river channels. Many of the world's flagship conservation species have been present in Vietnam at some stage, including the tiger (*Panthera tigris*) and the Asian elephant (*Elephas maximus*), as well as the world's 25 rarest primates (Timmins & Duckworth 2001). Since 1992, four mammal species have been discovered in Vietnam that were previously unknown to science (Sunderland *et al.* 2012).

After the Vietnam-American war, in 1986, 87 PAs were established in Vietnam. The number of PAs continued to increase to 2010 and now includes 21 PAs that are located within the LMB. Included within the basin is one of Vietnams 9 biosphere reserves, the Kien Giang Biosphere reserve located in the Mekong Delta.

A notable feature of the region's protected areas is that Vietnam has the greatest number of individual PAs distributed throughout the country but the least overall coverage. Many areas are of historic and recreational value but alone are too small and isolated for effective biodiversity conservation (ICEM 2003e). Some PAs do however provide important biodiversity connectivity with PAs in other countries within the basin. For example, Yok Don National Park in Vietnam is connected to the Mondulkiri PAs cluster in Cambodia, which includes Phnom Prich Wildlife Sanctuary (Section 7.3 of Annex 1: Baseline Case Study), and Phong Nha Ke Bang National Park is connected to the Khammouan PAs cluster in Lao PDR, which includes the Nakai-Nam Theun National Protected Area (Section 7.2 of Annex 1).

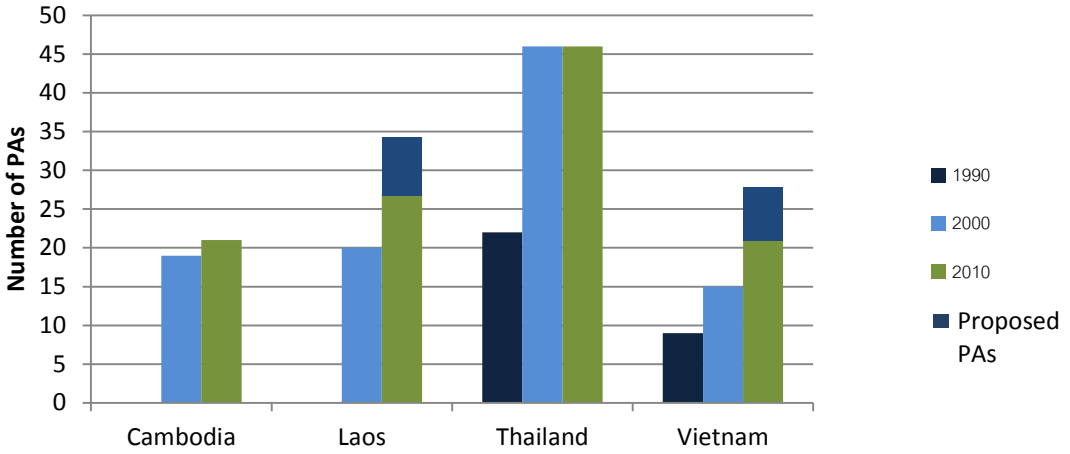
Despite a significant increase in the number and coverage of protected areas in Vietnam, biodiversity has continued to decline in the country. Half of the original forest cover was lost over the four decades to 2000 with only about 98,190 square kilometers, or 30% of the country's land area, covered in relatively poor-quality forests, remaining. Major reasons for this include the large migration of people to forested areas (e.g., from the Red River Delta to the Central Highlands which harbor the country's richest remaining biodiversity), fuel wood collection, logging, forest fires, and defoliation activity during the Vietnam-American war (ADB 2004). It is likely that populations of species of conservation concern have suffered significant declines over the same period due to deforestation, habitat fragmentation, and a raft of other human disturbances.

1.4 TRENDS IN PROTECTED AREAS OF THE LOWER MEKONG BASIN

From the country profiles it is evident that the overall number of PAs in the LMB has increased rapidly in the past two decades. The most significant increases occurred during the 1990s in Cambodia, Lao PDR, and Thailand. Cambodia and Lao PDR moved rapidly from having no designated PAs in 1990 to around 20 PAs in 2000, and the number of PAs more than doubled in Thailand (Figure 2).

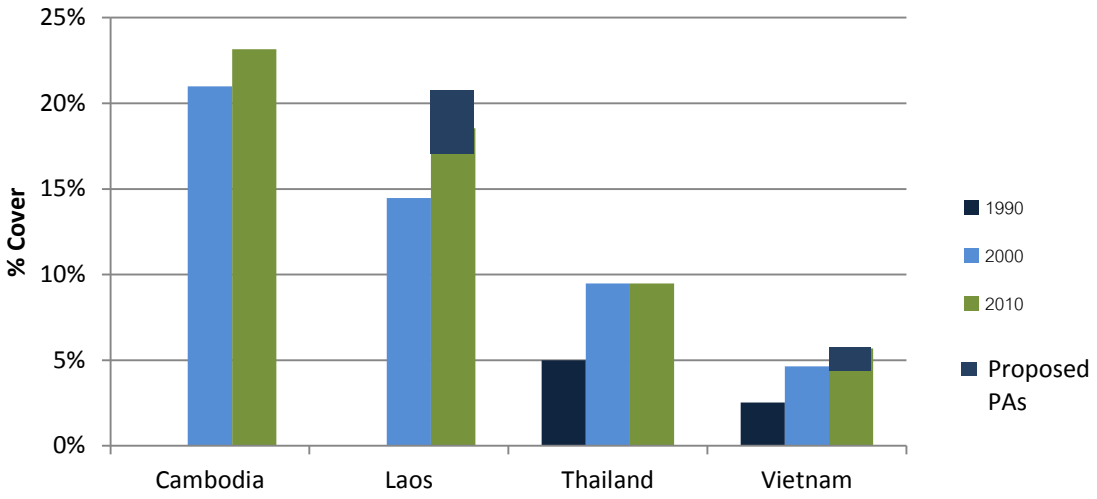
However, most growth in PAs occurred between 1990 and 2000 (Figure 2). Over the past decade PA land coverage has seen little change. There have been increases in the number of PAs in the Lao PDR and in Cambodia. These increases are attributed largely to areas established at the local level and others proposed for protection that have yet to be officially approved or declared as PAs (Figure 3). In many cases these areas are recognized by international and national government, and non-government organizations as key biodiversity areas. It is expected the coverage of officially recognized PAs will expand if these areas receive official status and proposed extensions to existing PAs are approved.

Figure 2: Growth in the number of Protected Areas in the LMB - *Source: World Database on Protected Areas (WDPA 2012)*



While LMB PA coverage is substantial, it is generally accepted that natural forest estate in the basin is shrinking (Sunderland *et al.* 2012), and that degradation of wetland ecosystems across the region is widespread (Gopal 2013). Should those trends continue, the role of protected areas in representing the last vestiges of the original plant and animal assemblages of the basin and the heartland for NTFPs and crop wild relatives will be critical.

Figure 3: Growth in Protected Area coverage in the basin (as a percentage of national land area in the LMB) - *Source: World Database on Protected Areas (WDPA 2012)*



1.5 ECOSYSTEM SERVICES: SOCIETY, ECONOMY, AND PROTECTED AREAS

The economic and social benefits of protected areas are widespread. PAs provide a range of direct and indirect ecosystem goods and services vital to healthy water resources, energy, agriculture, forestry, fisheries, subsistence hunting and collecting, industry, and the service sector (ICEM 2003c). These goods and services are of particular importance to poor communities given the established geographical overlap between the chronic poor and protected areas in the LMB (ICEM 2003c; Sunderlin 2006).

Indirect benefits provided by healthy natural systems in the LMB include human habitation, wildlife habitat, erosion control, recycling of soil nutrients, micro-climatic stabilization, and hydrological services such as the provision of reliable water sources for irrigation, mitigation against the sedimentation of reservoirs, regulation of water supplies, maintenance of ground water sources and water quality, and mitigation of flood impacts (ICEM 2003c).

To fully recognize and understand the range of ecosystem goods and services supplied by natural systems, four major themes are generally referred to (see (MEA 2005; TEEB 2010)).

- **Provisioning services** are ecosystem services that describe the material output from ecosystems. They include food, water, and other resources.
- **Regulating Services** are the services that ecosystems provide by acting as regulators, e.g., regulating the quality of air and soil or providing flood and disease control.
- **Habitat or Supporting Services** underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals.
- **Cultural Services** include the non-material benefits people obtain from contact with ecosystems. They include aesthetic, spiritual, and psychological benefits.

Table 2 provides an overview of ecosystem services generally provided by PAs in the LMB. Further discussion of goods and services provided by the four PAs included as baseline profiles is included in the separate document, *Annexes: Protected Areas Baseline Assessment, Vulnerability Assessment, and Adaption Planning*.

Table 2 – Ecosystem services matrix, adapted from ICEM (2003c), with reference to TEEB (2010)

	Agriculture	Flood mitigation	Water supply	Trade	Transport	Poverty reduction	Tourism	Health & nutrition	Education & research	Energy	Finance	Culture	Forestry	International cooperation
Provisioning Services	X		X	X		X	X	X		X	X	X	X	X
Regulating Services	X	X	X		X	X	X	X		X	X		X	X
Supporting Services	X					X	X	X	X		X	X	X	X
Cultural Services						X	X	X	X		X	X		X

Protected areas and linked natural areas of forest and wetlands are increasingly becoming an essential part of healthy productive farming ecosystems. It is estimated that more than 25% of the area within many PAs is used for agriculture, 30% for grazing, 30% for fisheries, and in many areas the entire PA is utilized for hunting, gathering, and extraction of non-timber forest products (NTFPs) (ARCC 2012).

In Cambodia, 70–90% of households are engaged in collection and trade of forest products in areas with evergreen and semi-evergreen forests, despite the pressure from logging and economic concessions (GMS Atlas 2012). In addition, fuel wood is widely collected throughout the LMB for domestic use and remains the primary source of household energy. Resin collection, hunting, and other NTFPs account for almost half of household income in communities around a protected forest in Mondulkiri, Cambodia and loss of income from these sources due to logging or clearance for economic concessions has major welfare impacts (WWF 2007). In Lao PDR, communities also continue to rely heavily on NTFPs. However, availability of some products such as leaves and fruit have declined, and birds and wildlife have also declined severely (GMS Atlas 2012). In Vietnam, NTFPs provide about half the annual income for households living in or near PAs (ADB 2004).

Most PAs tend to fall into the least populated and less accessible locations. In recent decades, however, there has been a trend of increasing migration towards PAs, both informal and in some cases encouraged through resettlement and land concessions. More than 85% of PAs in the LMB have communities living within them (IUCN 2003). Households depend on the natural resources of PAs for food security, such as wild vegetables, particularly as an emergency source in periods of stress when agricultural productivity declines.

Protected areas also have economic and recreational importance due to their tourism and cultural values. In pure economic terms, they attract international tourists to visit the basin's national parks and cultural sites, and, in doing so, inject income into the local economy. Cambodia in particular is renowned for its spectacular wetlands environment, which, as well as being an economic asset and a draw for international tourists, supports the livelihoods of millions of Cambodians who depend directly on key assets such as the Tonle Sap wetlands.

2 METHODS AND CASE STUDY BASELINE ASSESSMENT

2.1 ECOSYSTEM APPROACH

As a first step in identifying representative examples of protected areas for the climate vulnerability assessments and adaptation planning process, the USAID Mekong ARCC team defined 12 primary ecozones each supporting similar assemblages of plants and animals due to analogous climatic and biophysical conditions. Through this grouping, assessments undertaken at individual PAs provide a basis from which climate change assessments can be scaled up across an ecozone. This method generates common adaptive approaches and principles applicable to management, development, and conservation of biodiversity within each zone.

Table 3 lists the 12 ecozones identified in the LMB. Most of the PAs are representative of more than one ecozone. Some zones were commonly found in PAs, while others, such as large areas of floodplain wetlands (ecozones 1 &12), and wetland systems more generally, are uncommon or absent in the PA system (Table 3).

Table 3 – Number of PAs in each ecozone of the LMB

Ecozone	Code	PA Area (ha)	No. PA[2]	% Ecozone
Delta freshwater wetlands	1	0	0	0
Delta mangroves and coastal wetlands	2	18,831	6	2.1
Delta acidic swamp forest	3	34,475	7	2.3
High elevation moist broadleaf forest - Annamites	4	453,023	12	2.8
High elevation moist broadleaf forest - North Indochina	5	1,364,673	24	13.5
Low elevation dry broadleaf forest	6	1,920,691	41	28.1
Lower floodplain, wetland, lake (Pakse to Kratie)	7	89,803	4	1.4
Low-mid elevation moist broadleaf forest	8	2,431,310	41	16.8
Mid floodplain, wetland, lake (Vientiane to Pakse)	9	193,301	15	5.1
Mid elevation dry broadleaf forest	10	2,673,548	54	18.3
Tonle Sap swamp forest and lower floodplain (Kratie to delta)	11	632,548	5	6.1
Upper floodplain wetland, lake (Chiang Saen to Vientiane)	12	10,190	1	2.3
Total		**9,821,395**	**115**	

Low, mid, and high elevation broadleaf forest ecozones are well represented within the basin's PA system. Low elevation dry broadleaf forest is the best represented ecosystem with PAs covering 28.1% of that ecozone, occurring mostly in the northern plains (Kulen Promtep Widlife Sanctuary and Beng Per Wildlife Sanctuary) and the eastern plains of Cambodia (Mondulkiri PAs cluster). Low, mid, and high elevation moist broadleaf forests are found in a large proportion of Cambodia's Eastern Plains Landscape (Mondulkiri PAs cluster), PAs in the Central Highlands of Vietnam (Yok Don, Chu Prong, and Mom Ray),

[2] Some PAs cover more than one ecozone.

the southern part of Lao PDR (Phou Kathong, Phou Theung, and Xe Bang Nouan), and PAs in central and northern parts of Thailand (Pu Kiew, Pulan Ka, Puvieng, and Doi Phu Nang NP).

2.2 SELECTING REPRESENTATIVE CASE STUDY PAS

Methods: Climate change modeling in the USAID Mekong ARCC study projects changes in temperature, precipitation, water availability, drought, flooding, and sea level rise across the LMB to the year 2050. Based on this modeling, eight 'hotspot' provinces likely to be subject to significant changes in temperature, precipitation, and flooding were identified: Chiang Rai and Sakon Nakhon in Thailand; Khammouan and Champasak in Lao PDR; Mondulkiri and Kampong Thom in Cambodia; and Gia Lai and Kien Giang in Vietnam. Among these, the USAID Mekong ARCC study identified five priority provinces where climate vulnerability assessments were conducted: 1) Chiang Rai, 2) Mondulkiri, 3) Khammouan, 4) Gia Lai, and 5) Kien Giang (Figure 4).

PAs within hotspot provinces were selected on the basis of modeling results and the representation of a variety of ecozones. Final selection of PAs for analysis was based on a combination of:

- PAs located within priority hotspot provinces
- Individual PAs ranking for % change in climate conditions to 2050 (within priority provinces)
- PAs within the priority provinces that were representative of one or more ecozone
- PAs within a province that formed part of a PA cluster or contiguous boundary.

The PAs and ecozones represented by each PA are summarized in Table 4.

Figure 4: Climate change in the LMB (red circles show the five hotspot provinces, with case study PAs located within four of the hotspots at 1, 2, 3, and 5)

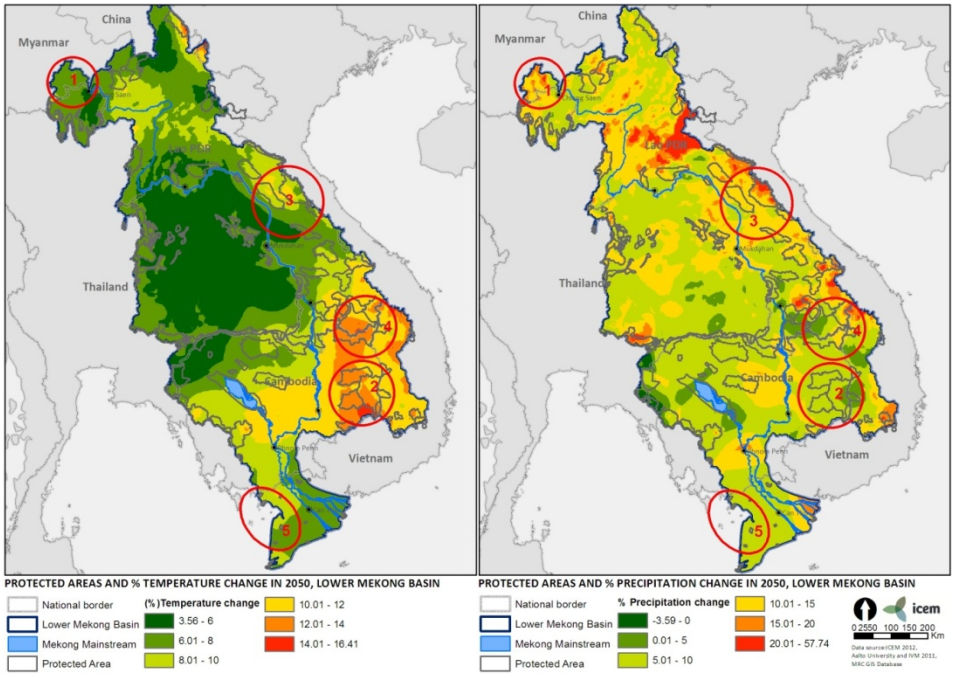


Table 4 – Selected PAs and representative ecozones

Province	Country	PA	Ecozone
1. Chiang Rai	Thailand	Nong Bong Kai - Non Hunting Area	Ecozone 12 - Upper floodplain wetland, lake
2. Khammouan	Lao PDR	Nakai-Nam Theun NBCA	Ecozone 4 – High elevation moist broadleaf forest Ecozone 8 - Low-mid elevation moist broadleaf forest
3. Mondulkiri	Cambodia	Phnom Prich Wildlife Sanctuary	Ecozone 6 – Low elevation dry broadleaf forest Ecozone 10 - Mid elevation dry broadleaf forest
4. Kien Giang	Vietnam	U Minh Thuong National Park	Ecozone 3 - Delta Low lying acidic area swamp forest

2.3 BASELINE CONDITIONS OF LMB PAS

2.3.1 ADDRESSING THE ADAPTATION DEFICIT

To inform the identification of adaptation options for PAs, the major non-climate driven pressures and threats for each case study PA were identified in the baseline assessment process. It is important to recognize these pressures when undertaking adaptation planning to ensure climate change adaptation remains relevant to local planners, managers, and community actors. In many cases adaptation options will address the same pressures that are currently degrading PAs. This need for adaptation to first address existing conservation management priorities is referred to as meeting the *adaption deficit* (Carew-Reid *et al.* 2011).

Examples of non-climate driven external pressures and threats to PAs are discussed in detail for particular PAs in the case study profiles. In summary, non-climate drivers of change are:

- **Land concessions** – In Lao PDR and Cambodia there has been a surge of land concession grants in recent years. A number of activities are associated with these developments, including commercial plantations, logging, hydropower, mining, livestock, and building factories to process agricultural products. Land concessions are a major driver of forest loss and by providing access to previously inaccessible areas they introduce or intensify illegal logging and poaching in surrounding areas. Any form of land degradation resulting from land concessions increases the vulnerability of ecosystems to climate change, as well as their capacity to adapt to these changes.
- **Population growth** – Population growth and migration towards protected areas makes PAs even more crucial for the continued production of a range of marketed and non-marketed ecosystem-based goods and services. On current trends, continued population growth will further degrade these services.
- **Agriculture** – Agriculture is the chief source of rural income within the LMB. Population growth within subsistence-based communities drives encroachment deeper into forested areas in search of arable land. With the expanding use of fertilizers and pesticides, agricultural runoff is polluting natural water sources. Agriculture adjacent to forested areas may also lead to incursion of invasive species into PA ecosystems.
- **Infrastructure development** – Infrastructure development, such as dams and highways, increases the accessibility of PAs in the same manner as land concessions. The developments have direct and indirect impacts on biodiversity and lead to overall degradation of natural systems.
- **Unsustainable and illegal logging** – Despite their legal status, PAs in the LMB are the sites of vigorous logging activities. Some of this logging is illegal, though often facilitated by state

officials; some is legally sanctioned, but unsustainable. At the households level timber remains the principal fuel source for many communities, although this is certainly not a driver of large-scale land clearing.

- **Wildlife trading** – Poaching and the wildlife trade in the LMB have both national and international dimensions. Communities may harvest animals for food on an unsustainable basis. In the case of some species, such as tigers, the demand for 'traditional medicines' in Vietnam and China is fueling a growing trade in the slaughter of rare and endangered animals. Higher incomes in these destination countries increase demand for poaching, even as prices rise due to increasing scarcity.
- **Tourism** – Tourism developments in the PAs of the LMB are often under-resourced and inadequately managed, resulting in lost economic opportunities for local communities and the protected area, and in damaging social and environmental impacts. Often poorly sighted or harmful tourist facilities and infrastructure degrade the conservation values of protected areas.

2.3.2 CASE STUDY PA BASELINE CONDITIONS

Key attributes of the four case study PAs were reviewed, and conditions and threats identified by conducting a desktop review of relevant literature. Baseline profiles provided the basis for climate impact and vulnerability assessments and adaptation planning for the four case study PAs. There is a severe lack of up to date information regarding the current condition and pressures faced by many PAs across the LMB. It is likely that development pressure has become worse since much of the literature was published so vulnerability results may understate the situation on the ground.

An overview of PA assets and threats in case study PAs is included below. Detailed baseline profiles appear as Annexes to this report.

Nong Bong Kai Non-Hunting Area, Thailand

Ecozone 12, Upper floodplain wetland, lake

Nong Bong Kai Non-Hunting Area is a natural depression surrounded by low hills located in Chiang Saen District, Chiang Rai Province, Thailand. The lake is well known as a significant bird sanctuary. A total of 432 ha of the area was designated as the 5th Ramsar wetland site in Thailand during 2001 (Tirisurat 2006), and the area was recognized as an Important Bird Area by BirdLife International in 2004 (BI 2004a). Numerous commercially important fish species are found within the PA, including migratory species reliant on high connectivity between wetland areas to complete rainy season migration patterns essential for their life cycles.

The lake system is important to groundwater recharge in the region, carrying significant value to neighboring vegetation, as well as domestic and commercial water users (ONREPP 2004). The lake also offers water purification services through the cycling of sediments and nutrients, and numerous plant and animal food sources are harvested from in and around the lake.

Generally, the health of the Nong Bong Kai wetland and basin areas is considered to be degraded (ONREPP 2004). Unsustainable fish harvesting, habitat disturbance and destruction by buffalo grazing in the riparian zone, along with continued encroachment and land development in areas surrounding the lake, and water pollution from human settlements have all been identified as contributing to this degradation. Invasion by pest species, particularly cogongrass (*Imperata cynlindrica*) and exotic fish species, is becoming an issue in some lake areas. Continued nutrient pollution from human settlements may exacerbate this threat over time.

Nakai–Nam Theun Biodiversity Conservation Area, Lao PDR

Ecozone 4, High elevation moist broadleaf forest and Ecozone 8, Low-mid elevation moist broadleaf forest

The Nakai-Nam Theun National Protected Area (NNT) and adjacent northern extension is the largest protected area in Lao PDR, occupying about 4000 km^2 along the border of Vietnam. NNT falls within the area defined by WWF as the Northern Annamites rain forests ecoregion (Robichaud 2012). This ecoregion hosts globally significant biological distinctiveness. The NNT is the largest protected area in the ecoregion, and has been rated as being of very high, or critical, conservation importance by several biodiversity assessments since the 1990s. Assessments include investigations into forest cover, vertebrate diversity (Ling 1999), biodiversity, watershed protection, ecotourism potential (Robichaud *et al.* 2001), and conservation importance (Baltzer *et al.* 2001; STEA 2004).

NNT along with adjoining PAs and proposed extensions provides the core of a series of contiguous conservation areas in Lao PDR and Vietnam. Forest cover in NNT is extensive, and the majority is of outstanding quality or primary forest condition. Due to the extent, condition, and connectivity of the forest held within the NNT and surrounding PAs, it is suggested that the NNT may be the highest quality evergreen/semi-evergreen forest block in the broader region of Lao PDR, Vietnam, Thailand, and Yunnan (China) (Robichaud 2012). NNT has the highest diversity of both birds and mammals found in Lao PDR (Ling 1999), and the park hosts globally significant vegetation communities and species (Robichaud 2012).

Population densities in NNT are low and are characterized by pronounced ethnicity, dependence on subsistence livelihoods with household income levels well below the national poverty line, and limited or no access to infrastructure and services such as education, health, electricity, and water supply. The forest is an important resource for most rural poor community's livelihoods, including as a source of foods, medicines, construction materials, and firewood.

The main threats to biodiversity conservation in NNT come from illegal logging and wildlife hunting for trade (Robichaud 2012). The development of the NT2 reservoir greatly increased accessibility into the PA. Boat access aided an increase of timber and wildlife poaching along the western side of the reserve from 2008. Slash and burn swidden agricultural practices present a further risk to the PA conservation, mostly due to population growth in the region. Population growth in the region will likely continue to result in increased pressure from these activities (Robichaud 2012).

Phnom Prich Wildlife Sanctuary, Cambodia

Ecozone 6, Low elevation dry broadleaf forest and Ecozone 10, Mid elevation dry broadleaf forest

Phnom Prich Wildlife Sanctuary (WS) represents 225,000 ha of one of the largest remaining relatively undisturbed extents of lowland forest in Southeast Asia, the Eastern Plains Landscape. Phnom Prich WS is contiguous with Mondulkiri Protected Forest to the northeast, and Seima Protected Forest to the South. Together, the protected areas lie at the core of the Lower Mekong Dry Forest Ecoregion. The area is considered to be globally significant for conservation (WWF 2012), due to its role as habitat for large mammals, along with birds and reptile species (Gray *et al.* 2011; Gray *et al.* 2012). The area has been identified as one of 12 critical tiger conservation and recovery landscapes by the World Wide Fund for Nature (WWF) (Wikramanayake *et al.* 2011).

WWF has worked for over five years with relevant Cambodian government departments to implement improved management of PAs in the Eastern Plains Landscape through the extension of the ranger/forest guard program. However, both legal and illegal logging continue to be major threats to Phnom Prich WS and surrounding forests, and without further funding for enforcement initiatives forest harvesting will likely continue. Illegal wildlife hunting and poaching for trade is also common in the park. Land concessions for cash crops, mining, and other activities continue to be an issue for management in the Eastern Plains Landscape. In Phnom Prich WS, both mining and economic land concessions, often utilized for agribusiness development, have been granted (Vrieze & Naren 2012).

Communities around the Sanctuary are very poor and heavily dependent upon natural resources. However, NTFPs and other forest resources are unsustainably used by both communities and outsiders. Major drivers of over-use include: increasing population density and pressure to open up new land, poverty, and unsustainable or illegal methods (i.e., guns for hunting, and grenades or poison for fishing).

U Minh Thuong National Park, Vietnam

Ecozone 3, Delta Low lying acidic area swamp forest

Covering 21,800 ha, U Minh Thuong National Park, along with nearby U Minh Ha National Park, is recognized as one of the highest priority sites for wetland conservation in the Mekong Delta. *Melaleuca* forests in both of these parks represent some of the last remaining areas of freshwater peat swamp forest in Vietnam. Healthy tropical peat swamps provide important habitat for endemic and endangered species (Page *et al.* 2009), produce economically valuable timber and NTFPs (Page & Rieley 1998), filter groundwater recharge and store fresh water during the dry season (Wosten *et al.* 2006), store carbon within the peat layer (Hirano *et al.* 2012), and support local livelihoods (Wosten *et al.* 2006).

U Minh Thuong is rich in flora and fauna species, with numerous species of global and national conservation concern including the hairy-nosed otter (*Lutra sumatrana*), the yellow-headed temple turtle (*Hieremys annandalii*), and the painted stork (*Mycteria leucocephala*). This rich wildlife attracts illegal hunting and trapping of waterbirds and reptile species for food and trade (Stuart 2004).

Tropical peat swamps such U Minh Thuong are highly sensitive to changes in water availability, and as such the hydrological integrity of peat swamp ecosystems is fundamentally important to their conservation (Wosten *et al.* 2006). Across the tropics, drainage of peat swamps and forest clearing for agricultural development has resulted in broad-scale degradation of these systems (Page *et al.* 2009). Water and water management is therefore key to the maintenance of the biodiversity and livelihoods supported by healthy peat forests such as U Minh Thuong. The management of hydrological regimes is particularly important to minimize the risk of peat fires in the park. Insufficient water availability during times of drought is a known prerequisite for the start of fires in peatlands (Dawson *et al.* 2000), and fire events have caused considerable damage to U Minh Thuong NP to date. There is an intensive checker-board network of canals in the buffer zone of the park, leading to high water surface evaporation and decreasing available water from the park as a whole. These dykes are commonly of poor quality, allowing a high rate of seepage to occur. As such water level can drop far below the ground in the dry season, allowing the peat layer to dry and elevating fire risk. The relationship between hydrology, forest health (canopy cover), and fire risk is complex, with fire events causing a positive feedback effect where the system is at a higher risk of fire following a fire event. Management actions that work to prevent forest degradation and minimize the risk of drought are of most importance in U Minh Thuong NP.

SECTION 2 – VULNERABILITY AND ADAPTATION OPTIONS

3 OVERVIEW

Climate models for the LMB predict continued warming across the basin and a range of other threats including decreased precipitation in the dry season, increased precipitation in the wet season, decreased soil water availability, and increased occurrence of extreme events. It follows that there is a growing awareness of the need to plan for future climate change. Planners and managers are faced with the practical need to prioritize and allocate resources for mitigation and adaptation to climate change impacts.

Vulnerability assessments help to identify which ecosystems, habitats, species, and communities are likely to be most affected by the projected changes in climate. Here we present vulnerability assessments for four case study PAs representative of the varying natural systems within the LMB: Nong Bong Kai Non Hunting Area; Nakai-Nam Theun NBCA; Phnom Prich Wildlife Sanctuary; and U Minh Thuong National Park.

Vulnerability assessments provide a framework to develop adaptation strategies. Through identification of sensitivity to climate change, adaptation strategies can be designed to best protect the capacity of PAs to continue to provide ecosystem goods and services throughout the LMB.

Key adaptation recommendations are relevant across varying habitats. While climate adaptation planning presented in the current report is focused primarily on four individual PAs, many strategies are applicable to a wide range of environments. This is generally because climate adaptation planning is based upon sound PA management.

Healthy, connected natural systems are best placed to deal with climate change. Actions that protect and enhance the quantity and quality of PA ecosystems across the LMB will provide the best climate insurance policy for species and communities reliant upon the habitats, the goods, and the services provided by the PAs.

3.1 ASSESSMENT RESULTS SUMMARY

Projected changes in climatic conditions vary across the LMB;

- **Temperature projections –** Generally, temperature in the LMB is expected to rise significantly over the next four decades. However, the level of predicted warming will vary between PAs from 1 to 5°C. In many cases, temperature projections predict exposure to extreme temperatures to lengthen, and for PAs to be exposed to conditions never before encountered.
- **Precipitation projections** – Both the quantity and seasonality of precipitation is projected to change. There is an expected reduction of rainfall in the dry season and, in many areas, an expected increase in the wet season.
- **Water availability projection** – Across most of the PAs, water availability is predicted to decrease overall with climate change. This modeled output is mostly a factor of higher temperatures and subsequent higher rates of evapotranspiration. Reduction in water availability is likely to be most severe in areas that also are projected to experience less rain during the dry season.
- **Drought –** Higher temperatures and decreasing relative humidity in the dry season is a common projection for selected PAs. As a result, droughts are projected to occur more often and for longer durations.
- **Flooding –** Increases in the intensity and volume of rainfall in the wet season is projected to increase the frequency of flooding events during this period. For PAs in the Mekong Delta and coastal zones, flooding is predicted to be more severe due to the effects of sea level rise.

- **Sea level rise projections –** Sea level is projected to rise by approximately 15 cm by 2030 and by approximately 30 cm by 2050. Sea level rise will likely cause changes to flooding patterns, drainage, salinity exposure, coastal erosion, and storm impacts.
- **Storm surge projections** – Projections regarding storm severity are uncertain, however the frequency of very strong storms is expected to increase and individual occurrences of very high rainfall events is expected to increase.

4 VULNERABILITY ASSESSMENT

4.1 METHODOLOGY

Vulnerability assessments were carried out for case study PAs within LMB using the CAM (Climate Change Adaptation and Mitigation) methodology (ICEM 2010). In this context:

Climate change **vulnerability** refers to the degree to which an ecological system or species is likely to experience harm as the result of changes in climate. The CAM methodology recognizes **vulnerability** as a function of (IPCC 2007):

- **exposure** to climate change: the magnitude, intensity and duration of the climate changes experienced;
- the **sensitivity** of the species, community, or asset to these changes; and
- the **adaptive capacity** of the system to adapt to these changes.

Each PA assessment used the CAM method to analyze the threats and consequences of changes in regular climate for identified key 'assets' or components of the PA systems, such as the ecological characteristics of habitats, species, communities, and ecosystem services identified in the PA baseline profiles.

4.1.1 DETERMINING CLIMATE CHANGE IMPACTS

Exposure of PA ecosystem components and services to climate change impacts was identified through analysis of climate modeling results, namely changes in temperature, precipitation, water availability, sea level and salinity, and consequently, changes in events such as drought, floods, and storms. An exposure category (as shown in Table 5) was assigned based upon scientific consensus of the level of climatic change considered to highly expose a system to climate change impacts.

Sensitivity of PA ecosystem components and services to climate change were determined based upon the best available scientific information. Where species or ecosystem-specific information was not available, general ecological principles were applied, i.e., the following conditions would make an ecosystem or species more sensitive to climate change:

- degraded or fragmented ecosystems
- systems currently stressed by periods of drought
- species with low population numbers or restricted distributions

This approach allows some general, broad-reaching adaptation options to be developed to address climate change where in-depth knowledge is not available to fully quantify impacts. While this approach will deliver many worthwhile adaption options, focused research efforts are required to fully understand the vulnerability of natural systems in the LMB to climate change.

A matrix (Table 5) guided the determination of the level of expected climate change impact given the assessed levels of exposure and sensitivity (i.e., exposure x sensitivity = impact).

Table 5 – Climate Change Impacts Matrix for climate change threats to a system

		Exposure of system to climate threat				
Sensitivity of system to climate threat		Very Low	Low	Medium	High	Very High
	Very High	Medium	Medium	High	Very High	Very High
	High	Low	Medium	Medium	High	Very High
	Medium	Low	Medium	Medium	High	Very High
	Low	Low	Low	Medium	Medium	High
	Very Low	Very Low	Low	Low	Medium	High

4.1.2 DETERMINING ADAPTIVE CAPACITY

Adaptive capacity refers to the ability of a system or species to recover from an **impact** and prepare for a future threat. Determinants of adaptive capacity include:

Natural systems

- Species diversity and integrity
- Species and habitat tolerance levels
- Availability of alternative habitat
- Ability to regenerate or spatially shift
- For individual species: dispersal range and life strategy

Infrastructure

- Availability of physical resources (e.g., materials and equipment)
- Backup systems (e.g., a plan B)

Social factors

- Social networks
- Insurance and financial resources
- Access to external services (Medical, Finance, Markets, Disaster response, etc.)
- Access to alternative products and services

Cross-cutting factors

- The range of available adaptation technologies, planning, and management tools
- Availability and distribution of financial resources
- Availability of relevant skills and knowledge
- Management, maintenance, and response systems including policies, structures, technical staff, and budgets
- Political will and policy commitment

A natural systems example of low adaptive capacity would be a degraded habitat with limited ability to regulate microclimate and naturally regenerate following a disturbance event. In comparison, a healthy, mature forest environment will generally exhibit a high adaptive capacity. Mature forests are able to regulate the forest microclimate where forest canopy cover is high, and generally exhibit high species diversity, facilitating natural regeneration following stress events.

A PA-based community exhibiting restricted institutional capacity and limited access to technical and financial resources provides a social system example of low adaptive capacity.

Table 6 provides the framework used by the USAID Mekong ARCC team to designate adaptive capacity, as well as providing the key for combining **impact** with **adaptive capacity** to define **vulnerability** (impact x adaptive capacity = vulnerability). A vulnerable system is one that is sensitive to changes and extremes in climate and hydrology, is exposed to these extremes, and one for which the ability to adapt is constrained.

Table 6 – Matrix to determine vulnerability based on impact and adaptive capacity

	Impact					
Adaptive Capacity		***Very Low*** *Inconvenience (days)*	***Low*** *Short disruption to system function (weeks)*	***Medium*** *Medium term disruption to system function (months)*	***High*** *Long term damage to system property or function (years)*	***Very High*** *Loss of life, livelihood or system integrity*
	Very Low *Very limited institutional capacity and no access to technical or financial resources*	***Medium***	***Medium***	***High***	***Very High***	***Very High***
	Low *Limited institutional capacity and limited access to technical and financial resources*	***Low***	***Medium***	***Medium***	***High***	***Very High***
	Medium *Growing institutional capacity and access to technical or financial resources*	***Low***	***Medium***	***Medium***	***High***	***Very High***
	High *Sound institutional capacity and good access to technical and financial resources*	***Low***	***Low***	***Medium***	***Medium***	***High***
	Very High *Exceptional institutional capacity and abundant access to technical and financial resources*	***Very Low***	***Low***	***Low***	***Medium***	***High***

4.2 RESULTS: VULNERABILITY OF ECOSYSTEM SERVICES

The majority of key ecosystem services provided by functioning natural systems were found to be moderately to highly vulnerable to climate change. However, climate vulnerability varied between PAs. The source of this variation can be attributed largely to differences in the baseline condition of PA assets and the sensitivity of specific key assets. In general, degraded PAs under significant external pressures were found to be more exposed and therefore vulnerable to climate change impacts. This trend may not be immediately apparent in the results of the vulnerability exercise due to extreme levels of climate change expected for all sites selected for analysis.[3] It is recognized that PAs (and particular PA zones) that are heavily utilized and relied upon for ecosystem services may enter a negative feedback cycle, whereby ecosystem services impacted by climate change will become more valuable and experience higher incidences of external pressure and, hence, higher vulnerability to climate change.

[3] PAs selected for analyses were primarily selected because their geographic area was ranked highest for percentage change in climate parameters, stemming from the results of downscaled GCMs for the LMB. It therefore stands to reason that all PAs analyzed in this process will receive relatively high exposure ratings, contributing to high or very high vulnerability ratings.

4.2.1 SUMMARY OF VULNERABILITY RESULTS FOR KEY ECOSYSTEM SERVICES

Provisioning Services

Climate change impacts were found to have serious consequences for a number of key provisioning services and assets of each individual PA. *Provisioning services* were deemed most vulnerable in buffer zones and the peripheries of PAs where key NTFPs, suitable agricultural land, and water sources are most heavily utilized, and, in addition, where exposure to climatic change was most pronounced due to reduced capacity of forested systems to regulate microclimates in edge habitats. Services will likely be impacted in a number of ways, including:

- Declines in plant and animal productivity through changed seasonal harvesting times; changes in pollination and flowering processes; drought in the dry season; and increased flooding or soil saturation in the wet season;
- Decline in, or loss of, NTFPs such as wild fruits, vegetables, and medicinal plants, both a factor of reducing suitable range of production and increased reliance and pressure upon NTFPs if agricultural production is impaired; and
- Decline in water source quality and/or quantity; clean water is a key provisional service of PAs. Increased drought and changes in species composition and soil structure may affect the quantity and quality of water entering streams, ponds, trapeangs, and lakes in and adjacent to PAs. Likewise, changes in surface water temperature, sediment delivery, and flood regimes will likely raise the vulnerability of aquatic systems to invasion by exotic species; negatively impact populations of fish and other aquatic species targeted for food; and negatively impact the provision of services such as food production and clean water. Such climate change impacts may also negatively impact a host of *Regulatory Services*, as will be discussed next.

Regulating Services

Climate change impacts were found to affect a host of regulatory services such as water purification, waste breakdown and nutrient recycling, soil erosion, climate (i.e., microclimate), pest control, and flood control. Identified vulnerabilities of regulatory services in the PAs include:

- Decreased regulation of erosion and sedimentation, i.e., an increased occurrence and decreased interception of sediment in water sources due to more extreme dry and wet conditions exposing soil surfaces (reducing vegetative groundcover) and subsequently flushing sediment into waterways;
- Decreased regulation of flash flooding and landslides causing habitat/dwelling destruction, riverbank erosion, bank collapse, and localized landslides primarily due to increased precipitation in the wet season and increased runoff;
- Decreased pest control functions; biological control services are expected to decrease reliability and effectiveness as climate change impacts the ecological balance within food webs, such as insect co-dependence and pest/predator relationships between insects, birds, amphibians, plants, and mammals. Dramatic changes are likely to favor invasive species, displacing native predators, for example, and allowing corresponding native or introduced pests to flourish. Drought conditions favor many pests and have been the root cause of considerable damage to crops during drought years; and
- Decreased nutrient recycling functions; drier surface litter from higher temperatures will lead to slower terrestrial decomposition processes and buildup of otherwise recycled products. Losses or decline in certain insect and microbial communities may also drastically reduce waste recycling, decomposition processes, and, hence, nutrient recycling services. Changes in water chemistry due to rising temperatures will likely severely disrupt food webs in some wetlands and river systems, and may negatively impact nutrient cycling and breakdown of pollutants.

Habitat or Supporting Services

Climate changes were found to be a cause of ecosystem shifts or degradation that reduce the necessary support for species to survive and change migration pattern of species. Identified vulnerabilities of *Habitat or Supporting services* in the PAs include:

- Shifting/changes in habitat; ecosystems are expected to shift or alter under climate change. The movement of certain species to higher latitudes could lead to the loss of habitat in one area, as well as the appearance of new habitat in other areas.
- Loss of habitat; e.g., the risk of fire is likely to increase the destruction of habitat and the reduction of support services. Human settlement and infrastructure will limit the movement of ecosystems and, in some circumstances, prevent ecosystem shifts altogether and thereby cause permanent removal of a habitat.
- Reduction/degradation in biodiversity; many species are expected to be at a heightened risk of extinction due to climate change while others, better adapted to new rainfall and temperature regimes, will replace them. The expansion of invasive species, such as bamboo forest and grassland into degraded forests, or the replacement of local aquatic plants by exotics becomes more likely under predicted climatic conditions. Some species may experience a reduction in reproductive cycles and an altered length of time between flowering and the falling of mature seeds.
- Reduction in species population size; due to habitat loss or significant change in habitat type, population sizes of key species will likely decrease. Large species are particularly vulnerable to habitat loss. Many migratory species may need to find new suitable areas for breeding and nesting, if available. Reduction in topsoil moisture will reduce microflora and fauna, suppressing decomposition and nutrient recycling.

Cultural Services

Changes to ecosystems under the impacts of climate change will likely affect tourism, recreation, mental and physical health, and spiritual experiences associated with natural resources in PAs, as well as inspiration for culture, art, and design. Identified vulnerabilities of cultural services in the PAs include:

- Declines in tourism; under climate change, transformation of the ecosystem is expected to generate losses in flagship species such as tiger and other cats – and subsequent losses in tourism. Climate change impacts, such as flooding and storms, may destroy tourist facilities and reduce access to tourist sites.
- Damage to infrastructure and culturally significant areas; flooding, storms, and sea level rise will damage infrastructure and cultural assets in and around the protected areas, including roads, bridges, temples, and tourism facilities.

5 VULNERABILITY WITHIN ECOZONES

Summaries of vulnerability assessments for each case study PA are included below. More detailed CAM assessment matrices are included in the Annexes. Vulnerabilities and their rankings are as follows:

T – Temperature
P – Precipitation
W – Water availability
Sa – Salinity
Sl – Sea level
D – Drought
F – Flooding
S - Storm

Very High
High
Medium
Low
Very Low

5.1 NONG BONG KAI NON HUNTING AREA - UPPER FLOODPLAIN WETLAND/ LAKE

Nong Bong Kai Non Hunting Area in Chiang Rai, Thailand is representative of the upper floodplain wetland/lake ecozone. Nong Bong Kai will be exposed to changes in: (i) temperature; the maximum temperature during the dry season is projected to increase by 2°C year round, with high temperatures reaching up to 42.5°C; and (ii) flooding; a greater intensity of rainfall during the wet season leading to flooding and flash flooding. Consequently:

- Important aquatic species that are sensitive to temperature increases will likely experience declining populations, particularly in already degraded habitats
- Degradation of water quality by: (i) higher temperatures and (ii) increased surface runoff and sediment delivery will likely affect macroinvertebrate species and aquatic plant communities (fish habitat), leading to population declines or loss of species, as well as a disruption of migration patterns
- Invasion of exotic species, particularly aquatic weeds such as cogongrass, may become a threat to wetland ecosystems under warmer conditions
- Flooding destroys subsistence crops, livestock, and agricultural areas, as well as wild products of the wetland
- Flooding is associated with increased crop diseases and crop destruction from pest species (e.g., insects and rodents)
- Increased flooding will likely damage infrastructure and cultural assets in and around the protected areas – including roads, bridges, houses, resorts, and tourism facilities

Table 7 presents an overview of key threats, impacts, vulnerabilities, and adaptation options for the Nong Bong Kai Non Hunting Area. Although these assessments are based specifically on Nong Bong Kai, their application more generally to PAs in the upper floodplain wetland/lake ecozone is possible with the acknowledgement that some site-specific details may need to be altered.

Table 7 – Climate change vulnerability assessment for Nong Bong Kai – Non Hunting Area (upper floodplain wetland/lake ecozone). This analysis summarizes and amalgamates information from the CAM assessment (Annex 2) and baseline PA profile (Annex 1)

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options[4]
From CAM table		*Summaries from CAM*	*From CAM table*	
Nong Bong Kai	**Change and shift in regular climate**			
	Temperature (2 degrees Celsius increase throughout the year)	- **Provisioning services**: Increased temperature in a shallow lake would cause significant impacts on biodiversity and reduce populations of some species - **Regulating services:** Potential for losses in soil nutrient runoff, increases in erosion and filling of lake with sediments - **Habitat and supporting services:** Increasing problems with aquatic weeds, loss of population and change in migration patterns of fish populations, macroinvertebrate species, and migratory bird species - **Cultural services:** Loss in fish population and migratory birds leads to losses in tourism	Very High	- Maintain key species - Promote sustainable agriculture within communities - Control pests and invasive species - Minimize destructive human activities - Build 'check dams' to maintain and increase soil water availability during the dry season
	Precipitation (increase throughout the year except for Jan and Feb decrease up to 24%)	- **Provisioning services**: Drier conditions lead to an increase in sediment loads, affecting aquatic species. Higher rainfall in the wet season may improve water quality and restore aquatic ecosystems - **Regulating services:** Increased sediment and nutrient loss during the dry season and increased fresh water supply for the lake during the wet season - **Habitat and supporting services:** Decreased precipitation in the dry season would reduce water quality in the lake and promote changes in species assemblags. During the dry season, fish distribution is already restricted to the eastern end of the lake. As it is a shallow lake, fish distribution will be more severely restricted in the dry season with CC. - **Cultural services:** Higher rainfall leads to flooding which damages infrastructure and cultural assets –leading to losses in the tourism sector	Medium	- Maintain hydrological functions - Protection and renewal of critical fish habitat - Restore wetlands, e.g., tree plantation and species conservation
	Water availability (reduced for most of the year, up to 1.4%)	- **Provisioning services**: Reduced productivity of wild fruits & vegetables, rice crops, and tropical fruit - **Regulating services:** Drier soils lead to erosion and	High	- Wetland rehabilitation - Build 'check dams' to maintain and increase soil

[4] Detail of adaptation options are described in Section 6 of this report

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options[4]
		sedimentation of water resources - **Habitat and supporting services:** Reduced wetland area causing loss in habitat and food sources for fish and migratory water birds; increased risk of invasive species becoming established - **Cultural services:** Reduction in water availability might affect some recreation activities, thus affecting tourism industry		water availability during the dry season and minimize sediment entering waterways - Introduce emergency spillway for excess water during flood events - Implement sustainable ecotourism
	Change and shift in extreme events			
	Drought (does not change much from the baseline)	- **Provisioning services**: Drought will increase algal growth and reduce populations of some fish and aquatic species - **Regulating services:** Drier conditions on the floodplain could affect water filtering, regulation functions, and erosion - **Habitat and supporting services:** Over time the area of existing habitats and plant and animal populations may fall - **Cultural services:** Repeated drought conditions will increase migration towards protected area resources, i.e., the wetland	Medium	- Enhance resilience of ecosystems - Rehabilitation and restoration of wetland - Collect sufficient runoff water during the dry season - Fire protection
	Flooding/ Flash floods	- **Provisioning services**: Destruction of crops, livestock, and wetland products - **Regulating services:** Flooding may bring benefits for soil nutrient enrichment, but also increase crop diseases, insects, and rodents - **Habitat and supporting services:** Flooding can destroy habitat, increase sedimentation (therefore filling the wetland), and make rehabilitation of natural systems more difficult - **Cultural services:** Flooding damages infrastructure and cultural assets, causing a loss of tourism	Very High	- Introduce emergency spillway for excess water during flood events - Establish monitoring of water flow - Enrichment planting - Maintain drainage system - Sediment removal and erosion control
	Storms (mostly associated with high rainfall)	- **Provisioning services**: Destruction of crops, livestock, and wetland products - **Regulating services:** Biological control services will be reduced following storms – due to losses in predators such as birds and amphibians - **Habitat and supporting services:** Damage to and degradation of remaining natural habitat may open the area to invasive species and increased human penetration - **Cultural services:** Reduced tourist access and visitation	High	- Rehabilitation - Introduce emergency spillway of excess water during flood events - Maintenance of infrastructure system

5.2 NAKAI-NAM THEUN NBCA – LOW-MID ELEVATION MOIST BROADLEAF FOREST, HIGH ELEVATION MOIST BROADLEAF FOREST

Nakai-Nam Theun NBCA in Khammouan, Lao PDR is representative of two ecozones: (i) low-mid elevation moist broadleaf forest, and (ii) high elevation moist broadleaf forest. Projected impacts from climate change include increased rainfall during the wet season, likely associated with more frequent flash floods and landslides. The principal vulnerabilities of the ecosystem associated with flooding are:

- Seasonal destruction of subsistence crops, livestock, and agricultural areas
- Reduced access to forest products, e.g., NTFP gathering
- Degradation of biodiversity through habitat destruction and the spread of invasive exotics
- Higher temperatures and moisture stress can alter tree mortality and recruitment, changing forest types and ecosystem function
- Population decrease of flagship species including large cats and primates
- Natural system provisional services becoming more important during and after extreme flooding, leading to greater exploitation of forest products if agricultural lands are destroyed and access to markets is reduced

In the low-mid elevation moist broadleaf forest, temperature changes are projected to have significant impacts. Key impacts include:

- Higher temperatures during the dry season leading to an increase in evapotranspiration and reduced water availability for agriculture and domestic uses
- Higher temperatures during the dry season creating drier soil surface layers and leading to increases in erosion and soil loss, particularly in already degraded areas
- Higher temperatures and moisture stress altering tree mortality and recruitment, changing forest types and ecosystem function
- Increase of up to 5°C in the wet season, leading to higher surface water temperature affecting aquatic plant growth and habitat suitability for key fish species. Spread of exotic aquatic plant and fish species resulting in further degradation of ecosystem functioning
- Temperature increases could lead to habitat shifts, in terms of both location and elevation, particularly towards logged areas at the edge of the Plateau and the base of the Dividing Hills
- Higher temperatures affect migration of waterbirds and the movement of larger species, such as tigers, guars, and large cats through the existing wildlife corridor
- Population decrease of flagship species including large cats and primates

Table 8 presents an overview of key threats, impacts, vulnerabilities, and adaptation options for the Nakai-Nam Theun NBCA. Although these assessments are based specifically on the Nakai-Nam Theun NBCA, their application more generally to PAs within the two ecozones, and particularly within the Khammouan PA cluster, is possible with the acknowledgement that some site-specific details may need to be altered.

Table 8 – Climate change vulnerability assessment for Nakai-Nam Theun NBCA (low-mid elevation moist broadleaf forest, and high elevation moist broadleaf forest ecozones). This analysis summarizes and amalgamates information from the CAM assessment (Annex 2) and baseline PA profile (Annex 1)

Most vulnerable system component or assets	**Threat**	**Impact summary**	**Vulnerability**	**Adaptation options**
From CAM table		***Summaries from CAM***	***From CAM table***	
NNT	**Change and shift in regular climate**			
	Temperature (1.5 - 5 degrees Celsius increase throughout the year, with a maximum in July) (annual average increase of 10% with a maximum of 16% increase in July)	- **Provisioning services**: Important species are sensitive to the projected high temperature increases and populations would be reduced especially in already degraded habitats. Potential for shift to climax bamboo grasslands in some areas - **Regulating services:** Increases in erosion and soil loss, especially in degraded areas. The forest floor could reduce natural water filtering and regulation functions - **Habitat and supporting services:** Change in microclimate would lead to the shifting of ecosystems, habitats, and species ranges. Species reliant on high elevation, cooler habitats may be lost from the region	Medium[5]	- Seeding and regeneration of forest - Control logging and collection of forest products - Invasive species and pest control - Planting high value trees - Creating buffer zones for refugee species - Enhance habitat connectivity
	Precipitation (increase in the wet season and decrease in the dry season)	- **Provisioning services**: Some medicinal plants and root plants might be sensitive to changes in precipitation - **Regulating services:** Changes in water regime of hydropower stations and their surroundings, increased risk of flash flooding and associated riverbank erosion, bank collapse and localized landslides - **Habitat and supporting services:** Early onset of the monsoon is expected to increase erosion and sedimentation of fresh water sources. Degraded water quality of streams and river would impact on fish habitat. High sediment loads are also a physical irritant, affecting fish gills, and on settling out can smother fish eggs and encourage algal growth, creating opportunities for invasive species to take over - **Cultural services:** Flooding and landslides will damage infrastructure and cultural assets, restricting access to remote	Medium	- Restoration of habitat - Protect and enhance riparian vegetation to minimize sediment entering waterways - Maintenance of hydrological function - Improve connectivity of PAs within landscape - Raising awareness of water conservation and sustainable cultivation, with a focus on soil conservation

[5] NNT elevation is high with unique fauna and flora assemblages that are less disturbed; thus, NNT will be less vulnerable to CC compared to other parts of the province

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
		areas		
	Water availability (reduced maximum of 1.6% in the dry season but increase of 7% in the wet season)	- **Provisioning services**: Reduced productivity of some root plant products - **Regulating services:** Highly saturated soil could lead to flash flooding during heavy rainfall events and longer-term erosion. Changes in schedule and regime for hydropower operation - **Habitat and supporting services:** Increases in invasive exotic species during dry conditions	Medium	- Sustainable forest management - Maintenance of water sources and hydrological function
	Change and shift in extreme events			
	Flooding/ Flash floods	- **Provisioning services**: Seasonal destruction of subsistence crops and livestock and agricultural areas, reduced access to potable water, reduced access to forest products - **Regulating services:** changed water regimes limit the ability to cope with regular flooding - **Habitat and supporting services:** Increased spread and pressure from invasive exotics leading to destruction or pollution of aquatic habitat - **Cultural services:** Restricted access to specific cultural and forest sites for hunting, and gathering NTFPs. Restricted access to tourist attractions and destruction of infrastructure	Very High	- Soil conservation - Safeguard against slope instability - Monitor water flow and flooding events - Maintain drainage system - Improve incident management
	Storms / typhoons	- **Provisioning services**: Potential losses in some wild food & products, such as bamboo and rattan shoots, fruits, greens, honey, khem grass, cardamom and malva nuts - **Regulating services:** Biological control services will be reduced following storms - **Habitat and supporting services:** Extreme storms will damage and degrade remaining natural habitat, opening the areas to invasive species - **Cultural services:** Reduced tourist access and visitation; damage to infrastructure	High	- Erosion prevention - Monitoring of extreme events - Rehabilitation of degraded areas - Maintenance of infrastructure systems - Develop early warning systems for storms and typhoons

5.3 PHNOM PRICH WILDLIFE SANCTUARY - MID AND LOW ELEVATION DRY BROADLEAF FOREST

Phnom Prich Wildlife Sanctuary (WS) in Mondulkiri, Cambodia is representative of the mid and low elevation dry broadleaf forest ecozones. Phnom Prich WS will be exposed to climate change impacts including: major increases of 3-4°C in maximum temperature; increased rainfall intensity and subsequent flash flooding; significant decreases in rainfall and water availability during the dry season leading to large increases in the frequency and duration of drought. The most vulnerable services are embodied in:

- Declining water resources due to a hotter and dryer climate reducing crop productivity and domestic water availability
- Habitat degradation for important commercially exploited NTFP species, such as resin trees and cardamom due to sensitivity to temperature increase (see NTFP section of the USAID Mekong ARCC Main Report), and their presence in already degraded habitats
- An alteration of tree mortality and recruitment due to higher temperatures and moisture stress, changing forest type, and ecosystem function
- Earlier drying of seasonal trapeang ponds leading to severe water shortages for dependent biota. Of particular significance to water birds and large mammal populations
- The shifting of ecosystems and incursion by invasive species causing biodiversity losses. An expected increase in the area impacted by invasion of climax bamboo grasslands, currently present in degraded forest areas
- Drier soils and early onset of the monsoon will likely lead to water quality degradation. Increased sediment and nutrient loads in waterways will negatively affect some fish species and encourage algal growth
- Increased fire risk and subsequent destruction of habitats and biodiversity
- Population decrease of flagship species such as the Asian elephant and the Indochinese tiger due to loss of suitable habitat and prey species populations

Table 9 presents an overview of key threats, impacts, vulnerabilities, and adaptation options for the Phnom Prich WS. Although these assessments are based specifically on the Phnom Prich WS, their application more generally to PAs in the mid and low elevation dry broadleaf forest ecozone is possible with the acknowledgement that some site-specific details may need to be altered.

Table 9 – Climate change vulnerability assessment for Phnom Prich Wildlife Sanctuary (mid and low elevation dry broadleaf forest ecozone). This analysis summarizes and amalgamates information from the CAM assessment (Annex 2) and baseline PA profile (Annex 1)

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
From CAM table		*Summaries from CAM*	*From CAM table*	
Mondulkiri cluster	**Change and shift in regular climate**			
	Temperature (3-4 degrees Celsius increase throughout the year)	- **Provisioning services**: Higher temperature increases evapotranspiration and reduces water availability for agriculture and domestic uses. Important species such as resin trees and cardamom may decline - **Regulating services:** Drier weather has the potential to increase erosion, soil loss, and soil nutrient runoff. This will impact regulation of multiple use areas and buffer zones - **Habitat and supporting services:** Drier forest conditions increase the likelihood of fire destroying habitat and ecosystems, and increase sediment loads entering waterways and bodies. The latter impact will likely reduce local aquatic plants, increase exotics such as water hyacinth, promote algal growth, and impact on fish breeding & migration. - **Cultural services:** Loss in flagship species such as tigers and other cats – and subsequent losses in tourism attractions	Very High	- Pest control - Fire prevention - For highly vulnerable and rare species, establish captive populations to conserve genetic diversity - Build resilience to give species, ecological communities, and ecosystems the best chance to adapt - Plant seedlings to maintain native species and introduce future climate-suitable species - Forest management plans - Establish and expand PAs as a refuge to protect threatened species, enhancing corridor habitats to create migration corridors
	Precipitation (up to 12% decrease in dry season and 14% increase in the wet season)	- **Provisioning services**: Decreased rainfall would reduce productivity of plants, such as medicinal plants and fruits. Earlier and more severe drying of trapeangs will reduce food and water availability for large mammals, such as Eld's deer, banteng, and wild and domesticated buffalo, as well as affecting birds and the productivity of species such as eels and worms - **Regulating services:** More intensive rainfall may lead to bank erosion and sedimentation of water sources. Reduced water and food availability could diminish natural predators of pests such as plant hoppers and	Very High	- Create migration corridors - Maintain connectivity within PAs - Pest control - Zoning policy with different zone management

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
		mealy bugs - **Habitat and supporting services:** Fundamental changes in the current rainfall regime, particularly persistent increases in wet season rainfall, will lead to significant and permanent changes in the ecosystem and species assemblages. Severe drying of trapeangs will lead to water shortages for dependent biota and create opportunities for invasive species - **Cultural services:** Increased flooding, flash floods, and landslides that will damage infrastructure and cultural assets, limiting access to tourism sites and sites for hunting and gathering		
	Water availability (reduction throughout the entire year up to 20%)	- **Provisioning services**: Reduced soil moisture may cause reduced productivity of wild fruits, herbs, vegetables, medicinal plants, and sap flow in trees - **Regulating services:** Drier soils will be more vulnerable to erosion, leading to sedimentation of water sources and reduced microflora and fauna and suppressed decomposition and nutrient recycling - **Habitat and supporting services:** Reduced biodiversity leading to permanent changes to the ecosystem and increases in invasive exotic species adapted to dry conditions	Very High	- Enrichment planting with species that are more adaptable to dry conditions in degraded forest areas - Enhance riparian vegetation to protect waterways from sedimentation - Maintain water sources, emphasize water source protection - Water management
	Change and shift in extreme events			
	Drought	- **Provisioning services**: Reduced availability of wild food and reduced productivity of agriculture, resin trees, and cardamom - **Regulating services:** Losses in soil nutrient enrichment and reduced regulatory services - **Habitat and supporting services:** Drier forest conditions and increased likelihood of fire destroying habitat and reducing support services. Fewer trapeangs and longer dry periods in those that remain resulting in severe water, food, and habitat constraints for	Very High	- Enrichment planting - Fire prevention - Maintain water regulation - Raising awareness of water conservation, sustainable cultivation and soil conservation

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
		dependent biota - **Cultural services:** Greater dependence and more intensive use of forest products to compensate for reduced agricultural production and increased migration towards protected area resources		
	Flooding/ Flash floods	- **Provisioning services**: Damage to crops, livestock, and agricultural areas - **Regulating services:** Flooding is associated with increased crop diseases, insects, and rodents; pest control will hold greater importance - **Habitat and supporting services:** Increased sedimentation and filling of trapeangs through flooding and drought conditions will make rehabilitation and enrichment planting in natural systems more difficult - **Cultural services:** Damage to infrastructure and cultural assets, limiting access to tourism sites, and sites for hunting and gathering	Very High	- Enrichment planting to reduce erosion and water runoff - Stabilize river banks – bio engineering - Create more wetlands and floodplains with capacity to withhold water - Flood control
	Storms	- **Provisioning services**: Destruction of crops and housing leading to greater dependency on wild products - **Regulating services:** Biological control services will be reduced due to losses in predators - **Habitat and supporting services:** Damage to and degradation of remaining natural habitat opening the area to invasive species and increased human penetration - **Cultural services:** Reduced tourist access and visitation	High	- Erosion prevention - Monitoring of extreme events - Rehabilitation of degraded areas - Maintenance of infrastructure systems

5.4 U MINH THUONG NATIONAL PARK – LOW LYING ACIDIC SWAMP AREA FOREST

The Kien Giang Biosphere Reserve includes the PA of U Minh Thuong National Park. The PA represents the low-lying acidic area swamp forest ecozone.

U Minh Thuong NP will be exposed to climate change impacts including a 2-4°C increase in temperature, and increases in precipitation, flooding, and storm frequency. The specific vulnerabilities of the ecosystems under climate change are:

- High temperature reducing water availability for agriculture and domestic uses. Temperature rise may also cause habitat loss and change the migration patterns of important bird species. High temperatures may raise water temperatures within wetland pools outside of the thermal tolerance range of fish species important to subsistence and commercial livelihoods
- High temperature increases the risk of acid swamp forest fires, causing loss of habitat, NTFPs, and ecosystem regulatory services
- Higher temperatures and moisture stress can alter tree mortality and recruitment, changing forest types and ecosystem function
- Early onset of the monsoon following a drier dry period is expected to increase erosion, sedimentation, and nutrient deposition in water sources
- Heavier rainfall would reduce the ability of local canals to drain, causing flooding and inundation in the surrounding floodplain that disrupts and destroys crops

Table 10 presents an overview of key threats, impacts, vulnerabilities, and adaptation options for U Minh Thuong NP. Although these assessments are based specifically on the U Minh Thuong NP, their application more generally to PAs in the low lying acidic swamp forest ecozone, and in some cases to the delta freshwater wetlands ecozone and the delta mangroves and coastal wetlands is possible with the acknowledgement that some site-specific details may need to be altered. In particular, this assessment does not include sea level rise, which will have major ongoing impacts on mangroves and coastal wetlands and the people who depend upon them for their livelihoods.

Table 10 – Climate change vulnerability assessment for U Minh Thuong National Park (low lying acidic swamp area forest ecozone). This analysis summarizes and amalgamates information from the CAM assessment (Annex 2) and baseline PA profile (Annex 1)

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
From CAM table		*Summaries from CAM*	*From CAM table*	
Kien Giang Biosphere Reserve	**Change and shift in regular climate**			
	Temperature (2-4 degrees Celsius increase throughout the year)	- **Provisioning services**: Loss of productive agriculture; reduced water availability for domestic uses; increased disease risk for shrimps; and, decline of other aquatic populations including harvested fish species - **Regulating services:** High temperatures leading to drying of peat in U Minh Thuong, increasing the risk of fire. Water regulation within the park will also be affected - **Habitat and supporting services:** Reduction in biodiversity and population size of some species - **Cultural services:** Decline of water birds in the area may lead to reduction in tourism	Very High	- Restoration of peatlands - Creation of refuges for migration of species, especially waterbirds - Manage water quality and quantity - Expand protected areas
	Precipitation (decreased rainfall in the dry season, but will increase in the wet season up to 15%)	- **Provisioning services**: Less rainfall during the dry season will likely reduce productivity of crops. Heavy rain in the wet season will likely impact on some crops and aquaculture, especially shrimp farms - **Regulating services:** Higher monsoonal rainfall would lead to erosion and sedimentation in water sources, but it could also assist biodiversity recovery from drought and improve water quality of wetlands - **Habitat and supporting services:** Less rainfall during dry season leads to shortage of water to support some plant species and creates opportunities for invasive species. Change in rainfall pattern will lead to changes in seasonal grassland habitat and migration patterns of water bird species - **Cultural services:** Increased flooding will damage infrastructure and cultural assets and restrict access to specific cultural sites for gathering and religious purposes	Very High	- Wetland restoration- removal of floating pest plants - Establishment of new meteorological and hydrological stations at U Minh Thuong National Park - Monitor water logging
	Water availability (decrease thoughout the year between 4-	- **Provisioning services**: Reduced water availability will reduce productivity of crops, and vegetables, as well as cause the drying out of grassland, peat, and wetland. Low water availability will lead to high exposure to salinity, affecting not only crops but also ecosystems, and decrease the water available for drinking and other domestic uses.	High	- Construction of small check dams to store water for consumption during the dry season

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
	8%)	- **Regulating services:** Drier soils will be more vulnerable to erosion, leading to sedimentation of water sources, reduction of microflora and fauna, and suppressed decomposition and nutrient recycling, as well as increasing the risk of fire and changing water regulation patterns - **Habitat and supporting services:** Decrease in available fresh water affecting growth rate of mangroves; permanent changes to the ecosystem and reduction of habitat for some species		
	Sea Level Rise (up to 50 cm by 2050)	- **Provisioning services**: Land losses for agriculture leading to decline in productivity; salt water may contaminate drinking water - **Regulating services:** Sea level rise will: exacerbate flooding (by virtue of inundation and limiting drainage capacity in coastal areas); increase salinity and coastal erosion; affect water transfer and transport - **Habitat and supporting services:** Higher sea levels lead to reduction in mangrove habitat, decline in mangrove animals, and decline in the number of species - **Cultural services:** Reduced area of human settlement: many households will have to migrate inward to higher ground, sea level rise will limit access or destroy some cultural icons along the coast	Very High	- Planting of mangrove forests - Maintain, upgrade and expand dyke system - Building raised model homes to cope with sea level rise - Integrate climate change into coastal zone management plans
	Saline Intrusion (salinity is expected to not change much for the area)	- **Provisioning services**: Limit to the choice of crops that can be grown and, at higher concentrations over long periods, salinity can kill trees and make the land unsuitable for agricultural purposes, hence reduce crop yields - **Regulating services:** Salinity increases the "hardness" of water, causing corrosion, scale, and poor steam quality - **Habitat and supporting services:** Salinity change causes a shift in the relative distribution of species within taxa occupying a halocline within the mangrove forest. Salinity reduces the ability of plants to take up water, which will affect the growth rate of some plant species	Medium	- Building sluice gates for all canals to prevent saltwater intrusion - Maintain, upgrade, and expand dyke system
	Change and shift in extreme events			
	Drought (a greater likelihood of drought for April, May,	- **Provisioning services**: Increased salinity and forest fire may lead to losses in crop production, reducing water availability for agriculture and domestic uses - **Regulating services:** Drier peat and grassland may lead to fire	Very High	- Better grazing regimes and management practices to maintain systems - Fire prevention within peatland and grassland - Agricultural training with sustainable ecological

Most vulnerable system component or assets	Threat	Impact summary	Vulnerability	Adaptation options
	November and December)	risk, changes in water regulation, and reduce the species populations, such as Sarus Crane, due to the lack of water and food during drought - **Habitat and supporting services:** Drying of grassland and peat affecting species habitat; potential destruction of some plant species		adaptation
	Flooding/ Flash floods	- **Provisioning services**: Seasonal destruction of subsistence crops, livestock, and agricultural areas (e.g., loss of rice crop, shrimp crop, damaged fruit trees, etc.) - **Regulating services:** Inundation of the surrounding floodplain will reduce the ability of local canals and paddy fields to drain, increasing erosion and sedimentation - **Habitat and supporting services:** Decrease in available fresh water affecting growing rate of mangroves, making rehabilitation and enrichment planting in natural systems more difficult - **Cultural services:** Damage to infrastructure, roads, houses and cultural buildings. Reduction in tourist access and visitation	Very High	- Enhance early warning and disaster response capacity - Introduce a flood insurance system - Investments in flood control and natural disaster mitigation and other programs - Awareness raising of climate change amongst communities
	Storms (storm surge and typhoons)	- **Provisioning services**: Destruction of crops and housing leading to greater dependency on wild products, loss of shrimp crop, fishing time - **Regulating services:** Reduction in salinity due to increasing volume of fresh water. Increased erosion, especially in coastal areas - **Habitat and supporting services:** Damage to and degradation of remaining natural habitat opening the areas to invasive species. Damage to mangrove forests, especially in coastal areas - **Cultural services:** Reductions in tourist access and visitation; damage to dykes, pond infrastructure, roads, and drainage facilities	Very High	- Enhance early warning and disaster response capacity - Maintain drainage and infrastructure systems - Enrichment planting to increase resilience to extreme events

6 ADAPTATION OPTIONS

6.1 APPROACH

Climate adaptation is defined as building climate change resilience in communities, sectors, and areas. In the context of natural ecosystem conservation and management, adaptation requires an understanding of how climate change may impact a given system (i.e., generate threats and stresses to the system) so that appropriate management strategies can be identified (Dubois *et al.* 2011). Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages. Furthermore, it is argued that human and natural systems will, to some extent, adapt autonomously and that planned adaptation can supplement autonomous adaptation. However, "options and incentives are greater for adaptation of human systems than for adaptation to protect natural systems" (IPCC 2007). Given the ecosystem services provided by PAs to human systems, and the impact human actions have upon the continued functioning of natural systems within PAs, adaptation measures identified in the current project aim to address both human pressures and climate change impacts.

6.2 ADAPTATION RESPONSE

To develop adaption response options, the next phase of the CAM process involves: (i) identifying adaptation options to address the vulnerabilities of strategic assets and systems, (ii) choosing between them, and then (iii) drawing up adaptation plans and projects (Carew-Reid *et al.* 2011). It is notable that in completing these steps it is necessary to consider the current conservation impact of management actions on protected areas.

Opportunities for increasing resilience (i.e., for reducing vulnerability) through adaptation can be found in natural, built, social, economic, and institutional systems, for example:

(i) Engineering options (e.g., flood protection dykes, sea walls, and effective drainage systems)

(ii) Traditional local strategies (e.g., terracing and selection of crops)

(iii) Social responses (e.g., resettlement and migration)

(iv) Land use planning (e.g., zoning and development controls)

(v) Economic instruments (e.g., subsidies and tax incentives)

(vi) Natural systems management (e.g., rehabilitation, conservation, watershed management)

(vii) Sector-specific adaptation practices (e.g., agriculture - species, cropping patterns)

(viii) Institutional options: associated policy, institutional and administrative innovations

In most cases, an effective response requires an integrated set of adaptation actions across those fields of management so that one reinforces the other. See Carew-Reid *et al.* (2011) for further details of the adaptation planning process used in the CAM methodology.

6.3 PA MANAGEMENT AND THE ADAPTATION DEFICIENT

The following review of management options for climate adaption in the protected areas of the LMB draws upon examples of successful PA management planning and implementation in the region. PA management in the LMB was the focus of a large Protected Areas and Development (PAD) project in the early 2000s, led by ICEM. The PAD project outlined a series of policy and management plans to

increase the quality and conservation of protected areas throughout the LMB (see ICEM (2003c)). Many of the conservation approaches have already been established in the LMB and continue to be important management actions.

However, some adjustments and new approaches to protected area management and planning will be needed under climate change. Without careful integration of climate adaptation planning into PA policies and management, extant measures to conserve PAs may not be sufficient to ensure the ongoing health and ecological functioning of natural areas within the LMB.

Below we outline major foci for PA management strategies that either currently are being implemented in the LMB, or *should* be implemented in the LMB. We consider, in some cases, inadequate implementation of these strategies to be the most prominent aspect of what we previously described as the adaptation deficit. Hence, our broader discussion of adaptation planning must be viewed in light of these broader management concerns, and any specific adaptation strategies must not be viewed as stand-alone actions.

6.3.1 MANAGEMENT ZONES

Management zones are fundamental to the effective management of activities within PAs of the LMB. Zoning defines what can and cannot occur in different areas of a PA in terms of: natural resources management; cultural resources management; human uses and benefits; visitor uses, experiences, access, and facilities; and, PA development, maintenance, and operations. Numerous PAs within the LMB utilize a series of management zones in their planning and operations.

An important consequence of climate change is shifting habitat. In turn, this shift may force the migration of species to become more frequent and necessary for genetic exchange. Facilitating this migration requires long term planning of buffer zones and corridors, including extensive scientific research to best place management actions. Climate-induced shifts of ecosystems may also require rezoning of PAs to balance conservation and development around PAs. Key actions for zoning management include:

- **Establishment of a core zone of significant ecosystems or habitat** – this zone is the central area of the PA and is the focus of strong protection measures. Defining the core zones' resources, as well as agreed-upon control and safeguards therein are important activities. In the context of climate change, this zone may need to be expanded or relocated to provide appropriate protection for significant habitat or species.
- **Buffer zone** – this zone is an extension of a PA that surrounds the core zone. The intensity of human activities is greater than that allowed in the core zone. This zone creates a buffer wherein NTFP collection, tourism, and other uses may occur; the existence of this area provides communities with an alternative to exploiting forest resources in the core zone and thereby protects the latter. Once again, it may be necessary to expand or relocate the buffer zone to increase resilience of the core zone to climate change.
- **Transition area** – this zone is similar to the buffer zone, except that even more intense development is permitted, such as agriculture.

Community participation and a flexible approach to management zones are crucial to their success as a policy tool (ICEM 2003c). Climate change represents a major regime change and, therefore, must be integrated into ongoing planning of management zones within PAs.

6.3.2 MANAGING ECOSYSTEM RESILIENCE AND CONNECTING LANDSCAPES

In general terms, the resilience of an ecosystem is expressed by its ability to absorb disturbance and maintain its original identity, composition, processes, and ecosystem functions (Folke *et al.* 2004). **Higher levels of biodiversity provide more options for existing processes to adapt and**

therefore offer greater climate change resilience (Folke *et al.* 2004). The size of an ecosystem is also known to influence its resilience, with larger, less fragmented systems being more resilient (Zhou *et al.* 2013).

It follows that the condition and characteristics of landscapes surrounding PAs will influence the resilience of the ecosystems in a protected area (Zhou *et al.* 2013). **Climate adaptation capacity is generally increased through improving landscape-scale connections between core habitat patches**. Corridors provide available habitat for organisms to move freely through the landscape following preferred habitat and climatic conditions. A key factor in the successful management of connected habitats will be effective collaboration across boundaries. Ecosystems and watersheds transcend national borders. Poor management in one country often has negative cross-border impacts in adjacent areas, and cross-country management will be key to PA conservation in the LMB.

To enhance the capacity of ecosystems to naturally respond and adapt to a changing climate, management policies, plans, and actions must work to **protect and enhance ecosystem condition within habitat patches, and strengthen habitat connectivity across landscapes**. These actions have the added benefit of enhancing the ecological, social, and economic benefits provided by PAs.

The structure and productivity of ecosystems in an undisturbed state represent their most healthy, resilient condition. Measures that bring the actual state of an ecosystem closer to this ideal will, by implication, optimize the value of ecosystem services they provide. From an ecological and economic perspective, it is also much easier to maintain the ecological integrity of productive existing habitats from external threats, such as climate change. The identification, maintenance, and proactive management of refugia and pockets of resilience should be a focus of restoration efforts. Interventions that protect ecosystem goods and services, support sustainable use of natural resources, and/or mimic natural processes are important management tools.

Actions towards this aim include:

- Assisted regeneration, including site preparation and pest management
- Identification of key processes sustaining fundamental biodiversity features – reinstatement of these processes where applicable
- Maintenance of appropriate disturbance regimes including fire control and managed flood pulses
- Pest management including mitigation of threats from invasive species and pests
- Definition and application of key concern thresholds for critical protected area management objectives
- Maintenance or creation of habitat corridors
- Breeding programs, e.g., for some threatened or critical species, breeding programs, including those in captivity, may assist the re-establishment of breeding populations

Specific actions targeted at the **restoration of degraded wetlands** include:

- Restoration of both the wetland area and adjacent terrestrial habitat
- **Management of water flow** regimes can be necessary, i.e., re-establishment of hydrologic connectivity with neighboring water sources.

Specific actions targeted at the **restoration of degraded forests** include:

- **Fire prevention** – Dry forest conditions outside of the wet season raise the risk of small human-lit fires, for crop management or household use, becoming large, destructive wildfires. In some locations, climate change will increase this risk in the LMB. Initiatives to prevent such occurrences include community education, warning systems, and developing incident response capacity within PA staff.

- **Secondary or regrowth forests** – Support to secondary or regrowth forests provides a foundation for rehabilitation of degraded areas.
- **Species management** – Management or restoration of species involves manipulating, enhancing, or restoring specific plant and animal populations, as well as vaccination programs and re-introducing species in former locations.
- **Community forest management** – This collaborative approach between communities and forest managers distributes the costs and benefits of improved forest management.
- **Enrichment planting** – An important technique in forest rehabilitation wherein valuable species are introduced or re-introduced to degraded forests that complement existing species. In some cases, this may involve plantations of native species for commercial purposes.

6.3.3 EDUCATION AND PUBLIC ENGAGEMENT

Community engagement is central to adaptation planning in the LMB, particularly with regard to PAs. Community awareness of ecosystem adaptation issues dictates their usage patterns and, by implication, the continuing productivity of those ecosystems. Although the following actions originate within recent trends towards community-based forest management, their significance is amplified by climate change.

- Adequate public consultation and input into protected area management zoning plans
- Linking climate change to immediate community issues, such as limited access to water or declining crop productivity
- Communication activities concerning the benefits of resilient protected area systems for the maintenance of ecosystem services
- Enhancing understanding and management of disturbance regimes such as floods and fires
- Raising awareness and understanding of the economic contribution of protected areas to water resources management
- **Promotion of sustainable agriculture** – minimize use of pesticides to protect pollinators and water resources; promote agroforestry and forestry activities on cleared land; and, support the adoption of organic farming methods and associated supply chains
- **"On farm conservation" –** maintain populations of local crop cultivars in the natural habitats, whether as uncultivated plant communities or in farmer fields as part of existing agro-ecosystems
- **Sustainable tourism** – Sustainable ecotourism generates direct income streams for local communities that if well managed provides long-term incentives for ecosystem conservation

6.4 ADAPTATION PLANNING FOR ECOZONES

Where above we provided a series of overarching recommendations for building ecosystem health and climate resilience within the LMB, specific actions at the PA level can be much more targeted. As an example, the following section provides specific recommendations for building climate adaptation capacity within the four case study PAs. While there is considerable overlap between those actions stated in the preceding section and the current section, it is evident that only at a PA scale do management recommendations become readily applicable.

6.4.1 NONG BONG KAI NON HUNTING AREA - UPPER FLOODPLAIN WETLAND/LAKE

Human activities in and surrounding the PA put enhanced pressure upon the lake environment, and may compromise the resilience and resistance of natural systems to projected climate change. With this in mind, adaptation options presented in Table 11 aim to mitigate impacts from climate change by addressing both human pressures and climate change impacts.

Table 11 – Summary of recommended adaptation options for Nong Bong Kai Non Hunting Area

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
Address adaptation deficit	▪ Maintain existing habitat – minimize grazing and other agricultural impacts adjacent to the wetland ▪ Soil conservation –reforestation and other bioengineering activities in riparian and sloping areas to minimize sediment entering waterways ▪ Education programs to promote sustainable agriculture and understanding of biodiversity conservation ▪ Manage pest species - remove invasive species, establish barriers between exotics and native species ▪ Promote native fish population increases by sustainably managing fish extraction ▪ Establish or maintain hydrological connectivity with nearby natural waterways ▪ Advocate for sustainable ecotourism which promotes the link between conservation and tourism development	▪ Monitor water quality and implement water treatment plan for runoff ▪ Strengthen the capacity of local and national disaster response systems for flooding ▪ Monitoring system for species generation, fish, and waterbirds habitat and populations ▪ Intensive monitoring system for riparian zone and slope stabilization ▪ Strengthen the capacity and efficiency of local administration organizations and communities to manage the wetlands	▪ Development and/or strengthening of national wetland conservation plan including buffer zone, riparian zone, and restricted areas ▪ Strengthening of national weather forecasting and extreme weather warning systems ▪ Implement effective planning and policies to minimize the impact of downstream hydropower developments on aquatic ecosystem connectivity
Additional adaptation	▪ Establish a consultation program regarding the impact of climate change on local communities and environments ▪ Incorporate climate change into agriculture and cultivation ▪ Development of management system to provide sufficient water to meet the needs of farmers and people according to activities and changes in climate ▪ Undertake enrichment planting in riparian areas with species suitable to predicted future climate in the region ▪ Development of refuge habitat areas for species breeding and nesting	▪ Installation or improvement of drainage systems to minimize future flood impacts ▪ Monitor the presence and density of threatened species ▪ Develop species conservation programs to protect identified threatened species ▪ Promote sustainable ecotourism ▪ Construct infrastructure to protect riparian communities from flooding, flash flooding, and landslides, such as flood control dams, flood diversion channels, and drainage systems	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species

Adaptation to induce system shift	▪ Restoration of degraded areas with native species adapted to predicted future climate in the region ▪ Improve the connection of the PA with surrounding forests or other PAs	▪ Land use planning allowing ecosystems to shift with minimal obstruction by community settlements and infrastructure ▪ Enhancement of the wetland, i.e. increase function performed by existing wetland under CC	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species

6.4.2 PHNOM PRICH WILDLIFE SANCTUARY - MID AND LOW ELEVATION DRY BROADLEAF FOREST ECOZONE

The current climate of Phnom Prich Wildlife Sanctuary, mid and low elevation dry broadleaf forest is generally very dry, and it is expected to experience higher temperatures along with reduced precipitation and water availability with future climate change. Adaptive options for this area incorporate mitigation to minimize the impact of hotter conditions. Adaptive actions are provided in Table 12.

Table 12 – Summary of recommended adaptation options for Phnom Prich Wildlife Sanctuary within mid and low elevation dry broadleaf forests

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
Address adaptation deficit	▪ Establishing buffer zone for different land use and conservation purposes ▪ Maintain water source for community's drinking water and fishing ▪ Soil conservation –reforestation and other bioengineering activities in riparian and sloping areas to minimize sediment entering waterways ▪ Build 'check dams' to maintain and increase soil moisture availability within the forest during the dry season ▪ Enrichment planting of degraded areas ▪ Education programs to promote sustainable agriculture and understanding of biodiversity conservation ▪ Develop an early fire warning system, restrict burning during the dry season ▪ Invest in fire fighting equipment and training of PA Rangers ▪ Manage pest species - remove invasive species, establish barriers between exotics and native species ▪ Scale-up forest ranger program to better protect against illegal logging ▪ Promote a sustainable forestry program ▪ Develop alternative livelihood programs to minimize the reliance of local communities on forest	▪ Increase protected forests to maintain habitats and allow species to make range shifts with climate change ▪ Restore and rehabilitate deteriorated forests. Increase forest canopies to reinstate functioning forest microclimates through enrichment planting and pest management actions to allow natural forest regeneration ▪ Strengthen the capacity of local and national disaster response systems for flash flooding ▪ Develop a fire monitoring program to rapidly detect and manage fire ▪ Strengthen the capacity of local and national administration organizations and communities to manage forest resources	▪ Develop and/or strengthen national forest protection plans ▪ Eliminate illegal forest harvesting within the PA and surrounding habitats ▪ Eliminate the illegal hunting and collecting of wildlife from within the PA and surrounding habitats ▪ Strengthen national weather forecasting and extreme weather warning systems ▪ Adequately enforce protected area policies ▪ Minimize economic land concessions and destructive mining activities within the PA

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
	resources ▪ Encourage community forest management, sharing costs and benefits of improved forest management		
Additional adaptation	▪ Identify and establish buffer zones to minimize the impact of climate change on core habitat ▪ Establish a community education campaign to inform local people of the impact of climate change on local communities and environments ▪ Incorporate climate change into cultivation activities ▪ Develop a management system to provide sufficient clean water to meet the needs of farmers and local communities ▪ Undertake enrichment planting with species suitable to predicted future climate in the region	▪ Monitor the presence and density of threatened species ▪ Develop species conservation programs to protect key identified threatened species ▪ Construct infrastructure to protect riparian communities from flooding, flash flooding, and landslides, such as flood control dams, flood diversion channels, and drainage systems	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species ▪ Relocate communities highly threatened by flash flooding ▪ Develop complementary but simplified legal frameworks across the countries of the region to enhance cross-border collaboration in forest management
Adaptation to induce system shift	▪ Restoration of degraded areas with native species adapted to predicted future climate in the region ▪ Investigate opportunities for Payment for Ecosystem Services (PES) to encourage better forest management by local communities	▪ Implement land use planning allowing ecosystems to shift with minimal obstruction by community settlements and infrastructure ▪ Increase the effectiveness of "Protected Area Systems" and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, and land use change	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species

6.4.3 NAKAI-NAM THEUN NBCA - HIGH ELEVATION MOIST BROADLEAF FOREST

Climate change in the high elevation moist broadleaf forest region of Nakai-Nam Theun NBCA will lead to increases in heavy rain events and flash flooding. Adaptive actions are provided in Table 13.

Table 13 – Summary of recommended adaptation options for Nakai-Nam Theun within high elevation moist broadleaf forests

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
Address adaptation deficit	▪ Soil conservation –reforestation and other bioengineering activities in riparian and sloping areas to minimize sediment entering waterways ▪ Enrichment planting of degraded areas ▪ Encourage community forest management, sharing costs and benefits of improved forest management ▪ Develop alternative livelihood programs to minimize the reliance of local communities on forest resources ▪ Advocate for sustainable ecotourism that promotes the link between conservation and tourism development ▪ Identify and monitor threatened/ critical species for conservation ▪ Maintain adequate supervisory and management regimes for production forests	▪ Increase protected forests to maintain habitats and allow species to make range shifts with climate change ▪ Restore and rehabilitate deteriorated forests. Increase forest canopies to reinstate functioning forest microclimates through enrichment planting and pest management actions to allow natural forest regeneration ▪ Strengthen the capacity of local and national administration organizations and communities to manage the forest ▪ Strengthen the capacity of local and national disaster response systems for flooding ▪ Establish conservation and restoration programs for key threatened species	▪ Develop and/or strengthen national forest protection plans ▪ Eliminate illegal forest harvesting within the PA and surrounding habitats ▪ Eliminate the illegal hunting and collecting of wildlife from within the PA and surrounding habitats
Additional adaptation	▪ Establish a buffer zone to minimize impact of climate change on core habitat ▪ Maintain ecological connectivity with other PAs in the region ▪ Establish a community education campaign to inform local people of the impact of climate change on local communities and environments ▪ Incorporate climate change adaptation into cultivation and other agricultural activities ▪ Undertake enrichment planting with species suitable to predicted future climate in the region	▪ Monitor the presence and density of threatened species ▪ Develop species conservation programs to protect key identified threatened species ▪ Construct infrastructure to protect riparian communities from flooding, flash flooding, and landslides, such as flood control dams, flood diversion channels, and drainage systems ▪ Promote sustainable ecotourism – monitor environmental impacts of ecotourism	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species ▪ Relocate communities highly threatened by flash flooding ▪ Develop complementary but simplified legal frameworks across the countries of the region to enhance cross-border collaboration in forest management
Adaptation to induce system shift	▪ Regeneration of degraded areas with native species suited to predicted future climatic conditions ▪ Improve the connection of the PA with surrounding forests or other PAs ▪ Manage pest species in and around PAs to provide suitable habitat to assist the effective migration of native species ▪ Investigate opportunities for Payment for Ecosystem Services (PES) to encourage better forest management by local communities	▪ Implement land use planning allowing ecosystems to shift with minimal obstruction by community settlements and infrastructure ▪ To the greatest extent possible, maintain aquatic ecosystem connectivity above and below hydropower developments in and around the PA	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species

6.4.4 NAKAI-NAM THEUN NBCA - LOW-MID ELEVATION MOIST BROADLEAF FOREST

Low-mid elevation moist broadleaf forest ecozone covers most of the PAs within Khammouan, including Nakai-Nam Theun Biodiversity Conservation Area. Adaptive actions are provided in Table 14.

Table 14 – Summary of recommended adaptation options for Nakai-Nam Theun low-mid elevation moist broadleaf forests

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
Address adaptation deficit	▪ Regulate land use to protect natural resources and environmentally sensitive areas and guide development away from hazard-prone areas through the establishment of PA zones ▪ Maintain adequate supervisory and management regimes for production forests ▪ Identification, protection, and restoration of critical fish habitat ▪ Soil conservation –reforestation and other bioengineering activities in riparian and sloping areas to minimize sediment entering waterways ▪ Enrichment planting of degraded areas ▪ Encourage community forest management, sharing costs and benefits of improved forest management ▪ Develop better farming systems and alternative livelihood programs to minimize the reliance of local communities on forest resources ▪ Advocate for sustainable ecotourism that promotes the link between conservation and tourism development ▪ Manage pest species - remove invasive species, establish barriers between exotics and native species ▪ Restore native wetland species ▪ Maintain hydrologic connection with other natural water resources	▪ Monitor and respond to new and emerging threats such as pest species ▪ Strengthen the capacity of local and national administration organizations and communities to manage the forest ▪ Strengthen the capacity of local and national disaster response systems for flooding ▪ Establish conservation and restoration programs for key threatened species ▪ To the greatest extent possible, maintain aquatic ecosystem connectivity above and below hydropower developments in and around the PA	▪ Establish or improve the national flood insurance program ▪ Develop and/or strengthen national forest protection plans ▪ Eliminate illegal forest harvesting within the PA and surrounding habitats ▪ Eliminate the illegal hunting and collecting of wildlife from within the PA and surrounding habitats

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
Additional adaptation	▪ Establish buffer zone to minimize impact of climate change on core habitat ▪ Maintain ecological connectivity with other PAs in the region ▪ Establish a community education campaign to inform local people of the impact of climate change on local communities and environments ▪ Incorporate climate change adaptation into cultivation and other agricultural activities ▪ Undertake enrichment planting with species suitable to predicted future climate in the region	▪ Monitor the presence and density of threatened species ▪ Develop species conservation programs to protect key identified threatened species ▪ Construct infrastructure to protect riparian communities from flooding, flash flooding, and landslides, such as flood control dams, flood diversion channels, and drainage systems ▪ Promote sustainable ecotourism – monitor environmental impacts of ecotourism	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species ▪ Relocate communities highly threatened by flash flooding ▪ Develop complementary but simplified legal frameworks across the countries of the region to enhance cross-border collaboration in forest management
Adaptation to induce system shift	▪ Regeneration of degraded areas with native species suited to predicted future climatic conditions ▪ Designate and/or connect PAs ▪ Manage pest species in and around PAs to provide suitable habitat to assist the effective migration of native species ▪ Investigate opportunities for Payment for Ecosystem Services (PES) to encourage better forest management by local communities	▪ Implement land use planning allowing ecosystems to shift with minimal obstruction by community settlements and infrastructure	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species

6.4.5 U MINH THUONG NP - DELTA LOW LYING ACIDIC AREA SWAMP FOREST

PAs in the Mekong Delta cover mangroves, saline water and low-lying acidic area swamp forest ecozones. These ecozones have a diverse ecosystem including seasonally inundated grassland, *Melaleuca* scrub, *Nypa fruticans* swamp, limestone hill plantation forest at the south of Hon Chong, peat swamp forest at U Minh Thuong National Park and mangrove forest along coastal areas. Climate change impacts on PAs in these ecozones are not only the result of higher temperature, less water availability, drought, flooding, and more frequent storm surges, but are also under threat from saline intrusion and sea level rise. Adaptive actions are provided in Table 15.

Table 15 – Summary of recommended adaptation options for U Minh Thuong NP, delta low lying acidic area swamp forests

Level of response	Short period (< 5 years)	Medium period (5 to 10 years)	Long period (> 10 years)
Address adaptation deficit	▪ Improve grazing land management to reduce the impact of grazing on sensitive environments ▪ Implement fire management planning to minimize or prevent fire within peatlands and grasslands ▪ Enhance early warning and disaster response capacity ▪ Construct freshwater reservoirs to enhance water availability in the dry season ▪ Improve the dyke and canal system to minimize water loss through seepage and evapotranspiration ▪ Restore degraded wetlands, peatlands, and grasslands ▪ Maintain hydrological connections between natural water resources ▪ Raise awareness and build capacity in sustainable fisheries management and use ▪ Reduce chemical inputs into agriculture and aquaculture to reduce water pollution	▪ Maintain, upgrade, and expand dyke system ▪ Invest in flood control and natural disaster mitigation ▪ Monitor water logging ▪ Establish new meteorological and hydrological monitoring stations at U Minh Thuong National Park ▪ Conduct fish population monitoring for key species with fishermen and set up community-based fish monitoring programs ▪ Strengthen the capacity of local and national disaster response systems for flooding	▪ Establish or improve national flood insurance program
Additional adaptation	▪ Provide agricultural extension services and training to promote climate adaptation in agroecosystems ▪ Create refugia for migratory species, especially waterbirds ▪ Rehabilitate fish populations ▪ Establish a community education campaign to inform local people of the impact of climate change on local communities and environments ▪ Incorporate climate change into agriculture and aquaculture activities	▪ Monitor the presence and density of migratory and threatened species ▪ Develop an early warning system for flooding and extreme weather events ▪ Construct infrastructure to protect riparian communities from flooding, flash flooding, and landslides, such as flood control dams, flood diversion channels, and drainage systems	▪ Establish biodiversity corridors between natural areas to allow shifting of ecosystems and species ▪ Expand protected areas
Adaptation to induce system shift	▪ Regeneration of degraded areas with native species suited to predicted future climatic conditions ▪ Designate and/or connect PAs ▪ Manage pest species in and around PAs to provide suitable habitat to assist the effective migration of native species ▪ Investigate opportunities for Payment for Ecosystem Services (PES) to encourage better forest and peatland management by local communities	▪ Implement land use planning allowing ecosystems to shift with minimal obstruction by community settlements and infrastructure	▪ Expand protected areas and/or establish new PAs to protect shifting habitat

6.5 NATIONAL ADAPTATION PLANS

The development of national climate adaptation plans will be fundamental to the successful conservation of natural ecosystems and protected areas in all LMB countries. National plans provide the policy backing from which individual PA management plans are based. A national plan should provide landscape-scale adaptation options, with a focus on supporting local adaptation strategies at the district, catchment, and PA level, as well as promoting connectivity of natural habitats. National adaptation plans should:

- Create a sound policy and legal framework for environmental protection, conservation, and sustainable economic development
- Develop policies to reduce the vulnerability of those sectors that are most sensitive to climate variability, namely forests, energy, and water resources
- Establish the principles for sustainable tourism development in protected areas
- Negotiate multilateral environmental agreements within the nation and between LMB countries
- Promote the development of stakeholders capacity in matters related to climate adaptation and preparedness
- Promote increased investment in adaptive conservation and soil protection measures
- Establish natural resource management plans for extractive and non-extractive resource intensive industries such as fisheries, forestry, and mining
- Maintain adequate supervisory and management regimes for production forests and protected area forests
- Provide sufficient resources to implement these policies
- Improve the economic returns flowing to the community and state arising from managed forest harvesting
- Develop policies and practices to facilitate access to Payment for Ecosystem Services (PES) opportunities, such as REDD+
- Create partnerships to support forest conservation with NGOs and other funders
- Develop a monitoring and evaluation program to ensure specific social, economic, and environmental goals are met and corrective responses are triggered when needed
- Adequately fund enforcement initiatives within PAs as required
- Develop a better understanding of the biodiversity within the forests of the region together with its spatial variation and its environmental constraints
- Develop complementary but simplified legal frameworks across the countries of the region to enhance cross-border collaboration in forest and water management
- Promote the conservation agriculture principles, such as the use of biodiverse crop varieties and soil conservation activities
- Approve and introduce new PAs
- Strategically manage the granting of land concessions for agricultural development, mining, and other uses to ensure the sustainable development and the protection of the national conservation estate

6.6 BASIN MANAGEMENT PLAN

Effective adaptation or mitigation of climate change will require a basin-wide approach. Countries within the LMB not only share natural ecosystems and resources; cross-border trading and business partnerships also closely connect their economies. The ten-year Greater Mekong Subregion (GMS) Strategic Framework (approved in December 2011) may provide a key step towards collaboration on environmental management objectives, amongst other things. However, to better understand the impact of climate change on natural systems within the GMS will require further emphasis and investment in

future planning. Such investment would allow the development of a basin-wide framework of regionally relevant climate adaptation options.

A basin-wide framework should provide: guidelines for PA managers to develop their adaptive options against climate change; broader management objectives to attract and distribute conservation funding; and a better support system to deal with climate change. The main climate adaptation frameworks for inclusion into the basin management plan include:

- The development of land-use planning and policies to enhance landscape-scale connectivity across national and international boundaries
- The development of water sharing plans that provide sufficient environmental flow (i.e., the timing and quality of water flows required to sustain aquatic ecosystems), and aquatic ecosystem connectivity, along with a regulatory framework to monitor and control water use where required
- International conservation agreements providing principles and guidelines for watershed management in PAs and surrounding landscapes to maintain healthy water resources
- The development of complementary but simplified legal frameworks across the countries of the region to enhance cross-border collaboration in forest management
- Effective monitoring of climate change patterns and strengthening of early warning systems for extreme events in the basin, e.g., heavy rainfall in the upper region of the Mekong River should trigger a warning system to inform those lower in the catchment of likely flooding

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SECTION 2 - ANNEXES

7 ANNEX 1: BASELINE CASE STUDY

7.1 NONG BONG KAI NON-HUNTING AREA - CHIANG RAI

7.1.1 OVERVIEW

Nong Bong Kai Non-Hunting Area is a natural depression surrounded by low hills located in Tambons Yo Nok and Pa Sak, Chiang Saen District, Chiang Rai Province, Thailand. It is situated within an upper floodplain wetland, lake ecozone (ecozone 12). The area was originally an intermittent floodplain surrounded by low mountains and hills. Villagers constructed an earthen dam on the Lua River to store water for agricultural uses. The Accelerated Rural Development Office later built a special weir across the river to stop the water from flowing out and "Chiang Saen Lake" was created in its current form, locally called Nong Bong Kai Lake (ONREPP 2004). The lake is well known as a significant bird sanctuary, and is recognized through 432 ha being designated as the 5th Ramsar wetland site in Thailand during 2001 (Tirisurat 2006).

The Chiang Rai Province Office of Natural Resources and Environmental Policy and Planning, with funding from the Danish Agency for Development Assistance (Danida), prepared a strategic wetland management plan for Nong Bong Kai in 2004. The plan collates a considerable amount of available information on the physical, chemical and biological parameters of the PA, and discusses the management of current and future threats to ensure the continued ecological functioning and integrity of the Nong Bong Kai Non-Hunting Area (ONREPP 2004).

7.1.2 PHYSICAL CONTEXT

Hydrology

Nong Bong Kai Lake is highly connected to other streams, rivers, lakes, swamps, and reservoirs, which provide water for agricultural lands, community consumption and other purposes in Chiang Saen Basin (WI 2001). The Nong Bong Kai catchment is relatively small (16.59 km^2) and the lake is rain fed. The area has an annual rainfall of 1,900 mm/year, generating approximately 27 million m^3/year of water inflow to Nong Bong Kai Lake. From this total flow, approximately 8 million m^3/annum flows from the wetland into the Lua River before joining with the Mekong River 6 km to the west at San That village. Evapotranspiration losses are estimated to be ~3.4 million m^3, soil absorption or leakage 1.1 million m^3 and present agricultural use 3.2 million m^3. The remaining water volume is thought to be lost through underground discharge. Recharge volumes to groundwater sources potentially carry significant value to neighboring vegetation; domestic and commercial water users are also dependent on underground water sources (ONREPP 2004).

Nong Bong Kai is a shallow lake with an average depth of 2 m and a maximum depth of 4.5 m. Maximum water storage in the lake is 4.9 million m^3. The water level subsides around 1-1.5 m during a typical dry season (Tirisurat 2006).

Water quality

Near surface (20 cm below) water temperature range has been recorded at between 28.5 and 30.98°C, dissolved oxygen between 20.5-32.6 mg/liter, and pH ranges between 6.4 and 9.0, the large variation of which is thought to be related to village activities and the oxidation of dead aquatic plants near the water's edge (Tirisurat 2006). Analysis of dissolved nitrate (NO3) and phosphorus (PO4) indicate significant waste water and agriculture chemical contamination occurs in the northwest of Nong Bong Kai Lake, an area near tourism resorts and orange orchards. Levels of NO3 and PO4 exceeded recommended levels for human consumption when measured during the mid-2000s (Tirisurat 2006).

However, overall water quality measurements indicated that water conditions remain within limits that support a range of aquatic flora and fauna.

Soils / Geology

Trisurat (2003, as cited in ONREPP (2004)) identifies residuum, local colluvium, and alluvium as the parent materials of the soil in the area. The texture is of clay, sandy/loam, stone, and water. This soil composition makes rice farming suitable in 42% of the area. A further 22% of the region is subject to problems with soil drainage and erosion, yet still considered to be moderately suitable for crops (Trisurat 2004).

About 93% of the area has a soil erosion rating of less than 5 t/ha/yr (considered a low erosion rate), but topsoil erosion in areas of old clearing and abandoned lands in hilly areas is greater. If water and soil conservation measures are not deployed, it is expected that Nong Bong Kai Lake would be filled with sediment in the next 500 years (ONREPP 2004).

Climate Baseline

The climate is under the influence of the northeast and southwest monsoon with an average temperature of 25.5°C. The hottest month of the year is April with an average temperature of 35.3°C and the lowest temperatures occur in January with an average temperature of 12.5°C. The rainy season is between July and October with highest average rainfall of 367.4 mm in July and average annual rainfall of 1,900 mm (ONREPP 2004).

Analysis of past climate data from 1980 to 2004 demonstrates previous experience of extreme events, such as heavy rain in 1996 with over 119 mm in one day, and temperature extremes with values such as 40.2°C and 42.4°C. Past drought periods have been recorded from November to April.

A climatic comfort zone for Nong Bong Kai has been calculated through analysis of historical climate. The historical range indicates tolerance between 31.95°C and 23.45°C in the wet season and between 40.16°C and 26.31°C in the dry season.

7.1.3 BIOLOGICAL CONTEXT

Key flora attributes

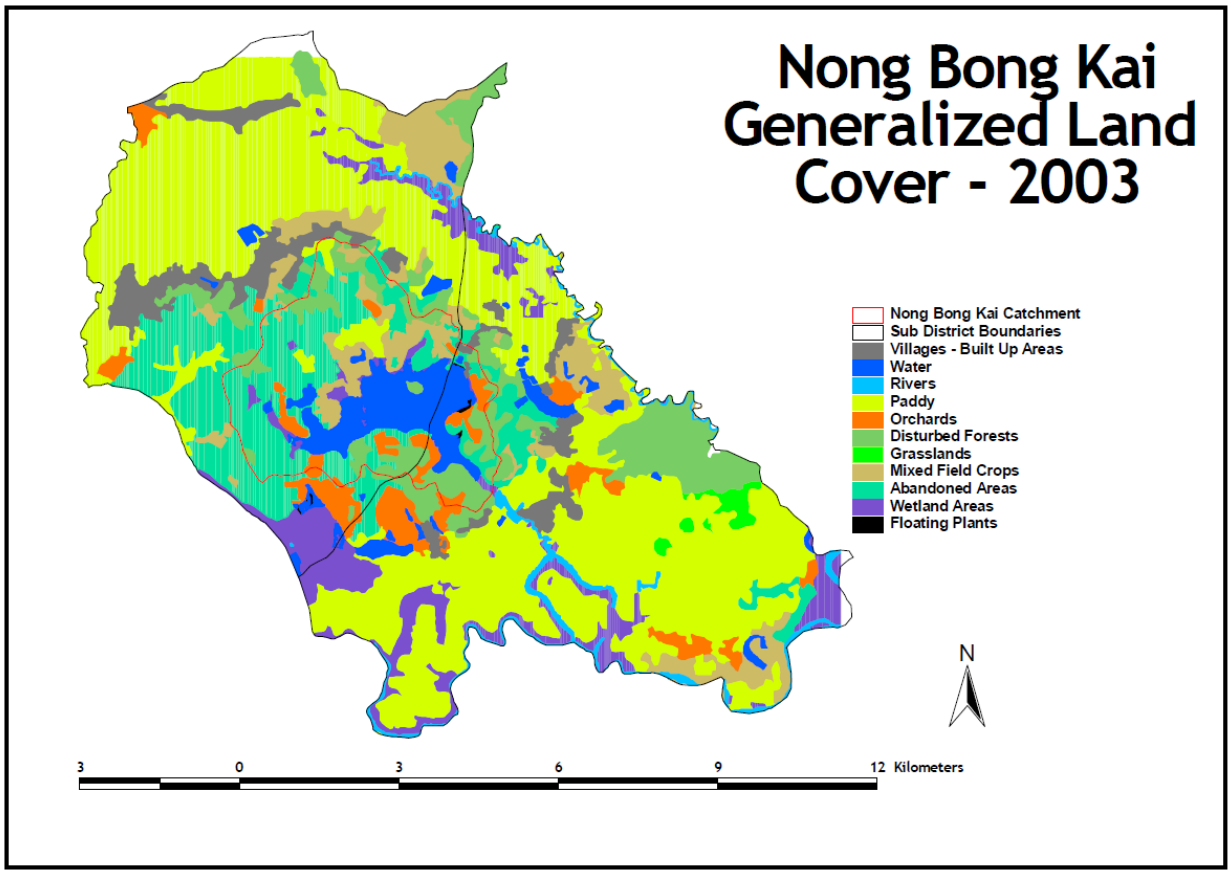
The Strategic Management Plan (ONREPP 2004) lists 11 categories of land cover types surrounding Nong Bong, classified using Land Development Department data and Satellite imagery interpretation in 2003. The distribution of these classifications is provided in Figure 1.

Privately owned land on the hills surrounding the lake host disturbed or regenerating mixed deciduous forest. Land closer to the lake is more intensively farmed, with paddy fields found close to Tambon Yo Nok village, and fruit tree plantations being common around houses (ONREPP 2004).

Twenty-four species of aquatic vegetation occur within the Nong Bong area (WI 2001). Marod *et al.* (2003) described these according to the following four zones.

Floating zone - In the open water of the lake, floating plant species such as water hyacinth (*Eichhornia crassipes*) and the water fern (*Azolla pinnatat*) are most common, with other species present including *Ipomaea aquatica, Jussiacea crenata* and *Lemna perpusilla*. These species can form mats of vegetative material on the surface of the lake, locally called "Peung". Close to the lake edge, cogongrass (*Imperata cynlindrica*) is commonly seen growing as a floating pad across the water, mostly on top of remnants of other floating species (Marod *et al.* 2003; ONREPP 2004). Nutrient pollution in water bodies is known to encourage the growth of floating species such as these. Where a dense mat forms across large areas, growth can seriously impact water quality where light penetration is restricted beneath the mat, limiting oxygen availability in the water column.

Figure 5: Land classification in the Nong Bong Kai region as defined by ONREPP (2004)



Submerged zone - Submerged plants are mostly soft-stemmed, introduced species such as Carolina fanwort (*Cabomba caroliniana*), common hornwort (*Ceratophyllum demersom*), *Hydrilla*, and native species including duck lettuce (*Ottelia alismoides*), and *Blyxa japonica*.

Emergent zone – This lake edge zone contains plants such as the water primrose (*Ludwigia adscendens*) and sacred lotus (*Nymphaea* sp. or *Nelumbo nucifera*).

Marginal zone - This lake edge zone hosts herbaceous species such as giant reed (*Arundo donax*), common reed (*Phragmites*), cogongrass (*Imperata cynlindrica*), *Isachne globosa*, *Lindernia anagallis, Hymenache pseudointerrupta, Leersia hexandra, Phragmites karka,* and *Sorgum halpense* (Marod *et al.* 2003). Further away from the lake, shrub-like species such as the giant sensitive plant (*Mimosa pigra*), pagoda flower (*Clerodendrum paniculatum*) and Siam weed (*Chromolaena odorata*) are common, behind which shrub and tree species such as cauliforus fig and bamboo (*Bambusa nutans*) occur (ONREPP 2004).

7.1.4 KEY FAUNA ATTRIBUTES

Birds

Nong Bong Kai Non-Hunting Area and adjacent wetlands are important habitats for both local and migratory waterbird species. The Non Bong Kai Non-Hunting area, as part of the greater Chiang Saen Basin, was recognized as an Important Bird Area by BirdLife International in 2004 (BI 2004a). Investigations in 2001 found Nong Bong Kai Non-Hunting Area is directly utilized by 121 species of birds

from 13 orders, 43 families, and 84 generas (Marod *et al.* 2003). By extending the survey beyond the lake into the adjacent wetlands of Jaw Nai Thongdam, Nong Chalab, Nong Luang and Nong Bua, it was found that as many as 225 bird species utilize the immediate area (Marod *et al.* 2003).

Seventy-nine migratory species use the region. These include 23 resident breeder species and 23 migratory resident breeder species. The site supports significant wintering populations of the globally threatened Baer's Pochard (*Aythya baer*) and the globally near-threatened Ferruginous Pochard (*A. nyroca)* (Figure 2). Globally and nationally significant species are provided in Table 1.

Figure 6: White Eyed Pochard, Grey Headed Lapwing, Boer's Pochard

Table 16
List of Threatened and Near-Threatened species known to occur in the region of the Nong Bong Kai Non-Hunting area. Data are from BI (2004a). Global categories are from IUCN Red List, and national categories are from BI (2004a). CE=Critically Endangered, E=Endangered, NT=Near Threatened, V=Vulnerable, R=Nationally Rare, LC = Least Concern, *=data unavailable

Common Name	*Scientific name*	*Global*	*National*
Baer's Pochard	*Aythya baer*	CE	*
Black-bellied Tern	*Sterna acuticauda*	E	*
Ferruginous Duck	*Aythya nyroca*	NT	*
Painted Stork	*Mycteria leucocephala*	NT	*
Swan Goose	*Anser cygnoides*	V	*
Great Cormorant	*Phalacrocorax carbo*	LC	CE
Purple Heron	*Ardea purpurea*	LC	E
Black Kite	*Milvus migrans*	LC	E
Bar Headed Goose	*Anser indicus*	LC	R
Greylag Goose	*Anser anser*	LC	R
Common Pochard	*Aythya ferina*	LC	R
Tufted Duck	*Aythya fuligula*	LC	R
Mandarin Duck	*Aix galericulata*	LC	R

Mammals

Terrestrial wildlife habitat in Nong Bong Kai and nearby areas has been mostly converted to agriculture of forest production, hence only small animals that can adapt to the changed habitat remain and numerous domestic animals such as water buffalo share the habitat. No detailed mammal survey data is publically available.

Aquatic fauna

The Nong Bong Kai strategic wetland management plan (ONREPP 2004) identifies at least 46 species of fish from 17 families within the broader wetland complex area connected to Nong Bong Kai Lake. Seventeen of these species are considered to have economic value for the local communities. The most abundant species is the banded shark (*Hampala macrolepidota)*. Sixteen species are reliant on high connectivity between wetland areas to complete rainy season migration patterns essential for their life cycles. The banded shark (*Hampala macrolepidota),* bighead catfish *(Clarias macrocephalus*), and silver barb (*Barbonymus gonionotus*) migrate from Khong River, while the Thai minnow and the walking catfish (*Clarias batrachus*) migrate from Lua River into the NBK wetland area (ONREPP 2004).

Five threatened species were identified in 2003 as endemic to the linked upper Mekong system: the bighead catfish *(Clarias macrocephalus*), walking catfish (*Clarias batrachus*), Siamese fighting fish (*Betta splendens*), barb (*Sp. unknown)*, and Badis (*Badis badis*).

There are nine exotic fish species that have been introduced including the hybrid walking catfish (*Clarias macrocephalus* x *Clarias gariepinus*), Indian barb, Mekong giant catfish (*Pangasianodon gigas*), iridescent shark catfish (Pangasianodon hypophthalmus), and giant snakehead (*Channa micropeltes*).

The Strategic Wetland Management plan (ONREPP 2004) indicates that a seasonal change in fish distribution across the Nong Bong lake was detected during a survey in 2003. During the wet season, fish were found to be distributed relatively evenly across the lake. In the dry season this distribution was restricted to the eastern end of the lake, where abundant aquatic plant communities exist. It is hypothesized that the fish utilize this area to spawn and raise young (ONREPP 2004).

7.1.5 SOCIAL DESCRIPTION

General summary

Demography	Description
Population	In 2004 the surrounding areas of Tambon Yo Nok and Tambon Pa Sak comprised 21 villages, consisting of 11,487 people overall.

Poverty and Living Standards	Description
Poverty Rate	An average income of Tambon Yo Nok and Tambon Pa Sak is 24,241Baht/person/year. People of Doi See Kaew, Doi Jun, Rong Bong, Thung Phaham and Kong Ngam villages had an average income of less than 20,000 Baht/person/year in 2004. The following table presents the income that Tambon Yo Nok and Tambon Pa Sak benefit from the Nong Bong Kai wetland

Descriptions	Baht/year	Percentage
Resource uses	3,664,911	23.9
Catching fish	3,660,714	23.9
Recreation activities	3,410,000	22.2
Using areas for agriculture	4,605,445	30.0
Using water without agriculture	47,400	0.3
Total	15,388,550	

Food Security	Both villages from Tambon Pa Sak and Tambon Yo Nok were found to directly use resources in Nong Bong Kai Lake and adjacent areas. The intensity of use was significantly related to proximity to the lake, with 53% of families in Tambon Yo Nok utilizing resources as compared to 20 percent of the total families in Pa Sak, which is predominantly in the highlands and 2.6 km from the lake.
Land tenure	The Nong Bong Kai Non-Hunting Area itself is covered by two land deeds for the area of 350 rai (56 ha) of the old Nong Bong Kai and another land deed for 1,375 rai (220 ha) of surrounding forest area. All surrounding areas, including small lakes and reservoirs, are

	privately owned. Most paddy fields are found at Tambon Yo Nok. There are also fruit tree plantations such as longans, mangos, and oranges around houses.

Livelihoods	Description
Agriculture	One crop of irrigated or rainfed rice is grown per year. Many areas of riverine floodplain are used for cultivating maize or green vegetables, and it is not unusual for cultivation to be practiced right up to the water's edge. As the water levels drop, from late December onwards, so the cultivation proceeds further into the fertile alluvial soils along the river margin. There are fruit orchards (mainly lychees) and fields of hill rice and maize in surrounding areas.
NTFPs	Gathering wetland resources and edible plants such as Tao or seaweed, lotus flower and lotus fruit, bamboo shoots and mushrooms is common in the park. In the village of Doi Kham, 90% of families are involved in gathering bamboo shoots.
Fishing	Fishing is done by using gill nets, throw-nets, and electrocution. Fishermen at Nong Bong Kai are able to catch approximately one kilogram of fish per day. In addition, small freshwater shrimps are harvested and are used to make chili paste.
Livestock	Chickens and cattle are kept adjacent to the Nong Bong Kai lake. Villagers graze buffalo mostly on the north of Nong Bong Kai Lake, near Jaw Nai Thongdam, in the east near roads, and at the pond close to the weir. Observations found that cattle trample lotus and destroy the wetland ecology.
Tourism	Nong Bong Kai Lake is an attractive resource for outdoor recreation and natural values, attracting approximately 1,300 tourists in 2004. Estimated income from the tourism trade was estimated at 3,410,000 Baht/year. Resorts surrounding the lake area are also providing job opportunities and income for local people, although the effectiveness of income distribution to villages was considered low in 2004.

Principal linkages between PA and communities

The main links between the PAs and communities are: (a) the provision of NTFPs for subsistence and commercial activities and (b) critical environmental services. These are detailed in the tables below.

Key NTFP species	Description
Lotus flower and fruit	Harvested from the lake
Bamboo	The village that uses Nong Bong Kai most is Doi Kham where 90% of the families gather bamboo shoots
Tao	Gathering Tao, a species of edible freshwater weed
Fish	Fishermen at Nong Bong Kai catch approximately one kilogram of fish per day
Birds	Recreational - bird watching

Key environmental services	Description
Flood mitigation	Natural wetland areas such as Nong Bong Kai Lake regulate flows and minimize flood impacts by allowing the flood wave to spread out across the wetland area, minimizing its depth and speed
Water supply in the dry season	Nong Bong Kai is one of several connected water bodies that provide water for agricultural lands, community consumption and other purposes in Chiang Saen Basin. Sustainable use of water resources and mitigation of flooding and drought management is a major task that is overseen by the Department of Water Resources.

Key environmental services	Description
Biodiversity reservoir	Land and water both inside and outside the Ramsar site contain important habitat for fish, water birds, and numerous invertebrate species that contribute to productivity
Groundwater replenishment	Recharge volumes to groundwater sources potentially carry significant value to neighboring vegetation; domestic and commercial water users are also dependent on underground water sources (ONREPP 2004)
Water purification	Wetlands cycle sediments and nutrients, improving water quality. For example, algae, along with aquatic vegetation, takes up excess nutrient from the water, improving water quality

7.1.6 Conservation Status and Threats

Conservations status

National and international conservation status – Nong Bong Kai Non-Hunting Area was formally declared as a protected area on the 4th of April 1985 by the Ministry of Agriculture and Cooperatives. Nong Bong Kai was registered as the 5th Ramsar Site of Thailand on the 5th of May 2001, being the 1101st Ramsar Site in the world.

Details of conservation – According to the Wildlife Protection Act (1992), Article 42, the Royal Forest Department and the Department of Fisheries are responsible for the protection of wildlife and aquatic fauna in the area by prohibiting:

- Hunting or performing any activities harmful to protected species
- Collection or destroying of the nests of protected species
- Land encroachment, tree cutting, altering waterways and other activities that may be harmful to wild animals

The Nong Bong Kai Strategic Wetland Management Plan defines three management zones and eight sub-zones. The zoning utilizes aspects of the approach of the Ramsar Convention, as well as similar wetland projects elsewhere in Thailand and on-going land use planning implemented by the Chiang Rai Provincial Declaration on Town and Country Planning. These zones are:

- Wetland Protection Zone
  - Protection Zone
  - Special Water Bird Conservation Zone
  - Water Conservation Zone
- Wise Use Zone
  - Agricultural eco-development zone
  - Service and Recreation Zone
- Intensive and Multiple Use Zone
  - Water Environmental Quality Protection and Fishing Zone
  - Agriculture and Rural Zone
  - Low Density Residential Zone
  -

Further information on the activities controlled in each of these zones is available in the Strategic Wetland Management Plan (ONREPP 2004).

Macro-level management issues

Land surrounding Nong Bong Kai has long been developed for housing, tourist resorts and facilities for recreation purposes, and agriculture. Some water quality impacts are evident including contamination by agrochemicals and nutrient pollution. Illegal hunting and habitat destruction directly affect bird numbers and species composition.

The Nong Bong Kai Strategic Wetland Management Plan identified the following management issues (ONREPP 2004):

- The ecosystem health of the of Nong Bong Kai wetland and basin areas is degraded - inhibiting the functions and values of Nong Bong Kai wetland and basin areas, including its role as the habitat for various fishes and migratory water birds
- Fish habitats in the lake are damaged and threatened by the fishery sector and various human activities
- Water bird habitats, both inside and outside the Non-Hunting Area, are being disturbed and destroyed by buffalo, and conflicts with fishermen and farmers
- Water quality in Nong Bong Kai wetland trends to be lower than the Thailand standards for drinking and domestic consumption due to the use of chemical substances in agricultural areas, waste deposits and waste water from communities, animal farms, and tourist enterprises. This is especially relevant in the areas near Ku Tao Village and communities
- Land speculators and investors are encroaching on the areas around Nong Bong Kai Non-Hunting Area

Climate change threats

Climate modeling and analysis has identified the following climate change trends for the area of Chiang Rai containing Nong Bong Kai - Non Hunting Area and Ecozone 12 of Chiang Rai (ACCCRN 2011):

- Increased temperatures all year round by 2 degrees Celsius
- Decreasing precipitation in the dry season and increasing in the wet season
- Drought occurs more often and longer duration, water availability decline
- More intense flooding is likely to occur

These climatic trends translate to a number of discrete climate threats for the wetlands biophysical processes, ecology and related livelihoods and social systems of benefiting communities. They are:

- Increased incidence of heavy sedimentation during anticipated flash flood events (coinciding with higher expected rainfall intensity in the wet season)
- Increased surface water temperatures in the dry season
- Increased evapotranspiration in the dry season
- Increased incidence of drought and lowering water levels in the Nong Bong Kai Lake

Chiang Rai economy is dependent on cool-weather agricultural crops and seasonal tourism (typically linked to river-based activities), both of which would likely be affected by future climate change.

Note: Considering the migratory nature of the PA assets, CC impacts are unlikely to be limited to the PA site and Chiang Rai Province. The impacts of warming or drought in the Siberian and Chinese alpine zones will affect the timing of incidences of migratory bird species.

7.1.7 KEY STAKEHOLDERS

- **Key NGOs working in the area** –BirdLife International
- **Relevant government ministries and authorities** – Nong Bong Kai Non-Hunting Area Office - Wildlife Conservation Division, Royal Forest Department, Local Administration Unit of Chiang Rai Province, local villages of Tambon Pa Sak and Yo Dok, private sector orchard, and tourism operations

7.2 NAKAI–NAM THEUN BIODIVERSITY CONSERVATION AREA

The Nakai-Nam Theun National Protected Area (NNT NPA) and adjacent northern extension is the largest protected area in Lao PDR, occupying about 4,000 km^2 along the border of Vietnam.

7.2.1 KEY PHYSICAL FEATURES

Climate Baseline

The area is under the influence of the Southeast Asia monsoon climate regime, however, rainfall varies across the reserve, contributing to the diversity of habitat types and biota found within the NNT NPA. The yearly average rainfall of the Plateau region is 2,417 mm, however annual rainfall in the upper catchment area of the NNT Conservation Area is estimated to be up to 3,000 mm (Robichaud 2005). The area is influenced by both the northeast and the southwest monsoon seasons. The southwest monsoon begins in May, reaches its maximum strength in August and disappears about mid-October. The climate then cycles through a transition period to mid-November when the northeast monsoon appears. Rainfall becomes very infrequent and light, the air is cool, and the humidity lower. The northeast monsoon lasts until the end of February when the hot and dry transition period begins.

In addition to the monsoons, the region is occasionally visited by typhoons and tropical depressions. The peak of the typhoon season in the central region of Lao PDR is generally September and October. The typhoons form over the South China Sea and move westward to Vietnam, lift over the Sai Phou Louang (Annamite) Mountains and pass on to the Nam Theun catchment. Mountain passes to the north (Ban Nape), central (Ban Maka), and south (Mu-Gia) offer easier paths between the mountain peaks.

Hydrology

NNT has abundant water resources. The Nakai-Nam Theun is an important watershed that feeds many Mekong tributaries as well as forming the catchment area for Nam Theun 2, the largest hydropower project in Lao PDR.

Drainage of the NBCA is generally SW into the Nam Theun, a large tributary of the Nam Kading, itself a major tributary of the Mekong. The Nam Theun already has two hydropower projects Theun-Hinboun and Nam Theun 2, both selling electricity to Thailand. The Nakai Plateau has been substantially inundated by the construction of these hydropower dams.

Elevation

Elevation in the PA ranges from 500 – 2,200 m. The Sai Phou Louang (Annamite) Mountains form the bulk of the NBCA (divided within the NBCA into the Northern, Central, and Southern Mountains areas). This mountain range runs in a NW-SE direction and is dissected by NE-SW oriented river valleys. The five main rivers (Nam Sot, Nam Mon, Nam Theun, Nam Noy and Nam One) emerge through gorges in the range and onto the Nakai Plateau. These river systems then widen and meander across the plateau, creating rich riverine forest habitat.

- Central Mountains - The heart of the protected area is formed by a block of mountains covering around 800 km^2. They are mostly above 1,000 m, with many peaks above 1,500 m and the summit ridge rising to 2,200 m at Phou Laoko. This is the catchment for the Nam Sot, Nam Mon and Nam Theun rivers.
- Southern Mountains - South of the Central Mountains there is a stretch of slightly lower mountains, which are the catchments of the Nam Noy and Nam Pheo, peaking at 900-1,300 m. To the south is another high area, the Phou Wang massif. Both river valleys have been settled and form the enclave of Taseng Theung.

- The Dividing Hills - These separate the lowlands of the Nakai Plateau from the mountainous areas further north, the major rivers cutting through them along rocky but fairly level courses. The peaks are mostly quite low (800-1,100 m). There are no villages in these hills, and only one road, Route 8B, crosses them at the northern end.
- Nakai Plateau - The Nakai Plateau is the relatively flat area around the confluences of Nam Theun with Nam Sot, Nam One and Nam Noy. The rectangular plateau covers about 1,200 km^2. It ranges from about 490 m to 600 m. To the south, the plateau drops away sharply (Sai Phou Ak escarpment) to the cultivated Gnommalat lowlands below 200 m. To the east, it abuts the hillier Nam One catchment. The center of the plateau is heavily settled and quite degraded. It is a noteworthy landform on a topographic map, being relatively flat in contrast to the rugged hill ranges that largely surround it. This area is also recognized through designation as an Important Bird Area (Ounekham & Inthapatha 2003).
- Sai Phou Ak Escarpment and the proposed Southern Corridor - About 45 km^2 of the Sai Phou Ak escarpment is included at the southern end of the NNT NBCA. Its lower slopes together with the proposed Southern Corridor are the only part of the protected area below 500 m. The proposed Southern Corridor forms the Lao PDR side of the Mu-Gia Pass through which Route 12 currently passes. To the south it joins with the impressive peak of Phou Etra, and the impressive limestone karst of the Hin Nam No NBCA.
- The Northern Mountains - The Northern Mountains are a continuation of the Central Mountains but drop to the south and east onto the Lak Xao plain rather than the Nakai Plateau. They are the catchment for two major rivers, the Nam Kata and the Nam Veo. Forest remains on most of the hills around the alluvial plains of the valleys, rising to over 1,200 m in places.
- Northern Extension - The Northern Extension consists of an approximately 550 km^2 swath of low mountains (600-900 m) along a stretch of the Sai Phou Louang Range, which borders Vietnam. Most of these forested mountains drain into the Nam Phao or the Nam Gnouang, both tributaries of the Nam Theun below the Nam Theun 2 dam site. The lower Nam Phao and Nam Gnouang are heavily settled, with shifting cultivation fast encroaching on the Northern Extension. This is particularly severe in the Nam Cham valley.

7.2.2 BIOLOGICAL CONTEXT

NNT falls within the area defined by WWF as the Northern Annamites rain forests ecoregion (Robichaud 2012). This ecoregion hosts globally significant biological distinctiveness. The NNT is the largest protected area in the ecoregion, and has been rated as being of very high, or critical, conservation importance by several biodiversity assessments since the 1990s. Assessments include investigations into forest cover, vertebrate diversity (Ling 1999), biodiversity, watershed protection and ecotourism potential (Robichaud *et al.* 2001), and conservation importance (Baltzer *et al.* 2001; STEA 2004).

NNT along with the HNN and PHP NBCA's, and proposed extensions, provide the core of a series of contiguous conservation areas in Lao PDR and Vietnam. With surrounding protected areas, these conservation parks together represent the most important protected area habitat in the Lao PDR-Cambodia-Vietnam region.

The high connectivity offered by the NNT and surrounding PAs offers opportunities for flora and fauna species to adapt to climate change impacts such as changing temperatures and rainfall patterns. Where connected, diverse, and healthy habitats are available, species that are subject to comfort zone range shifts have the best capacity to adapt. In addition, vegetated corridors such as that of the NNT and surrounding PAs accommodate the seasonal and nomadic movements of wide-ranging species such as elephants, dhole, and hornbills, and contribute to genetic variability of flora and fauna species.

7.2.3 KEY FLORA ATTRIBUTES

Forest cover in NNT is extensive, and the majority is of outstanding quality or primary forest condition. Due to the extent, condition, and connectivity of the forest held within the NNT and surrounding PAs, it is suggested that the NNT NPA may be the highest quality evergreen/semi-evergreen forest block in the broader region of Lao PDR, Vietnam, Thailand, and Yunnan (China) (Robichaud 2012).

Flora biodiversity in NNT is known to very species rich. Detailed flora surveys have identified close to 800 taxa from 150 families (Thomas *et al.* 2007a; Thomas *et al.* 2007b). This rich biodiversity is utilized by residents of local villages, with more than 450 plant species producing NTFPs (Foppes 2001). Given that the surveys of Thomas *et al.* (2007a and 2007b), generated 160 new records for Lao PDR, it is likely that these species counts greatly underestimate the diversity of flora within the NNT.

Vegetation assemblages found within the NNT are dominated by mixed semi-evergreen and evergreen forest exhibiting *Dipterocarpus* and *Shorea* species (Dipterocarpaceae), and species of the families Myristicaceae, Annonaceae, Rutaceae, Sapindaceae and Fabaceae. Riparian forests within the NNT protect a large variety of herb species, and are the only habitats where the climber *Poikilospermum* sp. (Urticaceae) is found. Some areas of mixed deciduous forest are also present, and cloud forest occurs on the summits of some of the highest peaks.

Conservation values

Species of conservation concern include at least five CITES-listed species, and the IUCN lists 34 flora species within NNT as of conservation concern, with seven taxa listed as either Endangered or Critically Endangered (Robichaud 2012). The tree *Aquilaria* sp. and the Chinese swamp cypress (*Glyptostrobos pensilis*) are recognized as threatened at both the local (*Aquilaria*) and global (*Glyptostrobos*) level. The following three forest types are of particularly high conservation significance:

- **Wet evergreen forest** is recognized as the most globally significant terrestrial habitat in Lao PDR, making its presence within NNT of particular importance. Wet evergreen forest occurs at mid-elevation (500-900 m), near the border of Vietnam. Although little information on plant communities is available, plant endemism is expected to be high in this forest type. Wet evergreen forest is recognized as one of the preferred habitat types of rare and endangered species such as the saola (*Pseudoryx nghetinhensis*) and Annamite striped rabbit (*Nesolagus timminsi)* (Robichaud 2012).
- **Everwet forest** is one of the unique features of the NNT Conservation Area and especially the Northern Extension in highly restricted areas. Everwet forest occurs only in narrow bands of low elevation saddles in the Sai Phou Louang (Annamite) chain. These saddles allow a preferential path for the Vietnamese northeast monsoon and consequently receive rain for up to ten months of the year. It is probable that the fauna and flora assemblages of this habitat are unique, as it occurs nowhere else in Lao PDR.
- **Cypress forest** with the presence of the near threatened conifer *Fokienia hodginsii* (Cupressaceae) (IUCN 1994) occurs uncommonly on dry ridges above 1,000 m (Robichaud 2005). *F. hodginsii* occurs mostly in a mixed association with oaks (Fagaceae). On the very upper ridges heath species (Ericaceae) tend to dominate. The IUCN recognizes that the classification of *F. hodinsii* requires updating, and given the exceptional value of the timber, it is highly likely the population has declined since 1994. Stands are found in the upper Nam Zot and Nam Theun catchments and on Phou Vang massif (Robichaud 2012).

7.2.4 KEY WILDLIFE ATTRIBUTES

Overview: The very high diversity of wildlife present within the NNT makes this area of high conservation value. Numerous threatened or endangered species are present within the park. A number of these

species will be under enhanced pressure from climate change impacts due to low population sizes, restricted distributions, and high elevation comfort zones.

NNT has the highest diversity of both birds and mammals found in Lao PDR (Ling 1999), indicating the rich faunal assemblages of the PA. Factors leading to this diversity include the broad range of physical conditions (altitude, precipitation, soil types) and vegetation communities. The region is also influenced by both Himalayan and Indomalayan faunal elements, as well as exhibiting endemism of many elements of the Annamite biota (Robichaud 2005).

A number of NNT's wildlife species are of global concern. Table 2 lists IUCN classified species occurring in the PA.

Table 17 – Total of NNT's global conservation concern reptiles, mammals, and birds by IUCN Red List threat category. Reptile and mammal data from Robichaud (2012), bird data from Evans (1998)

	Critically endangered	*Endangered*	*Vulnerable*	*Near threatened*	*Data deficient*
Reptiles *(all are turtles)*	2	5	3	1	
Mammals *(excluding bats)*	1-2	12	16	6	2-3
Birds	1-2	5	5	6	2

Birds

More than 400 bird species have been recorded in the NNT (Ling 1999), representing the highest bird diversity of any reserve in the Lao PDR, and among the highest of any Asian protected area with similar survey effort (Tobias *et al.* 1998). These records include 11 Threatened and 27 Near-threatened bird species (Table 3). The importance of the NNT as significant bird habitat was recognized by the designation of 278,000 ha of the PA as an Important Bird Area (IBA) by Birdlife International in 2003. The IBA is predominately located in lowland areas.

A number of bird species occurring in the NNT are distributed in high altitude areas within the park, making them particularly susceptible to shifting ranges associated with climate change induced temperature change. Cypress forest is habitat for the Beautiful Nuthatch (Sitta *Formosa*), and high altitude cloud forest supports the Spectacled Fulvetta (*Alcippe ruficapilla*), Whiskered Yuhina (*Yuhina flavicollis*), Rufous-necked Hornbill (*Aceros nipalensis*) and Chestnut-tailed Minla (*Minla strigula*) (Evans & Timmins 1998).

Species occurring in low altitude semi-evergreen forests within the PA include Red-collared Woodpecker (*Picus rabieri*), Pale-headed Woodpecker (*Gecinulus grantia*), Indochinese Green Magpie (*Cissa hypoleuca*), and the Rufous-throated Fulvetta (*Alcippe rufogularis*). Higher up, evergreen fagaceous forest supports Coral-billed Ground Cuckoo (*Carpococcyx renauldi*,) Green Cochoa (*Cochoa viridis*), Red-tailed Laughingthrush (*Garrulax milnei*), and Rufous-necked Hornbill (*Aceros nipalensis*) amongst others (Evans & Timmins 1998).

Figure 7: The Threatened Rufous-necked Hornbill (left) and Beautiful Nuthatch (right) are distributed only in the alpine areas of NNT

Table 18

List of Threatened and Near-threatened species known to occur in NNT. Data from Evans & Timmins (1998). [1] Categorization according to Collar (1994), and [2] categories of the IUCN Red List.
* Indicates species with high altitude distributions.

Common Name	*Scientific name*	*IUCN*[2]	
Threatened species[1]			
White-winged Duck	*Cairina scutulata*	E	
Greater Spotted Eagle	*Aquila clanga*	V	
Wood Snipe	*Gallinago nemoricola*	V	
*Rufous-necked Hornbill	*Aceros nipalensis*	V	
Grey-sided Thrush	*Turdus feae*	V	
*Beautiful Nuthatch	*Sitta formosa*	V	
Crested Argus	*Rheinardia ocellata*	NT	
Blyth's Kingfisher	*Alcedo hercules*	NT	
Red-collared Woodpecker	*Picus rabieri*	NT	
Short-tailed Scimitar Babbler	*Jabouilleia danjoui*	NT	
Siamese Fireback	*Lophura diardi*	LC	
Near-threatened species[1]			
Lesser Fish Eagle	*Ichthyophaga humilis*	NT	
Brown Hornbill	*Anorrhinus tickelli*	NT	
Japanese Paradise-flycatcher	*Terpsiphone atrocaudata*	NT	
Von Schrenk's Bittern	*Ixobrychus eurhythmus*	LC	
Jerdon's Baza	*Aviceda jerdoni*	LC	
Grey-headed Lapwing	*Vanellus cinereus*	LC	
Yellow-vented Pigeon	*Treron seimundi*	LC	
Coral-billed Ground Cuckoo	*Carpococcyx renauldi*	LC	
Spot-bellied Eagle Owl	*Bubo nipalensis*	LC	
Tawny Fish Owl	*Ketupa flavipes*	LC	
Blue-rumped Pitta	*Pitta soror*	LC	
Swinhoe's Minivet	*Pericrocotus cantonensis*	LC	
*Green Cochoa	*Cochoa viridis*		LC
Jerdon's Bushchat	*Saxicola jerdoni*	LC	
Grey Laughingthrush	*Garrulax maesi*	LC	
*Red-tailed Laughingthrush	*Garrulax milnei*	LC	
Spotted Wren Babbler	*Spelaeornis formosus*	LC	
*Spectacled Fulvetta	*Alcippe ruficapilla*	LC	
Rufous-throated Fulvetta	*Alcippe rufogularis*	LC	
Lesser Rufous-headed Parrotbill	*Paradoxornis atrosuperciliaris*	LC	
Black-breasted Thrush	*Turdus dissimilis*	LC	
Yellow-vented Warbler	*Phylloscopus cantator*		LC
Fujian Niltava	*Niltava davidi*	LC	
White-winged Magpie	*Urocissa whiteheadi*	LC	
Indochinese Green Magpie	*Cissa hypoleuca*	LC	
Pied Falconet	*Microhierax leucopterus*		
White-bellied Pigeon	*Treron sieboldi*		

The forests of the Northern Extension contain one of the largest populations ever recorded of Crested Argus (*Rheinardia ocellata*), an endangered pheasant (Timmins & Evans 1996) that in Lao PDR is restricted to moist forested areas (Collar *et al.* 2001).

Mammals

Field surveys indicate that mammal communities within the protected area are exceptionally diverse, making the PA important for mammal conservation, particularly those with large area requirements. At least nine species of primate occur, all of which are on the IUCN Red List (Robichaud 2012). Fifteen species of carnivore were identified during a single survey in NNT, and 12 species of forest ungulates likely occur in the reserve (Robichaud 2012).

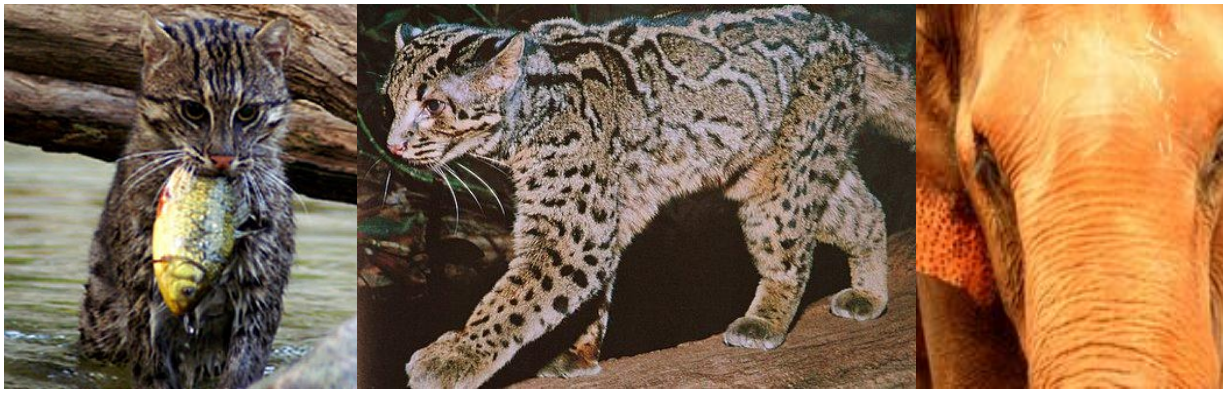
Included amongst the carnivores are nine Globally Threatened, three Data Deficient and six Nationally At Risk species (Duckworth 1998). Rare cats present in the PA include the Fishing Cat (*Prionailurus viverrinus)*, Golden Cat (*Catopuma temmincki)*, Marbled Cat (*Pardofelis marmorata)*, Clouded Leopard (*Pardofelis nebulosa)* and the Tiger (*Panthera tigris*), several of which have not been recently observed by biologists elsewhere in Lao PDR.

Three primates occurring in the park are globally threatened or vulnerable: the Pygmy Loris (*Nycticebus pygmaeus*), Douc Langur (*Pygathrix nemaeus*) (Timmins & Duckworth 1999), Francois' Langur (*P. nemaeus francoisi*) and White-cheeked Gibbon (*Hylobates leucogenys*) (Tobias *et al.* 1998).

Three of the last five large mammals to be discovered or re-discovered world-wide occur in the NNT Conservation Area, and globally more new species of large mammals have been described from the Annamites than any other area of similar size in the last 100 years (Robichaud 2012). The most distinct of these remarkable discoveries is the *Saola Pseudoryx nghetinhensis* (Dung *et al.* 1993; Schaller & Rabinowitz 1995). Further newly discovered endangered species include the Giant Muntjac, (*Megamuntiacus vuquangensis*) (Schaller & Vrba 1996; Timmins *et al.* 2008). The Indochinese Warty Pig *Sus bucculentus* was rediscovered in the area (Groves *et al.* 1997) after being considered extinct (Salter 1993).

Figure 8: Saola Pseudoryx nghetinhensis, White Cheeked Gibbon (Hylobates leucogenys), & Warty Pig (Sus Bucculentus)

Figure 9: Fishing Cat (Prionailurus viverrinus), Marbled Cat (Pardofelis marmorata), & Elephant (Elephas maximus)



The Nakai Plateau holds significant populations of many mammals including an estimated 100-150 Asian Elephants *Elephas maximus*. Few Elephants are found elsewhere in the NNT NBCA (WCS 1996a; Tobias 1997) and, moreover, few viable populations of elephants currently exist elsewhere in Lao PDR.

Figure 6: Douc Langur (*Pygathrix nemaeus)* and White-winged Duck (*Cairina scutulata)*

Fish

The fish fauna of the Nam Theun and Xe Bangfai basins was evaluated during Environmental Impact Assessments conducted under the planning of the NT2 Dam development (Roberts 2004; Blake 2005). Roberts (2004) identified 85 fish species in the lower Nam Theun River, fewer than are present in nearby river systems of a similar size. However, fish assemblages of the Nam Theun are considered very distinct, being characteristic of large, clear, coldwater mountain tributaries rather than the more common lowland Mekong river systems. This habitat has likely resulted in the presence of endemic species in the Nam Theun river systems; however, further research is required to fully assess this possibility. The Xe Bangfai has over 131 species present, but numbers are represented by uneven survey coverage and further work is required to clarify the distribution of local fish species (Blake 2005). The fish fauna of upland river systems in the watershed has not been studied and is likely to add significantly to the overall diversity and conservation value of aquatic resources in the NNT Conservation Area.

Roberts (2004) identifies 18 species as of conservation concern in the Nam Theun river system. Unfortunately, it is likely that the NT2 Dam will greatly impact the fisheries of the Nam Theun (Roberts

2004). Strongly migratory species represent up to 55% of the Nam Theun fish assemblages (Roberts 2004), and these species will be restricted from entering the stream headwaters now the dam is in place.

Three exotic (non-native) fish species have been observed.

- Nile Tilapia *Oreochromis niloticus*
- Carp *Cyprinus carpio*
- Silver Carp *Hypophthalmichthys molitrix*

7.2.5 SOCIAL DESCRIPTION

General summary

In general terms, population densities in the NNT NPA, on the Nakai Plateau, and along the Nam Theun downstream of the Nakai dam are low, and characterized by pronounced ethnicity, dependence on subsistence livelihoods with household income levels well below the national poverty line, and limited or no access to infrastructure and services such as education, health, electricity, and water supply.

<table>
<tr><th>Demography</th><th>Description</th></tr>
<tr><td>Population</td><td>The province population is 337,314.
In general, the population within the NBCA is very low due to the steep dissected limestone topography. Only small villages with limited access to infrastructure exist within NBCA areas. District level villages and estimated populations are below:
<table>
<tr><th>District</th><th>Villages</th><th>Persons</th></tr>
<tr><td>Nakai</td><td>52</td><td>10,000</td></tr>
<tr><td>Gnommalath</td><td>10</td><td>2,500</td></tr>
<tr><td>Boulapha</td><td>3</td><td>700</td></tr>
<tr><td>Khamkeut</td><td>10</td><td>2,500</td></tr>
<tr><td>TOTAL</td><td>75</td><td>15,700</td></tr>
</table>
Notes: (1) There has not been a comprehensive survey of NBCA boundaries and adjacent village boundaries; the above represents best estimates based upon work done to date.
(2) There are another 60 villages including about 9,000 inhabitants within about 3 km of the protected area boundary if all extensions are included.</td></tr>
<tr><td>Age distribution</td><td>Life expectancy in the province is 61. The Age Dependency Ratio is the number of the financially dependent persons (aged 0-14 and 65+) to every 100 working age persons (aged 15-64). In 2005, the dependency ratio was 83.6. However, there were large differences across provinces.</td></tr>
<tr><td>Ethnicity</td><td>100% of the population within the NBCA is considered "Lao Theung": Including a variety of Vietic (Mon-Khmer) speakers 31%, Brou (Western Katuic branch of Mon-Khmer) 55%, and Tai-Sek (Tai-Kadai) 14%. There is an increasing Hmong population on the periphery of the NBCA in Khamkeut District, Bolikhamxay Province</td></tr>
<tr><td>Inward and internal migration</td><td>Urban areas in Khammouan tend to have a higher density of population than rural areas. Urban regions contain 80 to over 150 people per square kilometer while in rural areas, especially the east of the southern and central provinces and most of the northern part, the rate is only around 10 to 30 people per square kilometer. Changes in the number of population at the provincial level depend on natural expansion, and domestically, and internationally net-migration. The movement of the population is mainly the consequence of job opportunities, infrastructure improvements, and the opportunities for improving living conditions.</td></tr>
</table>

Poverty and Living Standards	Description
Poverty Rate	The poverty rate of the area is greater than 45% (2009).
Health	o Infant mortality rate under 5 years old is 95/1000, and under 1 is 76/1000, life expectancy is 61 years o Villages with access to clean water account for 432 villages within the province, covering 293,859 persons or 79.69% of the total population. o There are 49 gravity-fed water systems, 3798 bore wells, 8213 wells. o 32,369 families have pit latrines or 48.82% of total population. o Schools with clean water account for 304 schools or 50.08% and pit latrines account for 295 schools or 48.60% o There is 1 provincial hospital, 8 district hospitals, and 76 health care centers
Education	There are only 3 primary schools in NNT located in Ban Na Vang, Ban Teung and Ban Na Meu/Na Meo.
Food Security	Rice still remains the staple food for people living in Khammouan, accounting for 39% of food consumption in Khammouan followed by meat (20%) then fish.. At the same time, people are consuming more ready-made food or "outside" food.
Infrastructure	NNT is remote and access into and within is difficult, especially during the wet season. Access is limited to footpaths and river transportation, which varies seasonally. About 74% of the overall province uses electricity, including electricity from state network, electricity produced by turbine, electricity from solar cell, and electricity from hydropower. Almost all villages in the urban areas use electricity
Land tenure	Land access is well distributed in Khammouan Province. Almost 99% of households have their own land and 100% of households have access to land. Concerning the agricultural assets, 46% of households own two wheeled tractors and 2% of them own four wheeled tractor, 27% boats, and 73% fishing nets.

Livelihoods	Description
Agriculture	Residents cultivate rotational swiddens on a total of about 3% of the land area of the NBCA, this includes fallows.
NTFPs	These residents also use a wide variety of NTFPs in their daily life (rattans, foods, Kho leaves, etc.). The forest is an important resource for most rural poor community's livelihoods, including a source of food intake outside the rice crop/flood periods, medicines, and construction materials and firewood, for instance approximately 80% of domestic energy consumption for household purposes is carbon based. The forest also provides a variety of NTFPs such as game, fish, bamboo and rattan shoots, fruits, greens, and honey (utilized for food); khem grass (for producing brooms and paper mulberry); cardamom and malva nuts (as condiments and medicinal products); benzoin, peuak meuak, resins, and leo resins, etc.
Fishing	Most of these people also supplement their agriculture with fishing and hunting. The majority of fishing in Khammouan is for subsistence purposes practiced on a seasonal basis. Finfish dominate the overall catch. Small-scale commercial fishing also occurs along the Mekong River and lower Xe Bangfai. In addition to capture fisheries, aquaculture is of importance to rural livelihoods and income generation in Khammouan. Small-scale aquaculture is most prevalent, and is widely adopted both to supplement wild fisheries and for subsistence during seasons when wild fish are scarce.
Other	A more significant use of wildlife and other more valuable NTFPs has been by outsiders. Almost all of the Eaglewood *Aquilaria* sp. has already been depleted.
Cultural values	Among the indigenous Vietic groups, considerable cultural differentiation has emerged. Their modes of production and space usage vary from foraging in small nomadic groups to a combination of swidden agriculture and sedentary irrigated rice cultivation. From the perspective of risk and vulnerability of indigenous ethnic groups, it is the upper river system Vietic groups that are most at risk. Among these, the most vulnerable groups are

	the Atel, the Thémarou, and the Mlengbrou, in the grouping Vietic I and characterized as "small group of foraging nomads". These people are known to have extensive knowledge of the forest and their culture and lifestyle is intimately based upon nature: Actually, the term "at risk" in their case is too conservative as their plight would more accurately be designated as "on the verge of extinction." At the present time, the last remaining members of these groups (16 Atel, 30+ Thémarou, and 9 Mlengbrou) are to be found living in or near villages to which they were assigned following the official government policy of village consolidation in the 1970s.
Recreation and Tourism	While the area offers spectacular forests and rivers, difficult access and lack of any accommodation or services limits tourism activities at present. Difficult access requires entry by boat or on foot, and also requires significant amounts of time. The prevalence of international poachers and other untrustworthy elements also forces local authorities to require an armed escort for visitors. The incidence of Malaria is high in the area. However, Route 8A (Lak 20 - Vietnam Border) offers ready access to the everwet forests along the Nam Phao from Ban Nape eastward to the Vietnam border. This area lies within a 3 hour drive of Route 13 in Lao PDR and Route 1 in Vietnam.

Principal linkages between PA and communities

The main links between the PAs and communities are: (a) the provision of NTFPs for subsistence and commercial activities and (b) critical environmental services. These are detailed in the tables below.

Key NTFP species	Description
Wild vegetables, roots, and other food-stuffs	Bamboo and rattan shoots, fruits, greens, and honey are collected mostly for household consumption.
Wildlife	Catching wild fish for household consumption and hunting wildlife – Commercialization of the trade in wildlife products is of particular concern when combined with improved road access along logging tracks and roads constructed as part of mining and hydropower development projects.
Damar resin	For chemical product
Khem grass	For producing brooms and paper mulberry
Cardamom and malva nuts	Collected as condiments and medicinal products
Others	Peuak meuak, and leo resins, etc. for chemical and perfume industries. Rattan collection, "Mai Dam" (black wood), the fungus infected heartwood of *Aquilaria* (Thymeleaceae), is important commercially and sold to Vietnam.

Key environmental services	Description
Water resources	It is estimated that 90% of water withdrawals are used for agricultural purposes, while withdrawals for domestic and industrial uses are between 4 and 6%. The two sectors that most impact water resources are irrigation and hydropower development. The majority of irrigation schemes in Khammouan are small and medium scale, with many schemes not being fully functional due to difficulties related to operations and maintenance. Development of the hydropower sector such as the Nam Theun 2 project was meant to ensure that the proper environmental and social safeguards are applied. Yet, hundred thousand people continue to suffer from hydropower project impact with reduced quality of life, livelihoods, and subsistence.
Pest Management	Pest control programs in NNT and Nakai Plateau are part of the national Pest Management Plan (PMP). Pest control is mainly for agriculture including rice and vegetation production. The PMP is designed to avoid the use of, or properly manage, agrochemicals.

Forest management	Illegal logging and the expansion of agriculture land lead to loss in forest area. Sustainable forestry management is needed to protect forest land, threatened species, stop unsustainable commercial harvesting and illegal logging, combat illegal wildlife trade, and restore forest cover.
Land management	This includes improving land tenure security in areas undergoing rapid land development, reducing most land disputes, particularly in forested areas subject to multiple pressures such as high population pressure, logging, and infrastructure development.
Fishery management	Fisheries contribute to food security and are a supplement to household income within the area. Sustainable management regimes by managing fisheries and water resource developments in a holistic manner are needed to ensure that the value of fisheries and aquatic resources to the subsidence economy is maintained.

7.2.6 CONSERVATION STATUS AND THREATS

Since the mid-1990s, NNT has undergone the most extensive management planning of any reserve in Lao PDR. The resulting NNT management strategy and five-year operational plan was completed in 2005 (see WMPA (2005)), with funding from organizations involved in the planning and development of the NT2 hydropower dam project. Funding is provided from the World Bank to undertake park management within the NNT, both as an environmental offset for damage incurred by the dam construction, and as a mechanism to protect the watershed above the dam. This funding makes the NNT one of the most highly funded PAs in SE Asia (Robichaud 2012).

Conservations status

- **Details of conservation**
  - The NBCA was gazetted in 1993. Systematic wildlife surveys in the area began in 1995.
- **Management resources (i.e., staff numbers and infrastructure)**
  - 5 staff (4 male, 1 female) seconded by Khammouan Province

Macro-level management issues

The main threats to biodiversity conservation in NNT come mainly from illegal logging and wildlife hunting for trade (Robichaud 2012). Slash and burn swidden agricultural practices present a further risk to the PA conservation, mostly due to population growth in the region. Together, swidden, NTFP trade or wildlife trade are the most important livelihood activities for local communities. Population growth in the region will likely result in increased pressure from these activities (Robichaud 2012).

The NT2 dam development threatens the viability of numerous aquatic species that cannot survive in reservoirs or rely upon high connectivity of waterways to complete their life cycle. The IUCN Red List identifies three species of endangered or vulnerable fish that are particularly at risk from dam developments, *Schistura nudidorsum* (Bignoli & 2012 2012), *Rhinogobius lineatus* (Kottelat 2012), and *Schistura tubulinaris* (Jenkins *et al.* 2009). There are likely to be many other aquatic species impacted by the NT2 development (Roberts 2004; Blake 2005).

The development of the NT2 reservoir also greatly increased accessibility into the PA. Boat access aided an increase of timber and wildlife poaching along the western side of the reserve from 2008. Almost all of the Eaglewood *Aquilaria* sp. has already been depleted. A rattan concession in 1996-97 seems to have also depleted most of the large diameter rattans from the NBCA. International poachers have been active in the area since the mid-1980s in force and they continue to deplete the wildlife on a significant scale (Robichaud 2005).

There is also a certain amount of logging beyond the inundation level at the edge of the Plateau and the base of the Dividing Hills as well as poaching by logging crews. While there are no main roads, timber

extraction, or other hydropower projects currently planned for the area, these types of projects represent significant potential threats.

Proposed extensions and wildlife corridors

The Northern Extension to the NBCA has long been regarded as compensatory mitigation for habitat lost to the NT2 Hydropower Project dam and reservoir. The above discussion on biodiversity values makes it clear that the Northern Extension is highly important for conservation, if managed sustainably. Furthermore, it provides a link between several distant protected areas, including Pu Mat and Vu Quang Nature Reserves in Vietnam. Preliminary surveys indicated that the Northern Extension is critical for conservation of the endangered Saola.

Climate change threats

- **Water availability**. Khammouan Province, where NNT is situated, has abundant water resources. Notwithstanding, seasonal reduction in surface water flow can result in inadequate amounts of water in some rivers and streams during the dry season. Groundwater is also subject to seasonal variability in some districts of Khammouan. Climate change will likely increase the duration of insufficient surface and groundwater. As noted above, an estimated 90% of water withdrawals in Khommouan are used for agricultural purposes, while withdrawals for domestic and industrial uses are between 4 and 6%. Any decease of water availability will impact agricultural activities in the region.
- **Drought**. The combination of dry forest systems along with the slash and burn cultivation techniques used in the region increases the risk of wild fires in the dry season. Any loss of forests will likely lead to a reduction in the availability of NTFPs.
- **Precipitation variability**. Reductions in rainfall during the dry season along with increases in heavy rainfall during the wet season may significantly affect water retention and flow regimes, leading to severe soil erosion. Any increase in the amount of sediment delivered to water systems will degrade water quality. High turbidity severely impacts aquatic ecosystems and fish habitat. High sediment loads are also a physical irritant, affecting fish gills, and on settling out can smother fish eggs.
- Changes in temperature and climate condition will likely cause shifts in forest types. Forest transition may allow ecosystems to adapt with climate change, however some habitats will likely suffer a loss of area.

7.2.7 KEY STAKEHOLDERS

- **Key NGOs working in area** – PAFO and NBCA staff oversee controls on logging in adjacent areas. WWF (linkage HNN and Phong Nha- Ke Bang through Parallel Conservation), CARE and European Union conduct a poverty alleviation project which provides food for work for 15 villages in Boualapha District. World Vision has a program for UXO Clearance and WSC conducts ecological surveys.
- **Relevant government ministries and authorities** – Department of Forestry, Ministry of Agriculture and Forestry

7.3 PHNOM PRICH WILDLIFE SANCTUARY

7.3.1 OVERVIEW

Phnom Prich Wildlife Sanctuary (PPWS) represents 222,500 ha of the Eastern Plains Landscape protected area complex. PPWS is contiguous with Mondulkiri Protected Forest to the Northeast, and Seima Protected Forest to the South. Together, the protected areas of the Eastern Plains Landscape lie at the core of the Lower Mekong Dry Forest Ecoregion, and are of global importance for biodiversity conservation (WWF 2012).

7.3.2 PHYSICAL CONTEXT

Hydrology

The Srepok River is the main hydrological feature of the area. The Srepok also has a number of major tributaries, many of which contain ponds (trepeangs) that progressively dry up during the dry season. The Prek Preah and Prek Krieng also run through the south of this area. There are also a large number of streams.

Soils / Geology

The protected area cluster is largely comprised of dry plains, with hilly regions and riverine areas interspersed throughout. Soil is generally considered infertile for agriculture in most regions, except some southern and western areas, as well as areas along the Srepok.

Climate Baseline

Mondulkiri Province has two seasons. The dry season generally runs from November to late April. There is very little rainfall during this period. In the early dry season the nights can be quite cool, and the days hot sunny, and dry. Later in the dry season it can get very hot, in the upper 30s degrees Celsius, but humidity is still relatively low. Approximately only 20% of days year round have a maximum exceeding 30°C.

The wet season is from May/June to October, but the wettest month is October. The day temperatures are in the low 30s degrees Celsius, and humidity is high. Typically it rains in the afternoon and early evening on most days, but rainfall patterns are not very predictable.

Much of the area of the PA cluster is highly susceptible to both drought and flooding at present. Types of flooding include: flash flooding caused by torrential rains and overflowing streams; flooding caused by water level variations stemming from hydropower operations; and, seasonal flooding during the wet season. Many communities describe flash floods as an annual event, lasting two to three days. Slow-onset flooding is relatively lower risk for communities compared to flash floods.

7.3.3 BIOLOGICAL CONTEXT

Phnom Prich Wildlife Sanctuary forms part of one of the largest remaining relatively undisturbed extents of lowland forest in Southeast Asia. The area is considered to be globally significant for conservation, due to its role as habitat for large mammals, along with birds and reptile species (Gray *et al.* 2011; Gray *et al.* 2012).

7.3.4 KEY FLORA ATTRIBUTES

Forest communities in Phnom Prich Wildlife Sanctuary are very diverse, with forest types ranging from dense semi-evergreen forest to open woodlands (WWF 2006). Deciduous dry dipterocarp woodlands, with an open canopy and grassy understory are widespread throughout the sanctuary. Tall semi-evergreen forests with obvious sub-canopy layers grow in areas where the annual precipitation is low,

and seasonality is pronounced. Bamboos are a common feature in semi-evergreen forest. Seasonally inundated wetlands (trapeangs) are interspersed through the sanctuary and provide food and water for wildlife, particularly during the dry season.

7.3.5 KEY FAUNA ATTRIBUTES

Birds

A number of bird species of national and global conservation importance utilize the habitat within the Phnom Prich Wildlife Sanctuary (Table 4). Of particular note is the presence of the Critically Endangered Giant Ibis, which is known to occur in small numbers within the PA (BI 2013b), and the Green Peafowl (BI 2013a).

Table 19

List of Threatened and Near-threatened bird species known to occur in the Eastern Plains Landscape. Data from WWF (2012). CE=Critically Endangered, E=Endangered, NT=Near Threatened, V=Vulnerable, R=Rare, C=Common

Common Name	*Scientific name*	*Global*	*National*
Giant Ibis	(*Pseudibis gigantea*)	CE	E
Green Peafowl	(*Pavo muticus*)	V	R
Bengal Florican	(*Houbaropsis bengalensis*)	E	R
Red Headed Vulture	(*Sarcogyps calvus*)	CE	R
Slender Billed Vulture	(*Gyps tenuirostris*)	CE	R
Lesser Adjutant Stork	(*Leptoptilos javanicus*)	V	R
White-winged Duck	(*Cairina scutulata*)	E	E
White-shouldered Ibis	(*Pseudibis davisoni*)	CE	E
Sarus Crane	(*Grus antigone*)	V	R
Black-necked Stork	(*Ephippiorhychus asiaticus*)	NT	E
Great Hornbill	(*Buceros bicornis*)	NT	E

Mammals

The Eastern Plains Landscape, with Phnom Prich as a core region, provides habitat for the conservation of numerous nationally and globally significant mammal species ((WWF 2012), see Table 5). The area is of particular importance to large mammal species such as the Asian Elephant, the Indo-Chinese Tiger and the Banteng. The largest Asian Elephant population in Cambodia is hosted within the EPL, and the Banteng population in the region is the largest in the world (Gray *et al.* 2012). These populations of large prey species are important to the conservation of the Indo-Chinese Tiger (Wikramanayake *et al.*; Sanderson *et al.* 2010).

The Eastern Plains Landscape is considered to be irreplaceable for tigers because it represents the only large (>10,000 km^2) block of dry forest habitat available in the region (Lynam 2010). The area has been identified as one of 12 critical tiger conservation and recovery landscapes by the World Wide Fund for Nature (Wikramanayake *et al.* 2011). Other key carnivores include leopard and clouded leopard, as well as marbled cat, jungle cat, and dhole.

Table 20

List of Threatened and Near-threatened mammal species known to occur in the Eastern Plains Landscape. Data from WWF (2012). CE=Critically Endangered, E=Endangered, NT=Near Threatened, V=Vulnerable, R=Rare, C=Common, DD=Data deficient, LC=Least Concern

Common Name	*Scientific name*	*Global*	*National*
Indo-Chinese Tiger	(*Panthera tigris corbetii*)	E	E
Asian Elephant	(*Elephas maximus*)	E	E
Banteng	(*Bos javanicus*)	E	R
Gaur	(*Bos gaurus*)	V	R
Eld's Deer	(*Cervus eldii*)	E	E
Leopard	(*Panthera pardus*)	LC	R
Sun Bear	(*Ursus malayanus*)	DD	R
Dhole	(*Cuon alpinus*)	E	R
Black-shanked Duoc Langur	(*Pygathrix nigripes*)	E	R
Yellow-cheeked Gibbon	(*Hylobates gabriellae*)	E	R
Stump-tailed Macaque	(*Macaca arctoides*)	V	R
Wild Water Buffalo	(*Bubalus arnee*)	E	E
Silvered Langur	(*Trachypithecus cristatus*)	E	C

Reptiles

Table 21

List of Threatened and Near-threatened reptile species known to occur in the Eastern Plains Landscape. Data from WWF (2012). CE=Critically Endangered, E=Endangered, NT=Near Threatened, V=Vulnerable, R=Rare, C=Common

Common Name	*Scientific name*	*Global*	*National*
Siamese Crocodile	(*Crocodylus siamensis*)	E	R
Elongated Tortoise	(*Indotestudo elongata*)	E	C
Indian Rock Python	(*Python molurus*)	NT	C

7.3.6 SOCIAL DESCRIPTION

General summary

Communities around the sanctuary are very poor and heavily dependent upon natural resources. The main livelihood is subsistence agriculture, although households typically engage in a diversity of livelihood strategies. Households are also engaged in a range of small-scale commercial activities. Some lowland communities (particularly along the Srepok) have two houses and move to upland areas during the flooding season, many of which are within PAs. Note that the data below is from a mix of different surveys conducted between 2005 and 2009 – the principal source is WWF (2007), a survey of 14 villages in and around the central area of the PA cluster (i.e., the MPF).

Demography	Description
Population	16,983; 3,542 households; 34.2% of Mondulkiri population. Population density around the MPF is 24 persons/km^2 > province-wide figure of 2 persons/km^2.
Age distribution	Range: 0-17 years (54%); 18-64 (43%); 65+ (4%).
Household size	More than 50% of households have 6-10 members (including extended family). Among Phnong communities most households consist of 2 to 3 families.
Ethnicity	Phnong 45%; Khmer 33%; Lao 13%; 8 other groups, mostly ethnic minorities.
Inward and internal	Increasing rapidly – 60% of inward migrants Khmer. 35% of households in current

Demography	Description
migration	residence for less than 4 years; 70% for less than 10 years. Major driver is better economic opportunities, mostly associated with search of land to cultivate.

Poverty and Living Standards	Description
Poverty Rate	Average household (cash and non-cash) income $572 per year; 45% of expenses on food. Mondulkiri is the poorest province in Cambodia. Communities closer to the PAs are relatively better off than those further away because of greater access to natural resources – this is a major driver of migration into the park.
Health	Poor– only 53% of households use health services due to poor service, distance, and lack of money. Access to safe water is low – majority of households use river/stream water.
Education	66% of children aged 6-17 attending school. Education delivery standards are low, e.g., more classrooms than teachers, irregular class schedule.
Food Security	Food insecurity is high in the province as a whole – surveyed households respond that food security is their primary livelihood concern. 53% of households state that their rice production is insufficient for their needs.
Infrastructure	60% of roofs thatched; 80% of floors bamboo; 76% of walls bamboo. 100% use of fuelwood for cooking; 69% use of kerosene for lighting. Inadequate access to safe water and sanitation.
Land tenure	Perceived openness in acquiring land. Between 68% and 89% of agricultural land acquired without permission.

Livelihoods	Description
Agriculture	96% households are involved in farming. Rice is the main crop in this region. Small land holdings, with low productivity are normal. Farmers are often unable to feed their own families. Irrigation infrastructure is poor to non-existent.
NTFPs	92% of households are engaged in some form of NTFP collection. 34% households hunting; 33% collecting resin; 58% collecting other NTFPs, including honey, wild vegetables, sleng seeds, bamboo, root crops. NTFPs are a critical source of cash and non-cash income in times of drought and flood.
Fishing	79% households involved in fishing. Only 13% identify fishing as a primary activity. Most households fish for home consumption. Common concern for dwindling fish catch, principal reason is illegal gear (e.g., grenades).
Livestock	92% households raise animals; 76% duck/chicken; 71% pig; cow/cattle 65%. Animals used for home consumption (including drought for cattle) or sold at market, particularly to provide income to compensate for rice shortage.
Other	Households generally have a mix between subsistence and commercial activities. Other livelihood activities involve trading, government, employment and hired labor. Typically, all members of households contribute to household income.

Principal linkages between PA and communities

The main links between the PAs and communities are: (a) the provision of NTFPs for subsistence and commercial activities and (b) critical environmental services. These are detailed in the tables below.

It is important to note that NTFPs and other forest resources are being unsustainably used by both communities and outsiders. Major drivers of over-use include: increasing population density and pressure to open up new land, poverty, unsustainable or illegal methods (i.e., guns for hunting, grenades or poison for fishing). External pressures are also a key driver of declining environmental quality, including: illegal land concessions and logging.

Key NTFP species	Description
Wild vegetables, roots, and other food-stuffs	Edible vegetables and fruits provide supplementary nutrition year-round and are particularly important when agricultural crop productivity is low (i.e., during drought). Key species include: bamboo shoots, manioc and wild yam.
Resin	Resin is collected from dry dipterocarp trees. Most trees are found in strict protection and regulated use zones.
Wildlife	Wildlife is collected for food (74%), trading (4%), and food and trading (22%). Major species targeted include the water monitor (34%), turtle (31%), civet (11%), and snakes (5%). Flagship exotic species are traded to Vietnam (e.g., tiger).
Honey	Honey hunting occurs in evergreen and semi-evergreen forest. Traditionally for household consumption but now mostly commercial (10% for personal use).
Sleng seeds	Nuts are used for poison, tonics, flavoring, and muscle relaxant drugs. Now there is commercial collection, outsiders have best information on prices; they have also been known to cut down whole trees.
Bamboo and grasses	Construction materials for housing.

Key environmental services	Description
Flood protection	Forest reduces runoff during extreme flood events and provides protection for riparian communities from flooding. Negative effects of flooding include: destruction of agricultural land (particularly riparian areas), damage to housing, disease (mosquito-borne and water contamination), and the attendant effects on poverty and food security.
Protection from insect infestation	The removal of forest cover and the destruction of their natural habitat drive insects into agricultural lands. Infestations destroyed 75% of the rice crop in 2004. Plant hoppers and mealy bugs are the main threats, though new insects have been detected following greater use of pesticides.
Water sources	Many villages rely on streams and rivers as primary water source, although some have access to springs and pump-wells. 50% draw water directly from streams and rivers, 40% from tube-wells (forests and groundwater).
Habitat	Fish habitat in streams and wildlife habitat in forests.

7.3.7 CONSERVATION STATUS AND THREATS

Conservations status

Phnom Prich Wildlife Sanctuary has global conservation status recognized by IUCN, category IV of their protected areas categories system, as a Habitat/Species Management Area. It is also recognized as a national government protected area since 1993. The sanctuary is managed by the General Department of Administration for Nature Conservation & Protection under the Cambodian Ministry of Environment.

Three zones are designated within the park: Core Zone, Conservation Use Zone, and Community Conservation Forest. Communities regularly access all zones within the park, and there is a movement towards greater community management of forests inside and close to the PA.

Management resources

WWF has worked for over five years with the Cambodian Ministry of Agriculture, Forestry and Fisheries to implement improved management of PAs in the Eastern Plains Landscape. WWF has provided ongoing support for five ranger stations and two sub-stations with 45 rangers working within the PA to control forest crime. The park is also equipped with a Mobile Enforcement Unit of 2 police

and 2 forestry administration officials. Thirty-four Community Patrol teams work in 22,931 ha of community forest areas across PPWS and neighboring Mondulkiri Protected Forest.

Macro-level management issues

- **Land concessions** - An estimated 126,700 ha of economic land concessions have been granted across the Eastern Plains Landscape, often within core zones or conservation areas of PAs. Land concessions for cash crops, mining, and other activities continue to be an issue for management in the Eastern Plains Landscape. In Phnom Prich WS, both mining and economic land concessions, often utilized for agribusiness development, have been granted (Vrieze and Naren 2012). Commercial plantations employing wage labor to cultivate rubber and other cash crops are becoming increasingly common. Land concessions are limiting access of communities to forest areas. There are also several mining concessions within the sanctuary.
- **Deforestation** – Forest cover has declined dramatically over the last three decades due to both legal and illegal logging.
- **Hydropower** – Dams on the Srepok upstream in Vietnam have negatively impacted riparian communities in the Eastern Plains Landscape.
- **Illegal activities** – Despite relatively high levels of resources being placed within the parks to control illegal forest practices, logging and wildlife hunting continue to be major problems in this area. An increase in the number of forest rangers is required to ensure all areas of the park can be regularly patrolled (WWF 2012).
- **Other** - A number of eco-tourism initiatives exist throughout the cluster. NGOs are also supporting the commercialization of sustainable community forest activities, such as honey harvesting.

Climate change threats

- NTFPs are a critical emergency and supplementary source of income (cash and non-cash); climate impacts on NTFPs would have a critical impact on livelihoods, particularly in crisis situations.
- Local villagers state that they have already seen significant non-standard variability in climate over recent decades, including: greater rainfall variability (specifically, increasing delay in the arrival of the wet season – this has put stress on water resources and some communities have actually had to purchase water), and windstorms. These changes have caused upland rice yields to decline by between 20% and 50% since 2005; food-based NTFPs have also experienced a decline of between 30% and 40%.

7.3.8 KEY STAKEHOLDERS

- **Key NGOs working in area** – WWF (major presence), Birdlife, Fauna and Flora International (FFI), and Action Contre Le Faim.
- **Relevant government ministries and authorities** – Department of Wildlife and Biodiversity, Ministry of Agriculture, Forestry and Fisheries, Ministry of Environment, and local government.

7.4 U MINH THUONG NATIONAL PARK

7.4.1 OVERVIEW

Covering 21,800 ha, U Minh Thuong National Park, along with nearby U Minh Ha National Park, is recognized as one of the highest priority sites for wetland conservation in the Mekong Delta. The area plays an important role in maintaining soil and water quality both within and adjacent to the park. *Melaleuca* forests in both these parks represent some of the last remaining areas of freshwater peat swamp forests in Vietnam. Tropical peat swamps such as UMT NP are highly sensitive to changes in water availability. Across the tropics, drainage of peatswamps and forest clearing for agricultural development has resulted in broad-scale degradation of these systems (Page *et al.* 2009). Healthy tropical peat swamps provide important habitat for endemic and endangered species (Page *et al.* 2009), produce economically valuable timber and NTFPs (Page & Rieley 1998), filter groundwater recharge, store fresh water during the dry season (Wosten *et al.* 2006), store carbon within the peat layer (Hirano *et al.* 2012), and support local livelihoods (Wosten *et al.* 2006).

The hydrological integrity of peat swamp ecosystems is fundamentally important to their conservation (Wosten *et al.* 2006). Water and water management is therefore key to the maintenance of the biodiversity and livelihoods supported by healthy peat forests such as U Minh Thuong.

7.4.2 PHYSICAL CONTEXT

Hydrology

U Minh Thuong NP is located on the plain of the Mekong Delta, and rises only a few meters above sea level. The park sits in a depression in the delta, 0.4 m lower than the surrounding land (Saqalli *et al.* 2009). As a result, water from the surrounding delta is received in the UMT NP. Floods in UMT NP occur at the beginning of the monsoon season, and last far longer than surrounding areas (Saqalli & Dosso 2011). The Cai Lon River is the main river of the area with a length of 60 km. A number of smaller rivers in the area are connected to Hau River, which is one of the main tributaries of the Mekong River.

There is a network of more than 71 canals in Kien Giang, mostly developed since the 1990s to supply irrigation used for rice crops. These canals have changed the hydrological flow regimes in the lower Mekong Delta, and disrupted natural wetland ecosystems (GIZ 2011). In the core zone of UMT NP, a perimeter canal and dyke system has been established to manage the water level. Water is released during the rainy season but retained at other times of the year.

Soils / Geology

Potential acid sulphate soils cover a large area of U Minh Thuong freshwater wetlands, and are extensive across the Kien Giang region (Saqalli & Dosso 2011). Where acid sulphate soils (ASS) are exposed to air, oxidization of the soil produces sulphuric acid.

The ASS layer is covered by a layer of peat 1-3 m thick. In areas that have recently been burnt, the peat layer has been lost, and the land surface has been lowered, often forming open swamp. In areas that have been cleared for agriculture, the peat layer has been oxidized and reduced in thickness. Despite the ASS, the water in the core zone, where the peat layer is intact, has an almost neutral pH level (pH 6-7). In the buffer zone, where forest has been extensively cleared and canal developments have changed hydrological regimes, the ASS has become exposed in many areas, and the water can be very acidic (pH 3-4) and toxic to aquatic organisms (BI 2004c; GIZ 2011).

One management strategy employed by the park to manage ASS is the use of a system of canals and dykes around the core zone, and within the buffer zone of the UMT NP. By keeping the water level high

throughout the dry season, this system reduces oxidization and thinning of the peat layer, and reduces the risk of fire.

Climate Baseline

The region is influenced by both the southwest and northeast monsoons. The dry season in Kien Giang ranges from December to April and the rainy season ranges from May to November. Mean monthly evaporation is around 150 mm. The average annual rainfall is 1,980 mm with monthly precipitation ranges between 0 mm in the dry season and around 250 mm in the wet season. The average temperature is 27.3°C, with an average maximum temperature of 34.3°C and an average minimum temperature of 21°C.

7.4.3 BIOLOGICAL CONTEXT

U Minh Thuong National Park (UMT NP) is one of the last remaining peat swamp forests in Vietnam. The area is nationally significant due to the ecosystem services it provides in buffering the effects of the Mekong River floods, in recharging aquifers, and as important habitat for wetland species. Forested wetlands of the Mekong Delta have been extensively cleared for agricultural development. The significance of remaining patches of natural peatlands as habitat for endemic and endangered species; a key gene pool for wild crop varieties; and a source of NTFPs is therefore elevated.

7.4.4 KEY FLORA ATTRIBUTES

A total of 226 plant species have been identified in the park (Triet 2000). Undisturbed areas have been found to be more diverse than areas that have been burnt (Guong 2010), indicating that burning practices are significantly altering the floral composition within the park. Fire is known to expose acid sulphate soils in peat swamps of the region, likely impacting the presence of herb and shrub species (Guong 2010).

Key flora communities within the 8,038 ha national park and adjacent 13,069 ha buffer zone include forest dominated by *Melaleuca cajuputi* on both peat and mineral soils; seasonally inundated grasslands dominated by *Phragmites vallatoria* and *Eleocharis dulcis* with *Vigna luteola, Panicum repens* and *Leersia hexandra*; and open swamps dominated by aquatic vegetation including *Typha domingensis*, *Pistia stratiotes*, *Nymphaea nouchali*, and *Salvinia cucullata* (Triet 2000), along with *Eichhoria crassipes, Ipomea aquatica, Ludwidgea adscendens, Centrostachys awuatica, Azolla pinnata, Lemna aequinoxialis,* and the rare duckweed *L. tenera* (Buckton *et al.* 1999).

Other species common within the park include the tree species *Trema orientalis* and *Combretum acuminatum,* ground flora species included ferns such as *Stenochlaena palustris, Asplenium* sp., *Cyclosorus* sp. and *Acrostichum aureum* together with *Flagellaria indica* and *Scleria sumatrensis* (Buckton *et al.* 1999).

7.4.5 KEY WILDLIFE ATTRIBUTES

A high diversity of wetland bird species is present within the National Park. Birdlife International and collaborators have undertaken several bird surveys, and species lists are available. Information on reptiles, mammals, and fish is scarce, however grey literature reports indicate up to 32 mammal species, 34 reptile species, 34 fish species, and 181 insect species are present within the National Park (GIZ 2011).

Birds

As relicts of what was once a widespread forest cover in the Mekong Delta, remaining *Melaleuca* swamps such as that of the UMT NP are of high importance for breeding colonies of large water birds (MRC 2010). The UMT was found to support the highest bird diversity of 10 key wetland sites in the Mekong Delta during surveys conducted by Birdlife International and the Institute of Ecology and Biological Resources during 1999 (Buckton *et al.* 1999). Birdlife International have designated it an Important Bird Area (BI 2004b), and as the area fulfils several criteria under the Ramsar Convention, it has also been recommended for notification as a Ramsar site (Buckton *et al.* 1999).

To date, 187 bird species have been identified at the site, including nine globally threatened or near-threatened species and a number of significant congregations of more common waterbird species (BI 2004c). A breeding colony at the northwest corner of the park is considered to be possibly the largest waterbird breeding colony in the delta (Buckton *et al.* 1999). Buckton *et al.* (1999) recorded over 5,000 individuals during their surveys in the late 1990s. Of particular significance was a large population of Glossy Ibis (*Plegadis falcinellus*), which could represent a significant proportion of the remaining Southeast Asian population of this species.

Table 22

List of Near-threatened and Vulnerable species known to occur in the UMT NP. Data from Buckton *et al.* (1999) and BI (2004b) and categories are from the IUCN Red List

Common Name	*Scientific name*	*IUCN*
Painted Stork	*Mycteria leucocephala*	NT
Spot-billed Pelican	*Pelecanus philippensis*	NT
Black-headed Ibis	*Threskiornis melanocephalus*	NT
Lesser Adjutant	*Leptoptilos javanicus*	V
Sarus Crane	*Grus antigone*	V
Greater Spotted Eagle	*Aquila clanga*	V
Grey-headed Fish Eagle	*Ichthyophaga icthyaetus*	NT
Oriental Darter	*Anhinga melanogaster*	NT
Asian Golden Weaver	*Ploceus hypoxanthus*	NT

Reptiles and amphibians

A number of rare and endangered reptile species occur in the park. A study of reptile species within trade shops close to UMT NP was conducted during 2000 (Stuart 2004). This study provides the most up to date estimation of reptile species present within the park. A total of 21 reptile species were identified during surveys, with 76% of these species also seen in the possession of local people in the park. Several species identified are listed on the IUCN Red List as of global conservation concern. A summary of these species is provided in Table 8.

Table 23

List of Threatened reptile species known to occur in the UMT NP. Data from Stuart (2004); categorization according to the IUCN Red List.

Common Name	*Scientific name*	*Global*	*National*
Malaysian Box Turtle	*Coura ambionensis*	V	E
Yellow-headed Temple Turtle	*Hieremys annandalii*	E	E
Malayan Snail-eating Turtle	*Malayemys subtrijuga*	V	V
Burmese Python	*Python molurus*	V	V

GIZ indicates up to 34 reptile species are present within the park (GIZ 2011), however this data is not verified.

Seven species of amphibians representing three families are reported to be present within the park. All amphibians are considered to be characteristic of disturbed habitats and of low conservation significance.

Mammals

Limited data is available providing comprehensive assessments of mammals within the UMT NP. Publically available grey literature indicates between 24 and 32 species of mammals have been identified in the park (GIZ 2011). Ten of these species are nationally or globally threatened, including four species listed in the Red Data Book of Vietnam, five species listed in the IUCN Red List and five species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It is not possible to verify this data without access to original reports.

A population of the Hairy-nosed Otter (*Lutra sumatrana*) was identified in the UMT NP during 2000 (Nguyen *et al.* 2001). This population is extremely rare, with only five sightings of the otter recorded between 1925 and this 2000 discovery. This species is listed by the IUCN Otter Specialist Group as one of five otter species of top global conservation concern (Foster-Turley *et al.* 1990). The IUCN Red List identifies the species listing as Data Deficient, with population decline of up to 50% in the past three generations (Hussain *et al.* 2008).

Fish

Wetlands such as the UMP NP provide vital habitat for the maintenance of breeding stocks of floodplain fish during the dry season, and in the wet season they function as breeding and nursery grounds for many fish species (MRC 2010).

No thorough assessment of fisheries has been undertaken in the UMT NP. An assessment of commercially important fisheries resources found nine species (Clough *et al.* 2012). It is considered likely that there are another ten or so small non-commercial species present (Clough *et al.* 2012), however no information is publically available. A GIZ document reports a total of 34 species of fish have been identified in UMT NP (GIZ 2011), however the source of this information is not publically available.

7.4.6 SOCIAL DESCRIPTION

General summary

Kien Giang's population was more than 1.6 million in 2010. Its capital city is Rach Gia and it has Ha Tien as an important deep sea port connecting the city with a wide array of destinations in the region.

Demography	Description
Population	67,698 people live in the U Minh Thuong area. Population density in U Minh Thuong is 1.56 people per ha
Household size	Average family size is 4.22 members
Ethnicity	Kinh 90.85%; non-Kinh 9.15%
Inward and internal migration	Net emigration is (-)0.7% suggesting that there is considerable net outward migration from the area to larger cities.

Poverty and Living Standards	Description
Poverty Rate	Kien Giang's proverty rate stands at 6% of the total population. GDP/capita stands at US$972 (2010) but significant variations exist.
Health	The number of doctors per 1000 people is 0. 6
Education	At U Minh Thuong, 89% of Grade 1 students (children aged between 7 to 11) attend

	school. The attendance rates drop to 65% for both grades 2 and 3. The reasons for the drop out of school are lack of money and distance to school.
Food Security	At Kien Luong, 88% of households eat fish every day, less than 10% of households produce their own vegetables or raise poultry or ducks for home consumption. 52% of households are eating vegetables, and 40% eat meat once a week or more. Only 20% of households grow their own fruit.
Infrastructure	At U Minh Thuong, 79% use wood as their primary source of fuel for cooking, most of which is collected from their own land.
Land tenure	Agriculture, particularly rice is the dominant land use of the province. There is also a growing area of land under aquaculture and some forested areas.

Livelihoods	Description
Agriculture	55% of household farming is mostly focused on rice-based agricultural production. Other agricultural productions are *Melaleuca* tree crops, subsidiary vegetables, coconuts, bananas, and sugarcane.
NTFPs	Wild fish are harvested from the canals and surrounding wetland areas. Illegal hunting occurs especially waterbirds and reptiles for pet, medicines, and meat (Stuart 2004). Honey is collected from plantations (Saqalli & Dosso 2011). Fish are illegally collected from within the core of the park, as well as legally from plantations in the buffer zone (Saqalli & Dosso 2011).
Aquaculture	4% of households are involved in fishing or aquaculture for off-farm incomes –primarily shrimp and *Pangasius* (catfish). Fishponds were constructed in many lots in the buffer zone of UMT NP with funding from CARE International (Saqalli & Dosso 2011). These systems often include a significant proportion of wild fish in the harvests (ICEM 2013).
Livestock	Households also raise a small number of livestock; duck farms are located along canals throughout the region. Houses in urban areas have swallow roosting sites on the roof to collect birds' nests and 4-5 story specialized buildings for swallow roosts. Pigeon coops are also found in both urban and rural areas.
Logging	Harvesting wood from plantation and *Melaleuca* forests is done for home construction. Illegal logging occurs within the core area of the UMT NP.
Tourism	Tourism is beginning to develop in the area, and the number of tourists visiting the region increases each year. Community-based tourism development provides an opportunity to involve local people in tourism development and share in the benefits.
Industry	Accounted for 37% of Kien Giang Province's GDP in 2010 including materials manufacturing and seafood processing. Quarrying for Limestone karst.

Principal linkages between PA and communities

The main links between the PAs and communities are: (a) the provision of NTFPs for subsistence and commercial activities and (b) critical environmental services. These are detailed in the tables below.

It is important to note that NTFPs and other forest resources are being unsustainably used by both communities and outsiders. Major drivers of over-use include: increasing population density and pressure to open up new land, poverty, and unsustainable or illegal use. External pressures are also a key driver of declining environmental quality, including land concessions, water extraction, logging, and quarrying.

Key NTFP species	Description
Wildlife	Illegal hunting/trapping of waterbirds. Food and trading for species such as Sarus Crane and ibis. Illegal hunting or trapping of reptile species for trade. Freshwater turtle species are particularly threatened. Wild fishes are harvested from the canals and surrounding wetland areas, using a variety of gears (lift nets, block nets, throw nets, and fishing lines). Harvesting occurs at a relatively small scale and is primarily for home consumption.

Key environmental services	Description
Water quality maintenance	Functioning forested wetlands filter excess nutrients and sediments from the water and support macroinvertebrates and microbial communities that cycle nutrients.
Flood protection	Flooding occurs every year in the area and people are adapted with the flood however severe flood events affect human life and destroy crops. Functioning forested wetlands help to minimize the impact of flooding by slowing the flood wave and storing water.
Fire protection	Degraded peat swamps are particularly susceptible to fire. A large fire in 2002 burnt down nearly 40% of UMT NP. Subsequently, a fire management program was developed to protect the forest from fire. A series of dykes and canals around the core zone of the park retains a high water level during the dry season, keeping high moisture content in the peat layer and reducing risk of fire.
Habitat	Fish and other aquatic plant and animals species. Wildlife, especially waterbirds.

7.4.7 CONSERVATION STATUS AND THREATS

Conservations status

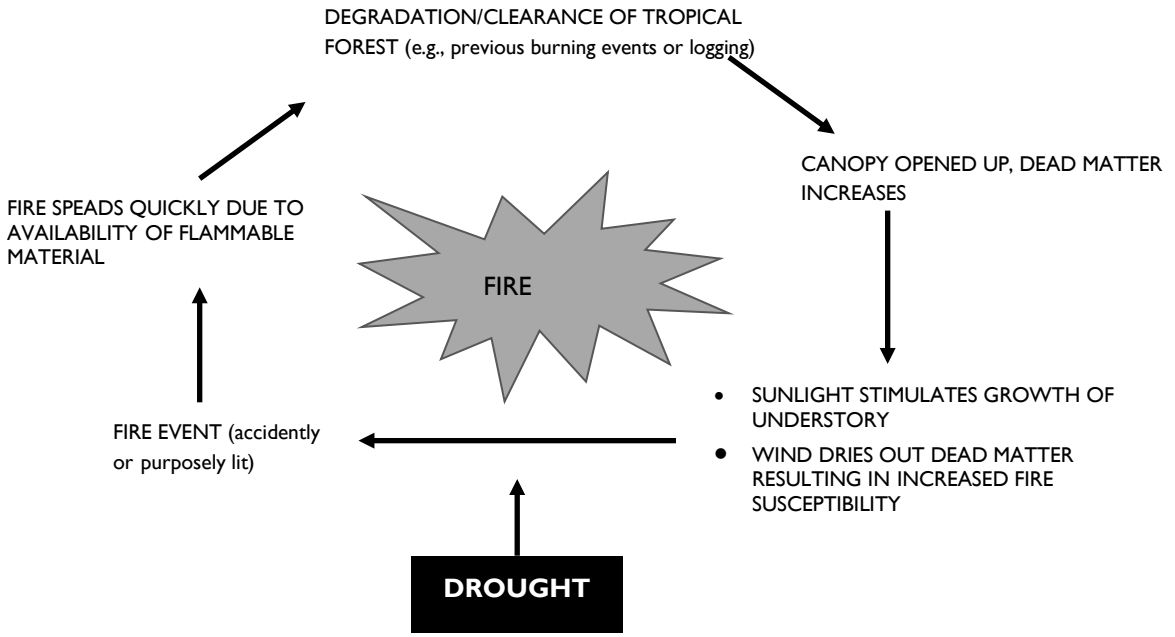
- **National and international conservation status** – U Minh Thuong NP is recognized as one of the three highest priority sites for wetland conservation in the Mekong Delta. The park was a nature reserve until January 2002, when its National Park status was designated. The Kien Giang region was recognized as a UNESCO Biosphere Reserve in 2006, with U Minh Thuong NP designated as a Core Zone (GIZ 2011).
- **Details of conservation activities**
    - Since designation as a National Park in 1992, the area has been managed as two zones by the U Minh Thuong Management Committee (UMTMC). The Special Protection Zone (SPZ, 80 km^2) is strictly regulated, and enforced for conservation outcomes. The buffer zone (138 km^2) is designated as Socio-Economic Forest. This buffer zone was subject to a colonization plan, where 3,500 households were moved into the area and provided four ha lots (Saqalli & Dosso 2011). These have been developed into rice and *Melaleuca* plantations through the establishment of a complex network of canals in the buffer zone. A number of forest guards deployed by the UMTMC are present within the park to enforce conservation objectives.
    - GIZ and AusAID collaboratively delivered a Conservation and Development of the Kien Giang Biosphere Reserve Project 2008-2011. In UMT NP, activities included supporting a series of workshops on "Conservation and sustainable development for UMT National Park". The workshop was aimed at initiating water, fire, and biodiversity management plans for the park. Particular focus was given to building capacity to manage water within the park to minimize the exposure of acid sulphate soils and fire risk. In addition, the project worked to provide skills and tools to improve climate change education in local schools.

- Since 1998, Care International became involved in the park management through launching a loan program for households in the buffer zone. The main aim of the project is to conserve the existing biodiversity of UMT by strengthening local management capacity and improving the livelihood security of local communities, thereby reducing their dependency upon natural resources. The UMTMC has maintained control over the area, and is responsible for managing the funds from Care International.

Macro-level management issues

- **Water and fire management** is key to the conservation of the U Minh Thuong peat swamps. The interrelationships between hydrology and ecology in tropical ecosystems have been demonstrated (Wosten *et al.* 2006). Insufficient water availability during times of drought is a known prerequisite for the start of fires in peatlands (Dawson *et al.* 2000). Dry peat and high available biomass cause fires to spread rapidly through these systems. Positive feedback from fire events makes peatlands more susceptible to subsequent fires (Wosten *et al.* 2006). In UMT NP, the intensive checker-board network of canals in the buffer zone of the park leads to high water surface evaporation, decreasing available water from the park as a whole. The dykes are commonly of poor quality, allowing a high rate of seepage to occur. As such water level can drop far below the ground in the dry season, allowing the peat layer to dry and elevating fire risk. Figure 7 depicts the fire and peatland feedback relationship, identifying the potential effects of extended drought periods upon the peatland system.
- **Water** - Intensive abstraction of water for the rice farming in the upper delta might also exacerbate salinity intrusion downstream, which in turn has negative consequences on agriculture and aquaculture, domestic water supplies, and the environment.
- **Illegal activities** – Illegal wildlife hunting is a major problem in this region; endangered species are being hunted within the protected area (Stuart 2004).

Figure 10: Feedback system in peatlands associated with forest fires. Black boxes represent impacts associated with climate change. Adapted from (Wosten *et al.* 2006) and (Dawson *et al.* 2000)



- **Land concessions –** Although formally under the control of the UMT Management Committee, during the 1990s parcels of land in the buffer zone of the UMT NP were provided to families under a 50-year renewable lease arrangement (Saqalli & Dosso 2011). Each plot has been developed into *Melaleuca* plantation, rice paddy, and some fishponds. The buffer zone has been divided by a series of canals and dykes to support these agricultural developments. Any form of land degradation resulting from land concessions within PAs increases the vulnerability of ecosystems to climate change, and their capacity to adapt.
- **Tourism development** – Tourism development has had some impact on the biodiversity of the region. For example, a road has been developed in the center of the U Minh Thuong National Park core zone to provide tourism access. The development of harmful tourist facilities and infrastructure such as this may obstruct the movement of species responding to climate change (ICEM 2013).

Climate change threats

- **Floods** are a common feature in the delta. With climate change, more severe floods are likely to occur in the region. In a recent Mekong River Commission (MRC) study, the increased flow in the Mekong River will increase water availability in the wet season in the Lower Mekong Basin, and increase the risk of flooding (MRC 2011). The wet season flow in the lower Mekong is projected to increase about 12%, and the percentage increase in flow for the dry season is around 15% in the delta region. However upstream of the delta, dams have been built or are planned to be built in the future on the mainstream in China and in the tributaries in the lower basin, and it is highly likely that these storages will influence the peak and base flow regime in the lower Mekong mainstream to some degree. Mainstream flooding is the most dangerous and destructive, causing flooding and inundation in the floodplain and reducing the ability of local canals and paddy fields to drain. This occurs when the upper catchment receives high rainfall and high tides cause water to back up in the mainstream and larger canals.
- **Sea level rise** (SLR) will reduce the area of agriculturally productive land in the lower Mekong delta in the longer term (Mackay & Russell 2011). An increase in sea level will further exacerbate freshwater flooding by restricting drainage.
- **Salinity and saline intrusion** issues are likely to continue in the future through a combination of high water extraction for domestic and agricultural purposes along with SLR, especially in conditions of drought and low river flow.
- **Drought** is already a problem in the Mekong delta. With projected changes in seasonality and dry seasons becoming drier it is possible that the occurrence and duration of drought conditions will worsen (ICEM 2013). Additionally, any rise in temperature will likely lead to increased water extraction for agricultural irrigation throughout much of the Mekong delta and higher catchment (MRC 2011), furthering pressure upon water resources in the region. Drought may contribute to an increased occurrence of forest fires in UMT NP. As shown in Figure 7, the combination of both rising temperatures and extended periods of drought will elevate fire risk within the park. Water and water management will be key to the ongoing conservation of the peat swamp system at UMT NP when faced with climate change.
- **NTFPs** are a critical emergency and supplementary source of income to poor people. Climate impacts on NTFPs, such as experienced by increased fire and flood events, will have a negative impact on livelihoods, particularly in crisis situations.
- **Extreme weather events** such as large storms and typhoons are expected to increase with climate change. Such events can lead to losses of infrastructure and land resulting from inundation and high winds and storm surges. Due to the low elevation profile of UMT NP, impacts from storm surges on water levels may be felt within the park.

- **Population –** Population growth increases the vulnerability of people and populations in the area to the effects of climate change. There are distinct regional differences in demographic composition and trends such as the migration of people towards coastal urban areas, which yields a greater than average growth of the population in some districts. Population growth is a major driver for change in the delta, in terms of increasing the exposure of people and households to climate change hazards and the demands placed on the available natural resources and its implications on sustainable livelihoods (Mackay & Russell 2011). Over the long term, population growth in U Minh Thuong NP is likely to contribute to and exacerbate not only the vulnerability to climate change as well as the difficulties in adapting to any detrimental changes in climate.
- **Agriculture** is the most important sector in U Minh Thuong region. Climate change will likely reduce agricultural production over the longer term due to saline intrusion, droughts, flood impacts, and changing rainfall and temperature regimes (ICEM 2013). When combined with population growth, any loss of productivity will affect household livelihoods, income, food security, poverty, and sustainability in other sectors.

7.4.8 KEY STAKEHOLDERS

- **Key NGOs working in area** –GIZ and AusAID collaboratively delivered a Conservation and Development Plan of the Kien Giang Biosphere Reserve Project 2008-2011.
  Birdlife, IFC, and the International Crane Foundation also work within the area.
- **Relevant government ministries, authorities, and staff** – U Minh Thuong National Park Director in Feb 2013 was Mr Le Hoang Huong. He worked closely with the AusAID-GIZ project team.
- Departments of Agriculture and Rural Development, Department of Fisheries, Department of Science and Technology, Department of Natural Resources and Environment, Department of Planning and Investment, Department of Finance, and local government.

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8 ANNEX 2: CAM – VULNERABILITY ASSESSMENT MATRICES

In the CAM vulnerability assessment matrices within Annex 2, the following code is used to indicate the relative level of exposure, sensitivity, impact, adaptive capacity, and vulnerability:

VH = Very High, H = High, M = Medium, L = Low, and VL = Very Low

8.1 NONG BONG KAI CAM

THREAT		*IMPACT*				*Adaptive capacity*	*Vulnerability*
Change and shift in regular climate	***Written description of the threat***	**Exposure**	**Sensitivity**	**Impact**	***Written explanation of what the impact is and reasons for score***		
Temperature	▪ Increased maximum temperatures in a typical year. a. 2 degrees difference in average maximum temperatures (1) b. Hotter dry season, maximum temperatures during the dry season can reach up to 42.5°C (1) c. Relative % temp change is 4.8-9.2% hotter for the whole year. From July to September (wet season) max temp increases by 9.2% (2) ▪ % of days exceeding 34 degrees is estimated to increase from 15% to 35% (3) ▪ Comfort zone - The current maximum temperature comfort zone is exceeded by 12 months of the year (4) d. The max temp comfort zone range is 60% outside the comfort zone during the wet season and 40% during the dry season (5) ▪ Min Temperatures: Increasing minimum temperatures in a typical year. e. 1-2 degrees increase in average daily minimum temperatures (7) f. between 10-22.5% relative change in minimum daily temperatures from Dec to March – highest change is at the end of Dec (22.5%) (8)	VH	VH [6]	VH	**Provisioning services** ▪ Higher temps, especially during the dry season will increase ET and reduce water availability for agriculture and domestic uses. ▪ Nong Bong Kai is a shallow lake area with an average depth of 2 meters, increase in ET could cause significant impact on its biodiversity ▪ Some important species are sensitive to the projected high temp increases and populations would be reduced especially in already degraded habitats **Regulating services** ▪ Higher temps during the dry season would cause drier soil surface layers leading to potential increases in erosion and soil loss especially in degraded areas. This will increase sedimentation in the lake ▪ Reduce water quality of the lake ▪ If surface litter is drier there is potential for losses in soil nutrient runoff and enrichment in surrounding areas ▪ We can expect some species and habitats to be lost from the system reducing biodiversity and population sizes **Habitat and supporting services** ▪ The invasion of exotic species, especially aquatic weeds consisting mainly of cogongrass, will become a bigger problem for wetland ecosystems under warmer conditions	VL	VH

[6] This is in very hot climate, 2 degrees of increase in temperature would be vital to some species.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
	g. relative change in minimum daily temperatures for the wet season is from 2.5 – 12% (8) ▪ The days experiencing daily min temperatures less than 17 degrees will decrease from 31% to 22% (9) ▪ Comfort zones: Wet season will experience higher minimum temperatures every month - by 1.5 degrees (June to November) (11) ▪ Temperature shift to warmer conditions (13)				▪ Water quality degraded by higher temperature will affect fish habitat (loss in population, change in migration patterns), macroinvertebrate species, and aquatic plant communities ▪ Temperature changes affect the timing of incidences of migratory bird species **Cultural services** ▪ A transformation in the ecosystem can be expected leading to losses in flagship species of waterbirds, fishes – and subsequent losses in tourism attractions		
Precipitation	▪ Monthly precipitation will increase most of the year except in Jan and Feb. a. Precipitation decreases 17% and 24% in Jan and Feb respectively. (15) b. Precipitation increases 4-18% during wet season c. Precipitation in August could reach 346 mm, which is a 21 mm increase from the baseline (14). ▪ 4% increase of monsoon started in May (rainfall >200 mm) (16) ▪ The comfort zone of wet season rainfall is exceeded by 40%. The max comfort zone becomes the median of CC total precipitation (18) ▪ The maximum rainfall events in each year is projected to be more extreme with higher volume (20) ▪ For at least 1 year in 25, rainfall events will be greater than ever experienced in the baseline	M	M[7]	M	**Provisioning services** ▪ Increased sediment and nutrient loads along with higher temperatures could affect populations of some fish species and encourage algal growth ▪ Higher rainfall during the wet season may improve water quality of the lake ▪ Species adapted to higher rainfall conditions in the wet season may become more dominant, for example invasive exotics and bamboo. **Regulating Services** ▪ Early onset of the monsoon following a drier dry period is expected to increase erosion and sedimentation in water sources. ▪ Potential for eutrophication of water bodies related to dry season build-up of nutrients in the soil surface sudden flushing into water bodies. ▪ Increase in precipitation during the wet season provides freshwater for the lake and could improve the aquatic ecosystem **Habitat and supporting services** ▪ The area will experience fundamental changes in the current rainfall regime – particularly persistent increases in wet season rainfall will lead to significant and permanent changes in the ecosystem such as in species assemblages. ▪ Degraded wetland might recover if aquatic ecosystem improves with higher rainfall throughout the year. **Cultural Services**	M	M

[7] The lake water quality is currently degraded, higher rainfall regime would improve water quality and aquatic habitat

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	Written description of the threat	Exposure	Sensitivity	Impact	Written explanation of what the impact is and reasons for score		
					▪ Increased flooding will damage infrastructure and cultural assets in and around the protected areas – roads, bridges, temples, tourism facilities ▪ Flooding can restrict access to specific tourist sites and heavy rain affects tourist activities – loss of tourism		
Water availability	▪ Water availability remains negative most of the year. It reaches normal conditions at the beginning of May, July, and from mid Nov to mid Dec (22) ▪ Water availability is reduced during dry season maximum 1.1% and during wet season of 1.4%[8] (22)	M	H[9]	H	**Provisioning services** ▪ Reduced water availability will reduce productivity of wild fruits, vegetables such as Tao, seaweed, and lotus plant ▪ Decreased water storage in the dry season for rice crops and tropical fruit growing. **Regulating Services** ▪ Drier soils will be more vulnerable to erosion leading to sedimentation of water sources and habitats ▪ Reduction in topsoil moisture will reduce micro flora and fauna and suppress decomposition and nutrient recycling **Habitat and supporting services** ▪ Reduced water availability throughout the year will reduce biodiversity and lead to permanent changes to the ecosystem – especially those areas already under stress. ▪ Will see increases in invasive exotic species adapted to dry conditions progressively replacing endemic plant communities ▪ Reduced wetland area thus reduces habitat and food sources for fishes and migrating water birds ▪ Reduction in fish population due to degradation of water quality in rivers and streams[10] **Cultural Services** ▪ Reduction in water availability might affect some recreation activities thus affecting tourism industry	L	H
Sea level	NA						
Change and shift in events							

[8] Higher change in temperature leads to higher change in evaporation however the increase in rainfall is lower comparatively.
[9] Even though water availability reduction is low, with the high temperatures in the area, it would be hard for ecosystems to cope with.
[10] Less water with higher temperature and higher sediment will lead to reduced DO levels and declining water quality. Water quality in this wetland is already lower than other places in Thailand, with water reduction, the condition will get worst.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
Drought (see definition)	▪ Drought condition does not change much from the baseline. Only Dec has less percentage of drought occurrence i.e., 4% decrease. (21) ▪ From Jan to March, Drought occurs 96% of the time	L	M[11]	M	**Provisioning services** ▪ Drier conditions will increase algal growth and eutrophication reducing populations of some fish and aquatic species **Regulating services** ▪ Drier conditions on the floodplain could affect the water filtering and regulation functions ▪ Drier soil surfaces layers would increase potential for erosion and soil loss when the rains come **Habitat and supporting services** ▪ Over time, biodiversity, the area of existing habitats, and plant and animal populations will reduce. **Cultural services** ▪ Repeated drought conditions will increase migration towards the protected area resources, i.e., the wetland	M	M
Flooding	▪ The incidence, extent, and duration of flooding is expected to increase [12]	H	VH	VH	**Provisional services** ▪ Seasonal destruction of subsistence crops and livestock and agricultural areas ▪ Increased flooding may reduce access to wetland products and also destroy wild products of the wetland **Regulating services** ▪ Increased flooding may bring benefits for soil nutrient enrichment in the floodplain area ▪ With increased severity in flooding the pest control services of natural systems become more important – flooding is associated with increased crop diseases, insects, and rodents. **Habitat and supporting services** ▪ Increased spread and pressure from invasive exotics – leading to degradation and pressure on natural systems – e.g., spread of weeds, exotic fish and aquatic plants replacing indigenous species ▪ Increased flooding combined with drier soil conditions brings increased sedimentation and filling of wetlands	L	V H

[11] Although the percentage of drought occurrence does not change much, higher temps and less water availability would make the drought condition more intense and slower to recover when the rain starts to pick up.
[12] This wetland is located on the floodplain; a precipitation increase in the wet season will result in more severe flooding.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					▪ Flooding and drought conditions makes rehabilitation and enrichment planting in natural systems more difficult **Cultural services** ▪ Flooding can restrict access to specific cultural and tourist sites ▪ Increased flooding will damage infrastructure and cultural assets in and around the protected areas – roads, bridges, houses, resort and tourism facilities		
Storms	▪ Extreme rainfall events will experience more rainfall. (21) ▪ Increase in storm incidence.	M	H	H	**Provisioning services** ▪ Potential losses in some wild food such as Tao, Bamboo, Lotus, and wild honey. ▪ Strong winds have caused destruction of crops and housing leading to greater dependency on wild products **Regulating service** ▪ Biological control services will be reduced following storms – due to losses in predators such as birds and amphibians **Habitat and supporting services** ▪ Extreme storms will damage and degrade remaining natural habitat opening the areas to invasive species and increased human penetration **Cultural services** ▪ Storms will reduce tourist access and visitation ▪ Damaged infrastructure such as roads and bridges will isolate some communities surrounding the area.	L	H

8.2 NAKAI-NAM THEUN CAM

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
Temperature	▪ Increased maximum temperatures in a typical year. a. 1.5-5 degrees difference in average maximum temperatures, the highest change is 5 degrees in July (1) b. Hotter wet season, maximum temperatures during the wet season can reach up to 31°C (1) c. Relative % temp change is 5.2-16.4% hotter for the whole year. In July, max temp increases by 16% (2) ▪ % of days exceeding 28 degrees will increase from 20% to 45% (3) ▪ Comfort zone - The current maximum temperature comfort zone is exceeded 12 months of the year (4). a. The max temp comfort zone range is 85% outside the comfort zone during the wet season and 30% during the dry season (5) ▪ Min Temperatures: Increasing minimum temperatures in a typical year. a. 1-1.5 degrees increase in average daily minimum temperatures (7) b. between 4.1-11% relative change in minimum daily temperatures– highest change is at the end of Dec (11%) (8) c. The wet season has lower relative change in minimum daily temperatures than the dry season (8) ▪ The days experiencing daily min temperatures less than 16 degrees will decrease from 15% to 10% (9) ▪ Comfort zones: Wet season will	M[13]	H[14]	H	**Provisioning services** ▪ Khammouan has abundant water resources, higher temps during the dry season will increase ET and reduce water availability for agriculture and domestic uses ▪ Some important species such as the resin trees and Cardamom are sensitive to the projected high temp increases and populations will be reduced especially in already degraded habitats ▪ Bamboo is the main construction material – it is resilient to extreme temps – so Hin Namno bamboo forest is unlikely to be affected – creating conditions for a succession change in ecosystems in disturbed areas and causing loss in biodiversity. Potential for shift to climax bamboo grasslands in some areas. ▪ Change in temperature and climate condition will lead to a shift in forest type. Forest transition might change to adapt with climate change ▪ Drier forest might affect some rainforest species such as rattan, which will reduce income from collecting rattan. **Regulating services** ▪ Higher temps during the dry season will cause drier soil surface layers leading to potential increases in erosion and soil loss especially in degraded areas ▪ Temp induced drier conditions on the forest floor could reduce natural water filtering and regulation functions. **Habitat and supporting services** ▪ Increase of 5 degrees in the wet season leads to increase in surface	M[15]	H[16]

[13] Compared to other areas in the basin, temperature changes in Khammouan are likely to be less intensive. Exposure at different elevation areas will be different.
[14] Although this area is not too hot or too dry of an area, some species would be very sensitive with the 5 degrees temperature increase in July.
[15] A rain-shadow effect from the Annamite Mountains helps the area to lower its temperature through higher rainfall mitigating the effects on the ecosystem from CC
[16] The vulnerability of high temperature will be variable for different parts of Khammouan. For example, temp increase will have little effect on the everwet forest in the Annamites but will have high impact on wetlands and grasslands on the Nakai Plateau.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
	experience higher minimum temperatures every month by 45% and the dry season by 25% (11) ▪ Temperature shift to warmer conditions (13)				water temperature, affecting aquatic habitat ▪ Temp increases could lead to habitat shifts/change (location and elevation), especially the over logging area at the edge of the Plateau and the base of the Dividing Hills ▪ Higher temps also affect migration of waterbirds and the movement of larger species such as tigers, guars, large cats, and hornbill within the PA cluster, i.e., there will be a change to the wildlife corridor **Cultural services** ▪ High temps lead to the loss or outward migration of flagship species such as tiger and other big cats – and subsequent losses in tourism attractions		
Precipitation	▪ Monthly precipitation increase in the wet season and decrease in Jan and Feb. a. Precipitation in August could reach 703 mm, which is a 57 mm increase from the baseline (14). b. Precipitation decreases up to 11% in Jan (15) c. Precipitation increases 6-22% during the wet season (15) d. Over 24% change in precipitation in April and May ▪ 8% increase of monsoon starting in May (rainfall >200 mm) (16) ▪ The comfort zone of wet season rainfall is exceeded by 60% and 50% in the dry season. More rain occurs during the dry season (18) ▪ The maximum rainfall event in each year is projected to be more extreme - and projected to have higher volume (20) ▪ For at least 1 year in 25, rainfall events will be greater than ever experienced in the baseline	M	M[17]	M	**Provisioning services** ▪ Higher rainfall in the wet season leads to flooding more often in the area, which could destroy or delay crop harvesting ▪ Species adapted to higher rainfall conditions in the wet season may become more dominant, for example bamboo and invasive exotics ▪ Some of the medicinal plants might be sensitive to the change in precipitation – they may die out or dry out. **Regulating Services** ▪ More intensive rainfall during July and August is likely to increase the risk of flash flooding and associated riverbank erosion, bank collapse, and localized landslides. ▪ Early onset of the monsoon following a drier dry period is expected to increase erosion and sedimentation in water sources. ▪ Potential for eutrophication of water bodies related to dry season build-up of nutrients in the soil surface followed by sudden flushing into water bodies. ▪ Drier in the dry season and intense rain in the wet season will affect the	M	M

[17] Only Jan and Feb are drier than the baseline, the rest of the year will receive more precipitation. It should not have significant impact on species, some species will even growth better with this rainfall changes.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					water regime of hydropower stations and the surrounding areas ▪ Intensive rain over degraded forest areas that are already degraded by over logging and cultivation **Habitat and supporting services** ▪ The area will experience fundamental changes in the current rainfall regime – particularly persistent increases in wet season rainfall will lead to significant and permanent changes in the ecosystem such as in species assemblages. ▪ Early onset of the monsoon is expected to increase erosion and sedimentation to fresh water sources. Degraded water quality of streams and rivers would impact on fish habitat. High sediment loads are also a physical irritant, affecting fish gills, and on settling out can smother fish eggs and encourage algal growth ▪ Degraded forest systems through climate related impacts will create opportunities for invasive species more adapted to the new rainfall regime **Cultural Services** ▪ Increased flooding, flash floods, and landslides will damage infrastructure and cultural assets in and around the protected areas including roads, bridges, and temples ▪ Flooding can restrict access to specific cultural sites for hunting, gathering, and religious purposes		
Water availability	▪ Water availability remains negative in the dry season until mid-April (22) ▪ Water availability is reduced during the dry season by a maximum of 1.6% and by the end of the dry season it increases to 7%[18] (22)	M	M[19]	M	**Provisioning services** ▪ Increased water availability in the wet season will reduce productivity of some roots and other plant products **Regulating Services** ▪ High saturated soil leads to potential flash floods during heavy rainfall events leading to erosion ▪ Changes in the schedule and regime for hydropower operations in response to water availability changes **Habitat and supporting services**	M	M

[18] This is when the potential for flooding occurs

[19] This area is not as sensitive to the decrease in water availability in the dry season; however, increased water availability in the wet season will increase the risk of flash floods and landslide.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					▪ In some parts, reduced water availability and increased temperature during the dry season will reduce biodiversity and lead to permanent changes to the ecosystem. ▪ Will see increases in invasive exotic species adapted to dry conditions progressively replacing endemic plant communities		
Sea level	NA						
Change and shift in events							
Drought (see definition)	▪ Drought condition does not change much from the baseline. Only Oct has a less percentage of drought occurrence equating to a 4% decrease. Drought occurs from Oct to April (21) ▪ Relatively high percentage of drought occurs from Nov to March	L	L[20]	L	**Provisioning services** ▪ Drought with high temps and low level of water availability will affect growing of wild foods and agriculture. **Regulating services** ▪ During droughts regulatory services will be reduced **Habitat and supporting services** ▪ Some degraded species affected by current drought conditions would continue to degrade with no management or conservation initiatives	M[21]	L
Flooding	▪ With heavier rain during the wet season, the incidence, extent, and duration of flooding is expected to increase.	H	H	H	**Provisional services** ▪ Seasonal destruction of subsistence crops and livestock and agricultural areas[22] ▪ Flooding will reduce access to potable water and destroy tube wells ▪ Increased flooding may reduce access to forest products ▪ Natural system provisions services become more important during and after extreme flooding leading to greater exploitation of forest products if agricultural lands are destroyed and access to markets is reduced **Regulating services** ▪ Increased flooding may bring benefits for soil nutrient enrichment in floodplain areas	VL[23]	VH

[20] The area will not be exposed to more intensive drought conditions. The ecosystem has coped with current drought conditions and it would continue to do so if no other threats occur.
[21] The ecosystem would maintain its condition.
[22] For example, flooding in 2010 destroyed 37,850 ha of rice fields; water inundated 3,441 hectares of wet season rice fields, affected 4,287 families, and killed 88 cows and left 19 ones missing. The damage by the flood was initially estimated at 583 million kip.
[23] External capacities to withstand and recover from extreme flooding is very low – whether considering poor local communities or the degraded natural systems

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					▪ With increased severity in flooding, pest control services of natural systems become more important – flooding is associated with increased crop diseases, insects, and rodents. ▪ Flooding will change water regulating services of the wetlands **Habitat and supporting services** ▪ Flooding increases spread and pressure from invasive exotics – leading to degradation and pressure on natural systems – e.g., spread of weeds, exotic fish and aquatic plants replacing indigenous species ▪ Increased flooding combined with drier soil conditions brings increased sedimentation ▪ Flooding and drought conditions makes rehabilitation and enrichment planting in natural systems more difficult ▪ Flooding also disrupted the fauna living in limestone caves around protected areas **Cultural services** ▪ Flooding can restrict access to specific cultural and forest sites for hunting and gathering NTFPs ▪ Flooding can restrict access to tourist attraction areas and tourist activities, i.e., kayaking, hiking. ▪ Increased flooding, flash floods, and landslides will damage infrastructure and cultural assets in and around the protected areas such as roads, bridges, temples, and tourism facilities		
Storms[24]	▪ Extreme rainfall events will experience more rainfall. (21) ▪ Increase in storm incidence.	M	H	H	**Provisioning services** ▪ Potential losses in some wild food & products such as bamboo and rattan shoots, fruits, greens, and honey; khem grass; cardamom and malva nuts; benzoin, peuak meuak, resins and leo resins, etc. ▪ Heavy rain could cause destruction of crops and housing leading to greater dependency on wild products **Regulating service** ▪ Biological control services will be reduced following storms – due to losses in predators such as birds and	L	H

[24] Storms in this area include intense rain and associated with flooding which damage crops, life stock and human life.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					amphibians **Habitat and supporting services** ▪ Extreme storms will damage and degrade remaining natural habitat opening the areas to invasive species and increased human penetration **Cultural services** ▪ Storms will reduce tourist access and visitation ▪ Storms can damage tourist and recreation facilities		

8.3 PHNOM PRICH CAM

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
Temperature	▪ Annual average max temp increases by 3 to 4 degrees (the new min increases to the old average) (1) ▪ From April to May (end of dry season) max temp increases by 17% (2) ▪ Early in wet season (June to Sept) max temp increases by 16-18.5% (2)	H [25], [26]	VH [27]	VH	**Provisioning services** ▪ Higher temps, especially during the dry season will increase ET and reduce water availability for agriculture and domestic uses ▪ Some important species such as the resin trees and Cardamom are sensitive to the projected high temp increases and populations will be reduced especially in already degraded	VL [28]	VH

[25] This area is identified as one of extreme climate change within the Lower Mekong Basin. The threats include significant increases in temperature. Disturbed forest areas and the buffer zones are likely to be more exposed to temperature changes than undisturbed areas.

[26] The exposure in some areas will be moderated by the elevation and microclimate effects within forests. Conversely dry grassland or open forest areas and important trapeang systems will be highly exposed to increased temperature and evaporation.

[27] During dry season max temp comfort zone is exceeded by 60% - the dry forest and grassland systems will be highly sensitive to this permanent change – but some forest ecosystems may have higher tolerance to more extreme temp ranges. In the wet season, temperature would be outside the "comfort zone" 100%

[28] Adaptive capacity is the ability to withstand and recover from shocks or stress. Internal capacity of Mondulkiri forest in its natural undisturbed state has high adaptive capacity. But this natural capacity is now severely reduced by mounting threats. External capacity from government sources is very limited – but international organizations are significantly strengthening capacity in the province. Overall the adaptive capacity of the cluster is being progressively lost and is judged to be low. External pressures include agricultural encroachment, illegal logging, hunting and gathering, increasing population and in-migration, and reduced connectivity due to transport corridors. For all those reasons the adaptive capacity of these natural areas has greatly diminished in recent years. The assessment of internal capacity cannot be divorced from external pressures. The protected area core zones tend to have higher internal capacity than multiple use and buffer zones. Their integrity is better conserved in terms of biodiversity and stability, but now even core zones are under pressure.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
	▪ 40% more days exceeding 30 degrees (shift from 20% to 60%) (3) ▪ 27% more days exceeding 32 degrees (shift from 10 to 37%) (3) ▪ Areas experiencing increase in extreme temps from 42 to 45degrees (3) ▪ During wet season max temp "comfort zone" is exceeding by up to 3 degrees every month (outside "comfort zone" 100%) (4) ▪ During dry season max temp comfort zone is exceeded by 60% (5) ▪ From April for 9 months in succession the area is 100% outside the "comfort zone" (5) ▪ Annual average min temp will increase by 2degrees (7) ▪ Dry season variation increases from 12.5deg to 15 deg but with min and max increasing (13)				habitats ▪ Bamboo is the main construction material – it is resilient to extreme temps so is unlikely to be affected – creating conditions for a seasonal change in ecosystems in disturbed areas and causing loss in biodiversity. Potential for shift to climax bamboo grasslands in some areas. **Regulating services** ▪ Higher temps during the dry season will cause drier soil surface layers leading to potential increases in erosion and soil loss especially in degraded areas ▪ Temp induced drier conditions on the forest floor could reduce natural water filtering and regulation functions ▪ If surface litter is drier there is potential for losses in soil nutrient runoff and enrichment in surrounding areas ▪ We can expect some species and habitats to be lost from the system reducing biodiversity and population sizes ▪ If temp increases induce biodiversity loss and forest ecosystem shifts or degradation, regulatory services will be reduced ▪ The impact on regulating services will be felt especially in the multiple use areas and buffer zones which are already degraded **Habitat and supporting services** ▪ Increasing temps will lead to drier forest conditions and increase the likelihood of fire – destroying habitat and reducing ecosystem support services ▪ Temp increases could lead to habitat shifts/change (location and elevation), especially southern aspect slopes and already degraded habitats ▪ Increased sediment loads entering waterways and bodies could reduce local aquatic plants and increase exotics such as water hyacinth reducing flow and leading to filling of trapeangs and other wetlands ▪ Higher temperatures may lead to earlier drying of trapeangs – leading to water shortages for dependent biota.		

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					▪ Increased surface water temperatures in water bodies (e.g., trapeangs) could lead to increased plant growth, and changing DO conditions and species composition and diversity. Algal growth and resultant eutrophication of trapeangs and streams is also a risk. **Cultural services** ▪ This area will be 60 to 100% outside its comfort zone – a transformation in the ecosystem can be expected leading to losses in flagship species such as tigers and other cats – and subsequent losses in tourism attractions		
Precipitation	▪ From Dec to April there will be drier conditions – up to 12% decrease in rain (in Feb) (16)[29] ▪ Up to 14% increase during the wet season (i.e., 70 mm in Oct) with earlier onset of intense rainfall events (16) and (17) – i.e., a 12% increase in chances of a May monsoon start (greater than 200 mm) ▪ In Oct increases of 70mm in typical year (15) ▪ June to November experience monthly increases (55% outside comfort zone) (19) ▪ Extreme rainfall events will experience more rainfall (i.e., the max daily rainfall event for each year will be exceeded by 15 to 25mm)[30] (21)	VH[31]	H[32]	VH	**Provisioning services** ▪ While the dry season decrease in rainfall is minor, the sensitivity of an already dry system to such changes could be significant. This is likely to reduce productivity of plants such as medicinal plants and fruits. ▪ Increased sediment and nutrient loads along with higher temperature could affect populations of some fish species and encourage algal growth ▪ Earlier and more severe drying of trapeangs in the dry season will reduce productivity of species such as eels and worms with associated impacts along the food chain. ▪ The drying of trapeangs in the dry season will reduce the food and water availability for large mammals such as Eld's deer, banteng, wild and domesticated buffalo, and birds. Given the importance of trapeangs as a dry season safety net, this drying could extirpate sensitive species or entire communities from affected areas ▪ Species adapted to higher rainfall conditions in the wet season may become more dominant, for example	M	VH

[29] Little rain falls during the dry season. Only small differences in monthly rainfall can give significant % changes. For example the 12% decrease in Feb amounts a 2.5 mm decrease. Temperature during this period may become the critical factor.
[30] Comparing with the 25 year baseline ranking of annual max rainfall events, only two annual events were not exceeded in 2050.
[31] PA cluster will experience significant changes in rainfall across the whole area
[32] The area will experience fundamental changes in the current rainfall regime – particularly persistent increases in wet season rainfall will lead to significant changes in the ecosystem. The dry season is also expected to become drier for 4 months.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					bamboo and invasive exotics ▪ Persistent increases in intensity of wet season events may induce water logging in some areas and reduce productivity of ground vegetables such as the wild potato, yam, and manioc **Regulating Services** ▪ More intensive rainfall during August and October is likely to increase risk of flash flooding and associated riverbank erosion, bank collapse, and localized landslides. ▪ Early onset of the monsoon following a drier dry period is expected to increase erosion and sedimentation in water sources. ▪ Pest control – natural predators, e.g., birds, amphibians, cats, bats, and snakes, of pests such as plant hoppers, Mealy Bugs, and rats are likely to have diminished populations due to reduced water and food availability ▪ Potential for eutrophication of water bodies related to dry season build up of nutrients in the soil surface followed by sudden flushing into water bodies. **Habitat and supporting services** ▪ The area will experience fundamental changes in the current rainfall regime – particularly persistent increases in wet season rainfall will lead to significant and permanent changes in the ecosystem including species assemblages. ▪ Lower rainfall during 4 months of the dry season will lead to more severe drying of trapeangs – leading to water shortages for dependent biota. ▪ Early onset of the monsoon is expected to increase erosion and sedimentation to fresh water sources. ▪ Degraded forest systems through climate related impacts (such as dry season fire) will create opportunities for invasive species more adapted to the new rainfall regime **Cultural Services** ▪ Increased flooding, flash floods, and landslides will damage infrastructure and cultural assets in and around the protected areas such as roads, bridges, temples, and tourism facilities.		

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					The ease of PA management and enforcement will also be affected. ▪ Flooding can restrict access to specific cultural sites for hunting, gathering, and religious purposes ▪ Localized pooling during increased wet season rains may expand habitat for mosquitos increasing disease		
Water availability	▪ Water availability is reduced throughout the entire year (23) ▪ Reducing the most during the end of the dry season. Soil water availability will decrease from Dec to May reaching a 20% reduction by the 1st of May (23) ▪ Water availability remains negative during the wet season reaching closer to normal conditions in Nov (23)	H [33]	VH [34]	VH	**Provisioning services** ▪ Reduced water availability will reduce productivity of wild fruits, herbs, vegetables, and medicinal plants ▪ The area is likely to experience an overall reduction in terrestrial primary productivity – influencing for example, the availability of fodder for wild and domesticated animals ▪ Reduced soil moisture may reduce sap flow in trees – for example in the resin trees. **Regulating Services**[35] ▪ Drier soils will be more vulnerable to erosion leading to sedimentation of water sources and habitats ▪ Reduction in topsoil moisture will reduce micro flora and fauna and suppress decomposition and nutrient recycling **Habitat and supporting services** ▪ Reduced water availability throughout the year will reduce biodiversity and lead to permanent changes to ecosystems – especially those already under stress. ▪ Will see increases in invasive exotic species adapted to dry conditions progressively replacing endemic plant communities ▪ Reduction in topsoil moisture will reduce micro flora and fauna suppressing decomposition and nutrient recycling **Cultural Services**	VL[36]	VH
Sea level	NA						

[33] Topography, aspect, and dense canopy cover will influence soil water availability in localized areas. Despite this, soil water variability is predicted to decrease during the entire year, which is the most significant variable.
[34] A year long reduction in soil moisture will affect all plants.
[35] Drier soils may lead to less runoff for the early part of the wet season as soil moisture is replenished
[36] In the process of adapting to permanent year round reduction in water availability ecosystems will change in terms of diversity and composition of species and habitats. Key natural assets such as trapeangs will be lost.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	Written description of the threat	Exposure	Sensitivity	Impact	Written explanation of what the impact is and reasons for score		
Salinity	NA						
Change and shift in events							
Drought (see definition)	▪ For April drought occurred in 57% of baseline 25 years. With climate change it will increase to 80% of the projected 25 years (22) ▪ Drought conditions will be experienced more frequently March to April (22) ▪ For Jan to Feb the 100% likelihood of drought conditions is maintained (22) ▪ Total drought periods annually will increase[37] (22)	H [38]	VH	VH	**Provisioning services** ▪ The availability of wild food will reduce due to more frequent drought conditions.[39] ▪ Increased duration and incidences of drought will reduce water availability for agriculture and domestic uses ▪ Some important species such as the resin trees and cardamom are sensitive to drought - populations are expected to reduce ▪ Bamboo is the main construction material – it is resilient to extreme conditions – so unlikely to be affected ▪ Drier conditions will increase algal growth and eutrophication reducing populations of some fish and aquatic species **Regulating services** ▪ Drier conditions on the forest floor could affect the water filtering and regulation functions ▪ Drier soil surface layers could increase the potential for erosion and soil loss when the rains come ▪ Drier surface litter will lead to losses in soil nutrient enrichment and reduced run off onto surrounding areas ▪ We can expect some species and habitats to be lost from the system, reducing biodiversity and population sizes ▪ During droughts, regulatory services will be reduced[40] **Habitat and supporting services** ▪ Over time, biodiversity, the area of existing habitats, and plant and animal populations will decrease – especially	VL	VH

[37] Given these projections, the team assumes that with the increase in incidence of drought that the duration of each drought event is likely to be longer.

[38] Localized areas will be less exposed to drought through factors such as topography (such as valley floors and aspect), areas of dense forest cover, permanent water bodies, groundwater springs and water course areas. The overall exposure of the PA cluster is however considered high, as localized ameliorating factors will reduce over time due to expected increases in the duration and incidence of drought conditions.

[39] Traditional forest-based sources of food and livelihoods have been steadily declining; wild vegetables and fruits, honey, wildlife, and fish are reported to have diminished by an estimated 30 to 40% over the past six years. http://www.recoftc.org/site/uploads/wysiwyg/Cambodia%20case%20study.pdf

[40] Drought conditions may be offset in some areas due to micro-climatic impacts of remaining healthy forests

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					large animals but also down to soil fauna and flora. ▪ Recovery of existing ecosystems will be inhibited by increased duration and regularity of drought conditions ▪ Increasing drought will lead to drier forest conditions and increase the likelihood of fire – destroying habitat and reducing support services ▪ Increasing duration and incidence of droughts will lead to fewer trapeangs and longer dry periods in those that remain – resulting in severe water, food, and habitat constraints for dependent biota. **Cultural services** ▪ Losses in flagship species such as tiger, banteng, and other cats will reduce tourism attractions ▪ Drought conditions will lead to a greater dependence on and more intensive use of forest products to compensate for reduced agricultural production ▪ Repeated drought conditions will increase migration towards the protected area resources		
Flooding	The incidence, extent, and duration of flooding is expected to increase[41]	H [42]	H	H	**Provisional services** ▪ Seasonal destruction of subsistence crops and livestock and agricultural areas ▪ Flooding will reduce access to potable water and destroy tube wells ▪ Increased flooding may reduce access to forest products ▪ Natural system provisional services become more important during and after extreme flooding leading to greater exploitation of forest products if agricultural lands are destroyed and access to markets is reduced **Regulating services**	VL [43]	VH

[41] 65% of villages surveyed in the Mondul Kiri Natural Hazards Mapping report (IOM 2009) were found at high risk of seasonal flooding threatening crops, livelihoods, livestock, and infrastructure. 90 per cent of villages in Mondulkiri are at medium to high risk of seasonal and flash floods ever year. http://www.iom.int/cms/en/sites/iom/home.html

[42] A national flood risk mapping study did not identify this area as a priority area – but provincial level surveys in Mondulkiri indicate that flooding is a serious seasonal problem.

[43] External capacities to withstand and recover from extreme flooding is very low – whether considering poor local communities or the degraded natural systems

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					▪ Increased flooding may bring benefits for soil nutrient enrichment in floodplain areas ▪ More frequent and longer duration flooding may recharge trapeangs and ground water sources. Modeling shows reduced water availability all year so increased incidence of flooding does not appear to provide long term benefits in this respect. ▪ With increased severity in flooding the pest control services of natural systems become more important – flooding is associated with increased crop diseases, insects, and rodents. **Habitat and supporting services** ▪ Increased spread and pressure from invasive exotics – leading to degradation and pressure on natural systems – e.g., spread of weeds, exotic fish and aquatic plants replacing indigenous species ▪ Increased flooding combined with drier soil conditions brings increased sedimentation and filling of trapeangs and other wetlands ▪ Flooding and drought conditions makes rehabilitation and enrichment planting in natural systems more difficult **Cultural services** ▪ Flooding can restrict access to specific cultural and forest sites for hunting, gathering, and religious purposes ▪ Increased flooding, flash floods, and landslides will damage infrastructure and cultural assets in and around the protected areas – roads, bridges, temples, and tourism facilities – also making good PA management more difficult		
Flash floods[44, 45]	▪ Extreme rainfall events will experience more rainfall leading to: (21)	M [46] H	VH	H	**Provisional Services** ▪ More intensive rainfall during August and October is likely to increase risk	VL	VH

[44] In this case, the definition of flash flooding includes rapid rising of small rivers and streams, overtopping of banks, and several days of inundation.

[45] In this area, flash flooding is associated with more localized catchment flooding. Flooding used to be rare in the Seima uplands, but SPF communities have experienced severe flooding four times in the past two decades. Heavy storms result in flash floods that inundate areas for two to three days. Apart from the negative effects of soil erosion and destroyed crops, water-borne diseases are on the rise and there is a growing risk of insufficient potable water in villages.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
	▪ greater incidence and ▪ more intense flash flooding				of flash flooding and associated riverbank erosion, bank collapse, and localized landslides. ▪ Increased severity and incidence of flash floods will lead to destruction and damage to infrastructure, housing, crops, livestock, and river bank gardens. ▪ Greater dependence on forest products for reconstruction - bamboo and forest products are the main housing materials **Regulating services** ▪ Forest regulating services will become more important in reducing intensity and recovery from flash floods ▪ Increase in flash floods leads to losses in soil and vegetation cover from river banks and affected subsistence cropping areas **Habitat and supporting services** ▪ Increased incidence of flash floods results in losses in forest and aquatic habitats opening up areas to exotic colonization **Cultural services** ▪ Destruction of roads, bridges, and tracks cutting off access to forests and wetlands		
Storms[47]	▪ Extreme rainfall events will experience more rainfall. (21) ▪ Increase in storm incidence.	H	H	H	**Provisioning services** ▪ Potential losses in some wild food such as fruits and wild honey. ▪ Strong winds have caused destruction of crops and housing leading to greater dependency on wild products **Regulating service** ▪ Biological control services will be reduced following storms – due to losses in predators such as birds and amphibians **Habitat and supporting services** ▪ Extreme storms will damage and degrade remaining natural habitat opening the areas to invasive species and increased human penetration	L	H

http://www.recoftc.org/site/uploads/wysiwyg/Cambodia%20case%20study.pdf. This local survey uses the term "flash flooding" to include local catchment flooding, which may last several days.

[46] Exposure to flash floods is very high in some but not all areas of the province. For the areas affected sensitivity is very high.

[47] Storms in this area include strong winds and intense rainfall. Typhoon Ketsana in 2009 displaced 404 families in Mondulkiri. A storm in 2011 brought the strongest winds in 30 years and extensive crop and housing damage. Storms also can bring flooding, flash flooding, and landslides.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					Cultural services ▪ Storms will reduce tourist access and visitation		

8.4 U MINH THUONG CAM

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
Temperature	▪ Increased maximum temperatures in a typical year. a. 2-4 degrees difference in average maximum temperatures b. Hotter dry season, maximum temperatures during the dry season increasing to above 40°C (up to 42) c. Hotter wet season, the minimum of maximum temperatures in CC is higher than the baseline average maximum temperatures) (1) d. Relative % temp change is 6-12% hotter for the whole year. 8-10% for March through to December and up to 12% hotter in the first part of the wet season (2) ▪ % of days exceeding 32 degrees will increase from 30% to 80% ▪ Existing temperature extremes will increase by 4 degrees to 42 (3) ▪ Comfort zone - The current maximum temperature comfort zone is exceeded 12 months of the year. a. From June to October the maximum temperature comfort zone is exceeded by 2 - 3 degrees b. The max temp comfort zone	H [48]	VH	VH	**Provisioning services** ▪ Higher temps, especially during the dry season will increase ET and reduce water availability for agriculture and domestic uses ▪ High temps lead to increase of river surface water temps, DO, and sediment in the river which will affect aquatic species, aquaculture. ▪ Loss of shrimp crop due to increase in disease risk. ▪ High temperature leads to drying out of peat in U Minh Thuong which reduces productivities of crops **Regulating services** ▪ Higher temps during the dry season would cause drier soil surface layers leading to potential increases in erosion and soil loss especially in degraded areas ▪ High temps lead to drying out of the peat in U Minh Thuong, which increases the risk of fire. Water regulation within the park will also be affected. **Habitat and supporting services** ▪ Increase in temperature might affect the production of buds and flower sets of mangroves. It can also change existing patterns in the reproductive cycle and alter the length of time between flowering and the fall of mature seeds and propagules.[49] ▪ Increase in temperature also causes an	VL	VH

[48] This area is one of the most disturbed areas more easily affected by CC
[49] Bjorn Kjerfve and Donald J. Macintosh, The impact of climate change on mangrove ecosystems

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
	range is 70% outside the comfort zone during the dry season (4) ▪ The differences between daily maximum temperatures in the dry and wet season are reduced. (6) ▪ Min Temperatures: Increasing minimum temperatures in a typical year. a. 1-2 degrees increase in average daily minimum temperatures (7) b. Between 5-8% relative change in minimum daily temperatures through the year - most change occurs at the end of the wet season (8%) (8) ▪ The days experiencing daily min temperatures less than 26 degrees will decrease from 85% to 30% (9) ▪ Comfort zones: Wet season will experience higher minimum temperatures every month - by 1-2 degrees (June to November) (10) ▪ Greater temperature variation between annual extremes (13) ▪ Significant temperature shift to warmer conditions (13)				increase in sea surface temperature, which may lead to the progression of some species of mangrove to higher latitude. ▪ We can expect some species and habitats to be lost from the system reducing biodiversity and population sizes ▪ Migration, breeding, and nesting patterns of some water birds night be affected by temperature change. **Cultural services** ▪ Hotter climate leads to the reduction of water birds in the area and as a result less tourism attractions ▪ Loss of grassland area might affect production of grassland handcraft products i.e., handcraft products made from *Lepironia* grassland		
Precipitation	▪ During the dry season there will be less rain - from 1 - 7 mm with greatest reduction in April (14) ▪ Wet season increase in rainfall between 10 and 27 mm of rainfall each month - largest change being Sept and October (14) ▪ Wet season increase of monthly precipitation in a typical year - up to 15% increase in September (15, 17) ▪ The comfort zone of wet season rainfall is exceeded. (18) ▪ The maximum rainfall event in each year is projected to be more extreme and projected to have higher volume (20) ▪ For at least 2 years in 25, rainfall	VH	H	VH	**Provisioning services** ▪ While the dry season decrease in rainfall is minor, the sensitivity of an already dry system to such changes could be significant. This is likely to reduce productivity of crops. ▪ Increased sediment and nutrient loads along with higher temperature could affect populations of some fish species and encourage algal growth ▪ More extreme volume of rainfall events increases the chance of flooding that destroys crops and aquaculture. **Regulating services** ▪ More intensive rainfall is likely to increase the risk of flooding. As this area is on a floodplain, intensive rainfall could cause high exposure	L[50]	VH

[50] Even though people are adapted to flooding that occurs frequently in the area, more extreme events will severely affect their daily life and health.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	Written description of the threat	Exposure	Sensitivity	Impact	Written explanation of what the impact is and reasons for score		
	events will be greater than ever experienced in the baseline				▪ Early onset of the monsoon following a drier dry period is expected to increase erosion, sedimentation, and nutrients in water sources ▪ Higher rainfall at the end of the dry season could help the biodiversity recover quicker and improve water quality of wetlands **Habitat and supporting services** ▪ Less rainfall during the dry season leads to a shortage in water to support some plant species ▪ Degraded forest systems through climate related impacts (such as dry season fire) will create opportunities for invasive species more adapted to the new rainfall regime ▪ Change in rainfall patterns will lead to changes in seasonal grassland habitat and migration patterns of water birds species **Cultural services** ▪ Increased flooding will damage infrastructure and cultural assets in and around the protected areas – roads, bridges, temples, and tourism facilities. ▪ Flooding can restrict access to specific cultural sites for gathering and religious purposes		
Water Availability	▪ A decrease in water availability throughout the year of between 4-8% (22) ▪ The wet season is expected to have 6-8% less water availability (relative to baseline) (22)	H	VH	VH	**Provisioning services** ▪ Low water availability will decrease water sources available for drinking and domestic usage ▪ Reduced water availability will reduce productivity of crops and vegetables ▪ Reduced moisture of the peat will lead to drying out of grassland, less nutrients for crops within peat areas. ▪ Low water availability will lead to high exposure to salinity which affects not only crops but also ecosystems **Regulating services** ▪ Drier soils will be more vulnerable to erosion leading to sedimentation of water sources and habitats ▪ Reduction in topsoil moisture will reduce micro flora and fauna and suppress decomposition and nutrient recycling	L[51]	H

[51] Kien Giang has an intensive system of canals and gates to regulate and reserve water for agriculture.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					▪ Drying out of the peat and grassland will lead to high risk of fire occurrence ▪ Reduced water will change the pattern of regulating and reserving water in the area **Habitat and supporting services** ▪ Decrease in available fresh water affects the growing rate of mangroves ▪ Reduced water availability throughout the year will reduce biodiversity and lead to permanent changes to the ecosystem ▪ Reduced water availability could lead to reduced wetlands and grassland areas, which is the loss of habitat for many species		
Change and shift in events							
Drought	▪ There is a greater likelihood of drought for April, May, November, and December. April has a 20% more chance of drought conditions occurring. (21)	H	VH	VH	**Provisioning services** ▪ Drought becoming more common and of longer duration will result in increased salinity and forest fire. It also leads to the loss of crop production[52] ▪ Increased duration and incidences of drought will reduce water availability for agriculture and domestic uses ▪ Drier conditions will increase algal growth and eutrophication reducing populations of some fish and aquatic species **Regulating services** ▪ More drought occurrence leads to drier peat in U Minh Thuong NP; water regulation patterns would also be changed. ▪ During the dry season, Sarus crane often moves to wetter areas (wetlands). With increasing drought condition, Sarus crane numbers will be reduced due to the lack of food and fresh water. ▪ Drought will increase the likelihood of fire occurring within the grassland and forest **Habitat and supporting services** ▪ Drought leads to drying out of grassland and peat, affecting species habitat in the area ▪ Long duration drought might cause some plant species to die out	VL	VH

[52] The 1997–98 El Niño-related drought was one of the most widespread and worst droughts Vietnam has experienced. It caused the loss of 15,900 ha of winter crops in Ca Mau and Kien Giang (ADB 2007)

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
Flood	▪ With intensive rainfall during the wet season and sea level rise, floods will likely occur more often and with greater magnitude. ▪ Flash flooding is also likely to occur more often	VH [53]	H	VH	**Provisioning services** ▪ Seasonal destruction of subsistence crops and livestock and agricultural areas (loss of rice crop, shrimp crop, damaged fruit trees, etc.) **Regulating services** ▪ Mainstream flooding is likely to occur often. It is the most dangerous and destructive flood, and results when large volumes of water fall in the upper catchment and high tides back water up in the mainstream and larger canals, causing flooding and inundation in the surrounding floodplain as well as reducing the ability of local canals and paddy fields to drain [54] ▪ Increase in erosion and sedimentation ▪ Carry away deposits and silt in rivers, lakes, and estuarine areas **Habitat and supporting services** ▪ Decrease in available fresh water affects the growing rate of mangroves ▪ Flooding and drought conditions make rehabilitation and enrichment planting in natural systems more difficult **Cultural services** ▪ Flooding will damage infrastructure, roads, houses, and cultural buildings ▪ Flooding will reduce tourist access and visitation	L	VH [55]
Storm	▪ Storm surge during monsoon condition is likely to occur more often. ▪ Typhoons are also more intense than before	H	H	H	**Provisioning services** ▪ Potential losses in some wild food. ▪ Strong winds have caused destruction of crops and housing leading to greater dependency on wild products ▪ Loss of shrimp crop, and fishing time **Regulating service** ▪ Biological control services will be reduced following storms – due to losses in predators such as birds and amphibians ▪ Reduced salinity due to increased volume of fresh water during flood events ▪ Increased erosion especially in coastal	VL	VH

[53] Kien Giang's topography is flat and it is on a floodplain; when flooding occurs, it will affect the majority of areas of the province.
[54] Kien Giang has river based flooding with a flood protection system that is not adequate.
[55] Although people in this area adapt to the flooding season as it happens every year, with sea level rise, inadequate flooding protection systems and life dependence on natural resources make them more vulnerable to CC.

THREAT		IMPACT				Adaptive capacity	Vulnerability
Change and shift in regular climate	*Written description of the threat*	Exposure	Sensitivity	Impact	*Written explanation of what the impact is and reasons for score*		
					areas **Habitat and supporting services** ▪ Extreme storms will damage and degrade remaining natural habitat opening the areas to invasive species and increased human penetration ▪ Storm/typhoons will also damage mangrove forest especially in coastal areas. **Cultural services** ▪ Storms will reduce tourist access and visitation ▪ Damaged dykes, pond infrastructure, roads, drainage, etc.		