Water Resources Management Sector Development Program: Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments

Rapid Assessment of Eco-Hydrology for the Tonle Sap River Basin and Mekong Delta River Basin, Cambodia

FutureWater Report 206
December 2019

Client
Asian Development Bank
TA-7610 CAM

Authors
Anthony Green
Kent G Hortle
Wim Giesen
Bas Van Balen
Dararath Yem
Juliet Mills
Indigo Brownhall
Peter Droogers
Gijs Simons
Johannes Hunink
Chantha Oeurng
Toch Bonvongsar

Consultants
FutureWater (lead)
Mekong Modelling Associates (JV)
Euroconsult Mott MacDonald
Green Enviro-Sult Cambodia

FutureWater
Costerweg 1V
6702 AA Wageningen
The Netherlands
+31 (0)317 460050
info@futurewater.nl
www.futurewater.nl

Document Details

Prepared by

Anthony Green (Water Resources Modeler / Team Leader)
Kent G Hortle (Snr Fisheries Specialist)
Wim Giesen (Snr Aquatic Ecologist)
Bas Van Balen (Snr Ornithologist)
Dararath Yem (Environment and Water Quality)
Juliet Mills (Environmental Scientist)
Indigo Brownhall (GIS)
Peter Droogers (Senior Hydrologist)
Gijs Simons (Hydrologist)
Johannes Hunink (Senior Water Resources Information Specialist)
Chantha Oeurng (Hydrologist)
Toch Bonvongsar (Hydrologist)

Purpose

This document has been prepared as the Report “Rapid Assessment of State of Eco-hydrology Tonle Sap River Basin Group and Mekong Delta River Basin Group” for ADB. FutureWater accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared. FutureWater has no liability regarding the use of this report except to ADB.

Cover Photo shows the fish pass and attraction flow release at the Stung Chinit Irrigation diversion dam in Kampong Thom. The fish pass successfully passes fish upstream; and when the diversion dam is upgraded various modifications could be incorporated to increase the efficiency of both upstream and downstream fish passage. Photo Courtesy: Kent Hortle.

Abbreviations

ADB = Asian Development Bank
AFD = the Agence Française de Développement
AMSL = Above Mean Sea Level
CARM = Cambodia Resident Mission of ADB
CCAI = Climate Change Adaptation Initiative (MRC)
CFi = Community Fisheries
CFR = Community Fish Refuge
CNMC = Cambodian National Mekong Committee
CSIS = Center for Strategic and International Studies
DFAT = Australian Department of Foreign Affairs and Trade
DHRW = Department of Hydrology and River Works
DOM = Department of Meteorology
E – Flow = Environmental Flow
ECMWF = European centre for medium range weather forecasts
EFR = Environmental Flow Requirement
EIA = Environmental Impact Assessment
EMC = Environment Management Classes
ERA5 = 31km spatial resolution historic weather information reanalysis product
EU = European Union
EWD = Environment Water Demand
FiA = Fisheries Administration of MAFF
FW/MMA = FutureWater/Mekong Modelling Associates JV
IBA = Important Bird Area
IFR = Instream Flow Requirement
IFREDI = Inland Fisheries Research and Development Centre
IRRI = International Rice Research Institute
IUCN = International Union for Conservation of Nature
IWMI = International Water Management Institute
JICA = Japan International Cooperation Agency
JRC = Joint Research Centre (EU)
KBA = Key Biodiversity Area
KOICA = Korean International Cooperation Agency
LULC = Land Use and Land Cover
MAFF = Ministry of Agriculture, Forestry and Fisheries
MAFF = Ministry of Agriculture, Forestry and Fisheries
MAR = Mean Annual Runoff
MoE = Ministry of Environment
MOWRAM = Ministry of Water Resources and Meteorology
MRC = Mekong River Commission
PA = Protected Area
PMFM = Procedures to Maintain Flow in the Mainstream
RBG = River Basin Group
TA = Technical Assistance
ToR = Terms of Reference
VU = Vulnerable (in reference to species)
WCS = Wildlife Conservation Society
WDPA = World Database on Protected Areas
WMO = World Meteorological Organization
WUP – FIN = MRC Water Use Project Finnish
FFI = Flora
and Fauna International
RUPP = Royal University of Phnom Penh
EN = Endangered (in reference to species)
LMB = Lower Mekong Basin
OAA = Other Aquatic Animals
DO = Dissolved Oxygen
RAMSAR = Wetlands of International Importance under the RAMSAR convention
WQMN = Water Quality Monitoring Network
TSS = Total Suspended Solid
TOTN = Total Nitrogen
TOTP = Total Phosphorous
COD = Chemical Oxygen Demand
BOD = Biological Oxygen Demand
CNMC = Cambodia National Mekong Committee

Table of Contents

Appendices

Table of Figures

Table of Tables

1 Introduction

1.1 Project relevance and objectives

1.1.1 Project background and objectives

ADB Technical Assistance (TA) 7610-CAM: *Supporting Policy and Institutional Reforms and Capacity Development in the Water Sector* supports the Water Resources Management Sector Development Program in Cambodia and is focussed to enhance food security. The expected outcome of the TA is improved management of water resources and irrigation services. The TA has two outputs: (i) Output A: enhanced capacity for sustainable water resources management; and (ii) Output B: enhanced capacity of the Ministry of Water Resources and Meteorology (MOWRAM) to manage and deliver irrigation services.

MOWRAM has developed the Roadmap and Investment Program for Irrigation and Water Resources Management, 2019-2033, in 2019. This investment program builds on the experiences of ongoing projects in the water resources management and irrigation sector to provide a comprehensive and strategic framework for the country's investment in the water resources and irrigation sector. Its guiding principles include significant change for MOWRAM for providing the infrastructure necessary for subsistence level farming that will focus on works to target profitable agriculture.

For this assignment which follows on from earlier activities largely completed in 2014/15, TA 7610-CAM supports critical activities including (i) rapid water resources assessment of the Tonle Sap and the Mekong Delta river basin groups; (ii) ecological assessment of these two river basin groups to identify areas for development and conservation; (iii) detailed surface water resources assessment for five river basins within these groups.

The objective of the assignment is to support MOWRAM to make more informed, evidence-based water resources management and irrigation investment decisions through better understanding of water resources and ecosystems of two river basin groups: the Tonle Sap and the Mekong Delta.

1.1.2 Context

Hydro-ecology is the interdisciplinary study of the effects of hydrological processes on the structure and function of ecosystems (Moore et al., 2015), where an ecosystem's' structure refers to its characteristics and its function is the rate of its processes. It involves the integration of ecological and hydrological interactions at a catchment scale.

Organisms have specific niches determined by their tolerance to environmental factors (such as flow regime, soil and sediment type). Human interference has caused changes to natural regimes including increasing pollution and perturbation to flow regimes.

Many people rely on the ecosystems including the fisheries of the Tonle Sap and Mekong Delta and therefore understanding ecosystem processes and how they could potentially be affected by future development plans is of critical importance for Integrated Water Resource Management (IWRM).

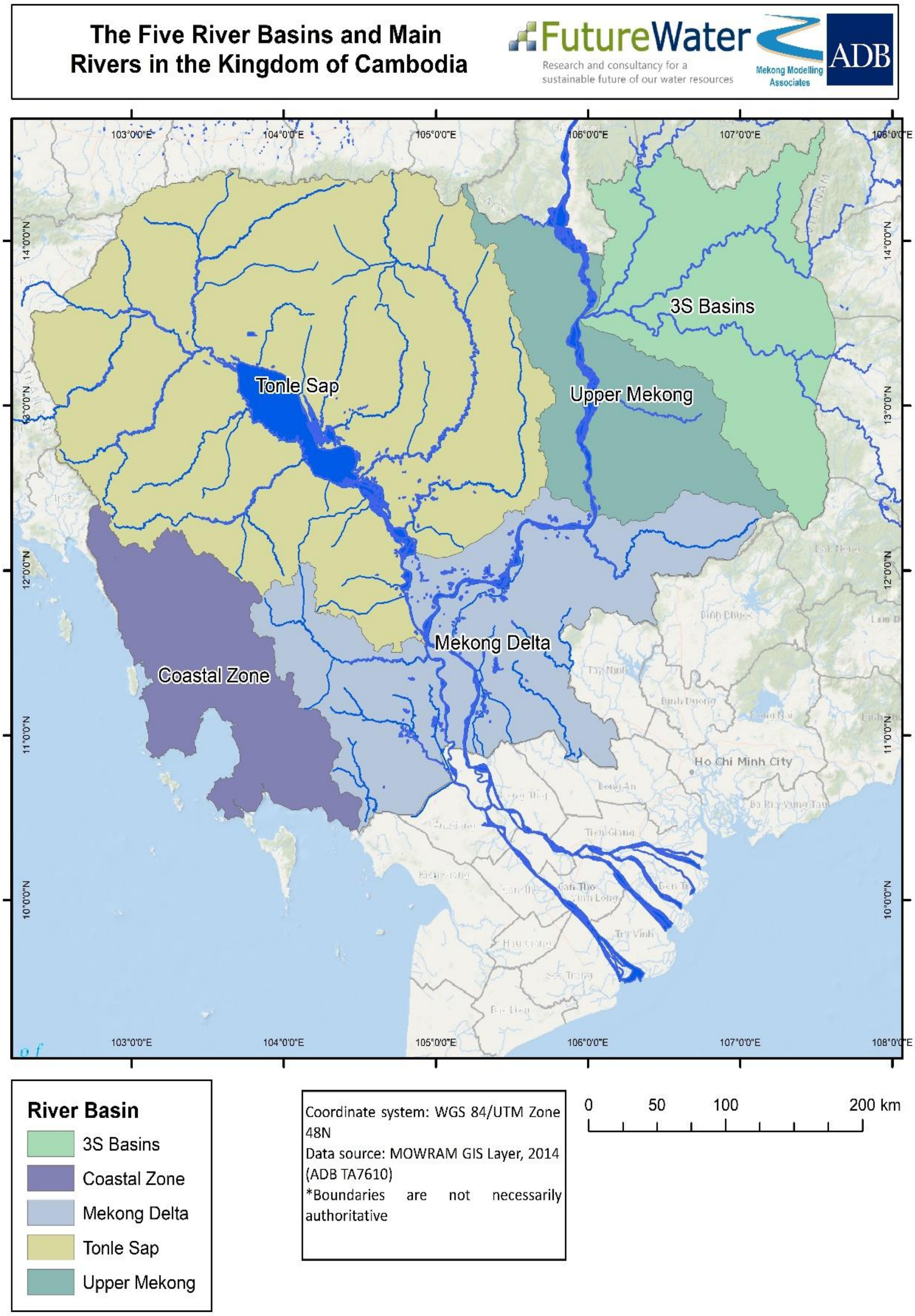


Figure 1: The Five River Basin Groups of Cambodia

1.1.3 Scope of this report

MOWRAM distinguishes five River Basin Groups (RBGs) in Cambodia, based on their respective hydrology (Figure 1). This is described in more detail in the Cambodia Water Resources report developed under the earlier phase of TA7610-CAM.

This report describes the first phase of the rapid hydro-ecological assessment of the Tonle Sap and the Mekong Delta RBGs. The study intends to support the implementation of MOWRAM's Roadmap and Investment Program for Irrigation and Water Resources Management, 2019-2023.

This report is prepared to provide:

(i) A fit-for-purpose analysis and characterization of the ecosystems and their minimum water regime requirements to support the key service provisions they provide. Potential risks from current and future hydrologic alterations and other human impacts are also identified.

(ii) Help MOWRAM to understand the:

a) Water regimes to maintain the health of high-priority ecosystems and critical habitats, and to help ensure development of water resources do not extend so far as to incur irreversible damage to critical habitats.
b) Potential water savings from not irrigating high conservation areas during the dry season that could be used for supporting other environmental, economic and social needs.

This rapid eco-hydrological assessment is intended to broadly assess key ecosystems and the hydrological regime required to maintain them. It forms the basis of further, more detailed assessments in selected critical catchments in the Detailed Surface Water and Resources Assessment (SWRA).

1.1.4 Aims and Objectives

The aim of the Rapid Assessment of Eco -Hydrology of the Tonle Sap and Cambodia Mekong Delta Tributaries is to:

1. Achieve a better understanding of the health of high-priority ecosystems and their water demand in relation to current and foreseen development of water resources.
2. Include an assessment of the aquatic ecosystems and current management including fisheries and other aquatic animals important to the Cambodian population.
3. Include specific consideration of the importance of aquatic systems for birds and the ecosystems they depend on.
4. Identify critically important areas by considering all 24 sub-catchments of the Tonle Sap River Basin Group and the Mekong Delta River Basin Group.

Identification of important areas has been done following desk review and rapid field assessment based on the following factors:

a. Degree of disturbance,
b. Ecological representativeness,
c. Values of competing complementary uses (ranking of catchments ranges from relatively pristine to highly stressed). People rely on the ecosystems of the Tonle Sap and Mekong Delta and how they could potentially be affected by future development plans.

The study has been carried out in a short period of time between May and July 2019 and depends inevitably on the available data and a limited amount of field work. Previous studies have largely concentrated on the Tonle Sap Lake, for this study the lake itself is not the focus of the study although inevitably the Great Lake is an important and central for the ecosystems surrounding it.

1.2 Framework for Defining Environmental Flows

It is believed that this is the first comprehensive study of the Eco-Hydrology of the two RBGs, although as a policy environmental flows have been estimated at project level in a number of cases.

ADB published 'Basin Water Allocation Planning' (Speed et al., 2013) which defines the context of risk based from environmental flow assessments, the importance of maintaining freshwater ecosystems and the services and functions that rivers provide to human communities.

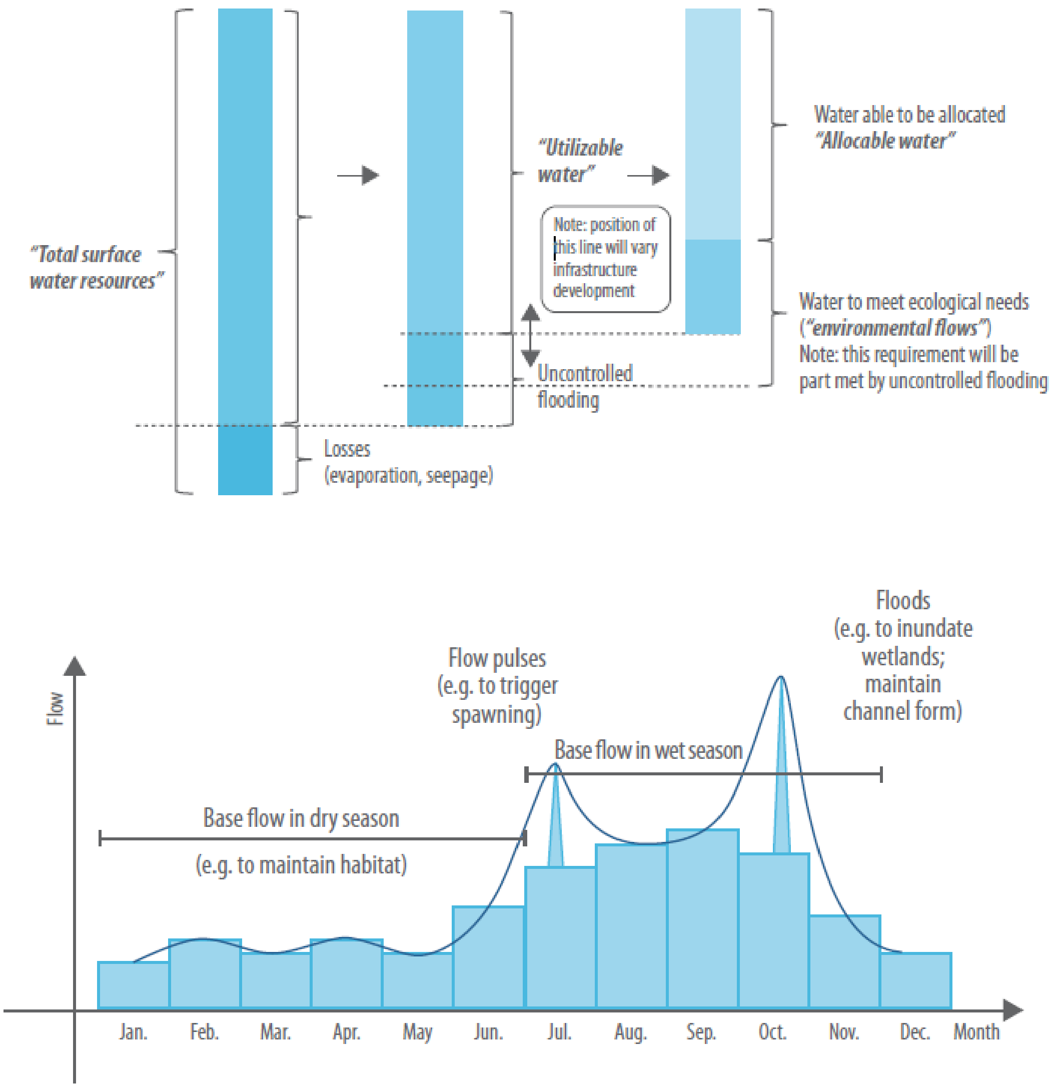


Figure 2: Ecological Flow Requirements (ADB/Speed et al. 2013)

1.3 Relevant Guidelines and Legal Framework

There are a number of Cambodian laws relevant to the application of environmental flows although, as far as we can determine there is no prescriptive procedure regarding their application of environmental or minimum flows. Although in some cases this could be expected included in existing protections for ensuring environmental impacts are considered. The relevant laws and regulations are:

1.3.1 Cambodian Laws

1. **Law on Environmental Protection and Natural Resource Management (1996)**

This law requires developers or project owners to prepare Initial Environmental Impact Assessment or a full EIA report for their proposal.

2. **Environmental Impact Assessment Process Sub Decree (1999)**

This sets out the EIA procedures and the duty of the Ministry of the Environment to review prior to submission to Government for approval. The Annex to the Sub Decree gives guidance on whether IEE or EIA is required depending on the type of scheme and its size.

3. **Law on Water Resource Management (2007)**

This law provides procedures for the management or water resources and the obligations and rights of different water users. MOWRAM may declare any basin as a Water Law Implementation area where there are likely to be conflicts between users

4. **Water Pollution Control Sub Decree (1999)**

This sets out relevant water quality standards for rivers, lakes and reservoirs and applies to all activities causing pollution of public water bodies. Standards for public water supply are also given.

1.3.2 International Law and Agreements

The Mekong flows and abstractions are set out in the 1995 Mekong Agreement between the four countries of the Lower Mekong Basin, Cambodia, Lao PDR, Thailand and Vietnam. The agreement covers various aspects of water management and has agreed procedures for:

- Maintenance of Flow on the Mainstream (including Tonle Sap reversal) PMFM
- Notification and Prior Consultation of schemes that may impact on the mainstream (PNPCA)
- Procedures for water quality monitoring
- Procedures for water use monitoring
- Procedures for exchange of information (PDIES)

The 1997 Convention on the Law of the Non-Navigational Uses of International Watercourses, and the 1992 UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes are also relevant but of the Mekong countries, only Vietnam has ratified these.

1.3.3 ADB Guidelines

ADB Safeguards are delivered through a safeguard policy statement (SPS) that lays out the delivery process for the safeguard policy. Sub-project screening through a rapid environmental assessment (REA) determine whether an Initial Environmental Assessment of a full EIA is required. Environmental Guidelines for Agricultural and Natural Resource Development projects (1991) are available. Safeguard documents are made publicly available.

2 Review

2.1 Eco-hydrology in the Tonle Sap and Mekong Delta River Basin Groups

2.1.1 Tonle Sap Catchments overview

The Tonle Sap river basin group consists of 16 sub-catchments, including the Tonle Sap Lake (Boeng Tonle Sap) in the centre (Table 1; Figure 3). There are 11 major tributaries that feed into the lake, the largest is Stung Sen. To the north of the basin is the Dângrêk Mountain range and to the Southwest is the Cardamom Mountains. The lowlands in the centre of the catchment are below 10 m AMSL.

Table 1: Sub-catchments in the Tonle Sap river basin group

River Basin		Area (km^2)	River Basin		Area (km^2)
1	Stung Krang Ponley	3,033	9	Stung Sisophon	5,593
2	Stung Baribour	3,003	10	Stung Sreng	9,931
3	Stung Bamnak	1,116	11	Stung Siem Reap	3,619
4	Stung Pursat	5,964	12	Stung Chikreng	2,714
5	Stung Svay Don Keo	2,228	13	Stung Staung	4,357
6	Stung Moung Russei (Dauntry)	1,468	14	Stung Sen	16,342
7	Stung Sankger	6,052	15	Stung Chinit	8,236
8	Stung Mongkol Borey	5,264	16	Tonle Sap Great Lake	2,743
	Sub-Total Area of Tonle Sap: 81,663 km^2				

2.1.1 Tonle Sap RBG Flood Regime

The Tonle Sap Lake is a central component of wetland ecosystems in the Lower Mekong basin (Penny, 2006). As one of the most productive freshwater ecosystems in the world, largely because of the flood pulse, high annual sedimentation and nutrient fluxes from the Mekong River. The productive ecosystem is driven by the natural flood reservoir from the lower Mekong basin driven by the monsoon season (Kummu et al., 2014). Water level in the lake is predominantly controlled by levels in the Mekong mainstream (Kummu et al., 2014), with over 50% of water coming from the Mekong.

It is expected that an alteration in the flood pulse of Tonle Sap in the future will lead to higher water levels in the dry season and reduction of the maximum flood extent in the wet season. This could result in the permanent inundation of ecosystems adapted to seasonal submergence, as well as agricultural expansion into natural habitats (Arias et al, 2013). Ecosystem productivity is under threat if the flood pulse and fish migration routes do not remain intact (Baran et al., 2007). Infrastructure also affects seasonally submerged habitats, by preventing inflows or outflows of water.

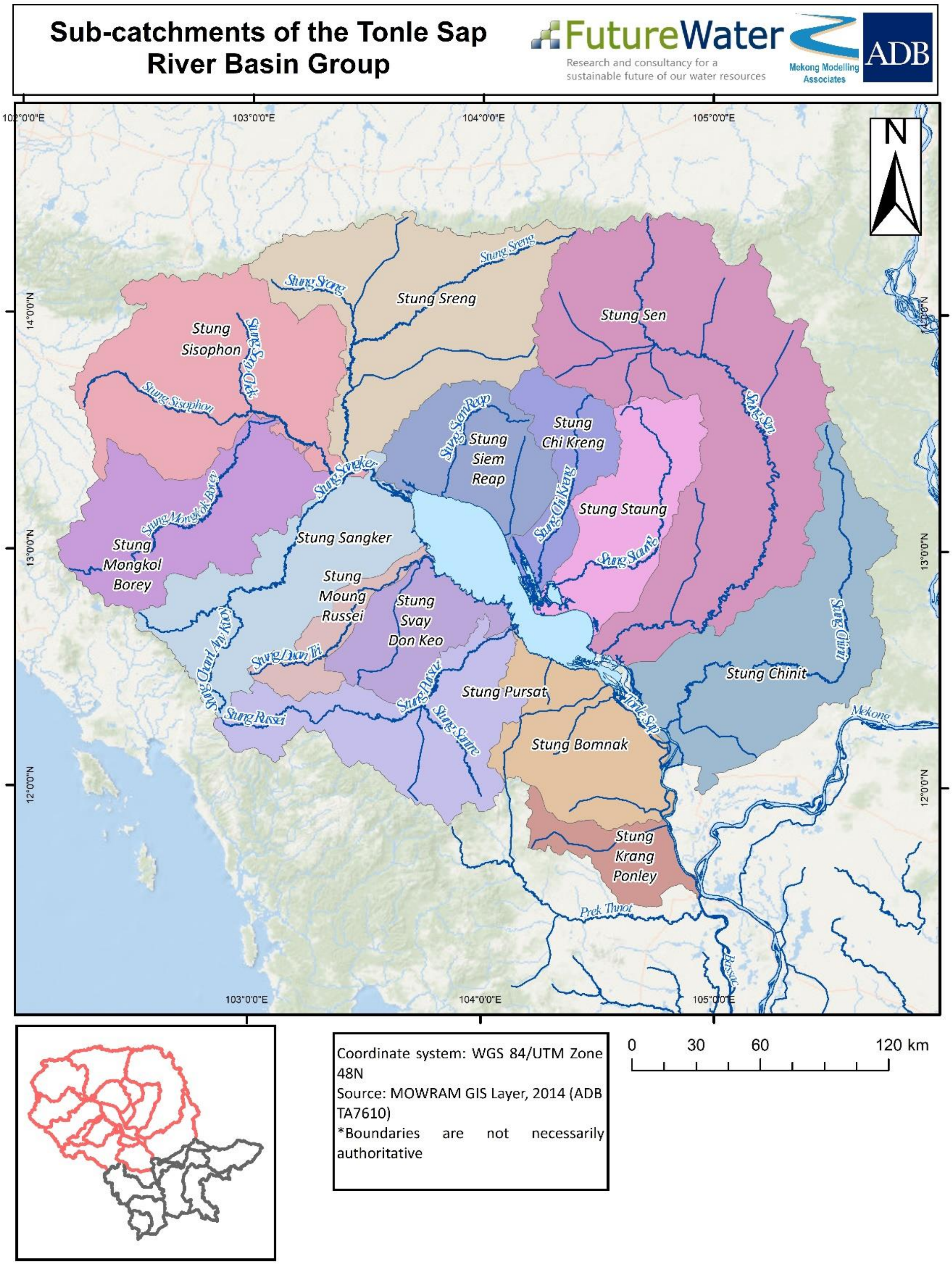


Figure 3: Sub-catchments of the Tonle Sap River Basin Group

The overall flood regime that influences ecosystems includes that from the Mekong which is a regular flood pulse though of variable magnitude and the flood regime of tributaries. The flood depth is shown in Figure 4, which is derived from hydrological modelling and includes tributaries. The frequency of flooding (average number of days per year inundated) is derived from a long-term time series of satellite imagery (as shown in Figure 5) for the main river system. The tributaries are not well represented in the satellite data due to the relatively short duration of floods and the difficulties encountered in finding visible range imagery without cloud cover. Flooded forest and other thick or floating vegetation also confuse the analysis of satellite detected flooding.

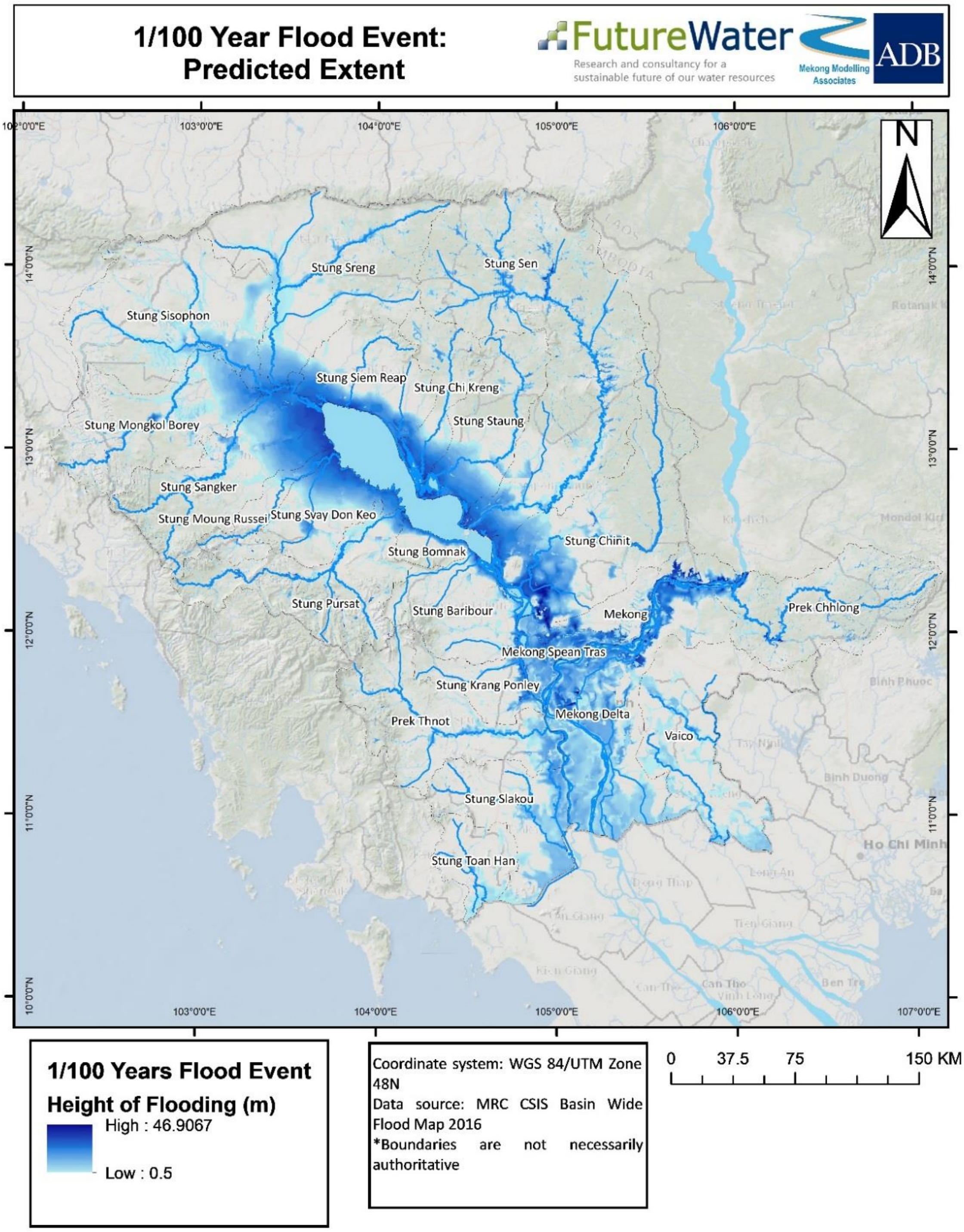


Figure 4: Modelled Flood Extent including Tributary Floods (MRC CCAI, 2016)

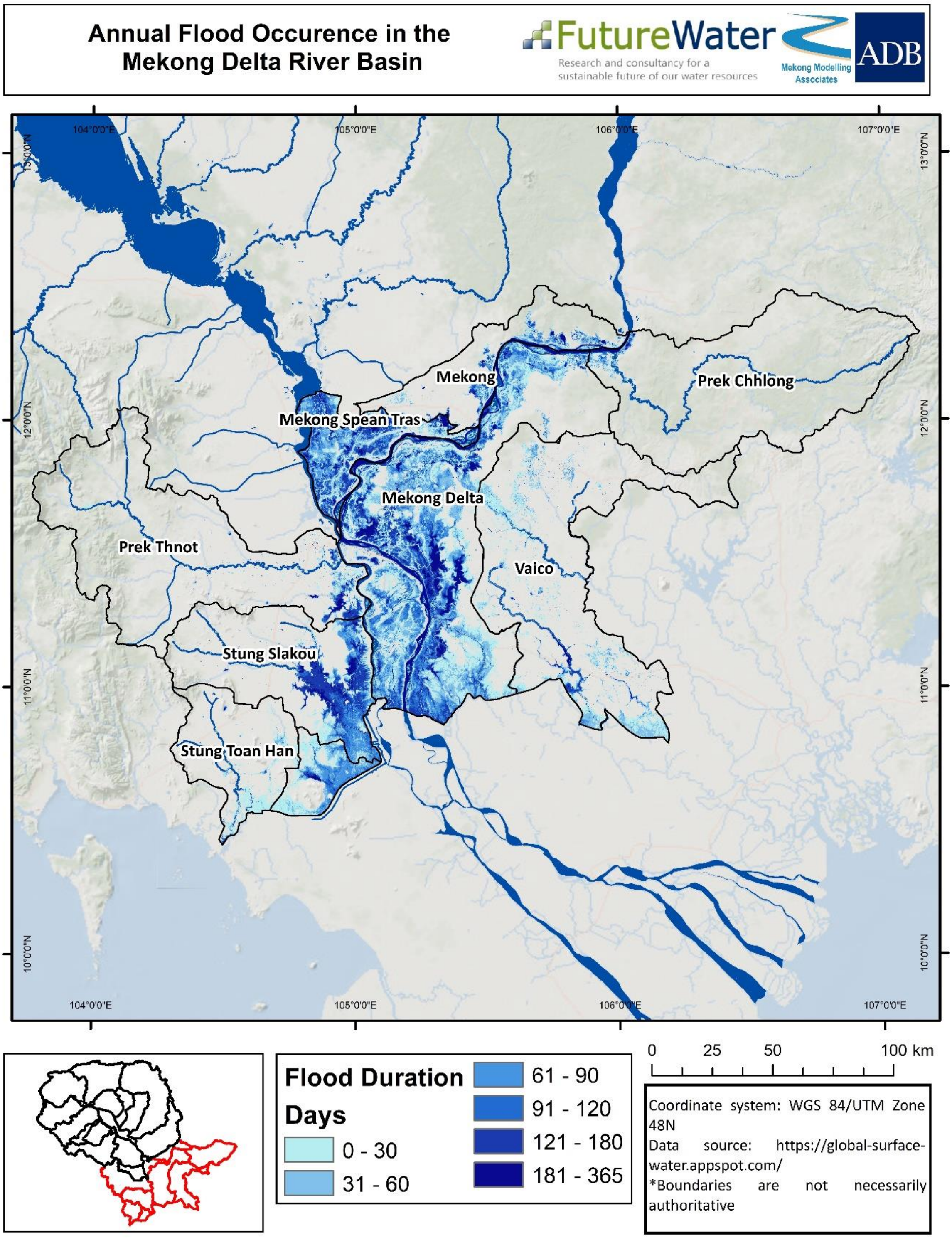


Figure 5: Average Annual Flood Duration in the Tonle Sap Basin.

n.b. flooded forest areas and deep shrubland may not show up as flooded due to satellite detection limitations

2.1.2 Tonle Sap Catchments Low Flow Regime

The Tonle Sap tributaries have low base flows, which can almost completely dry up during the dry season. Fisheries are adapted to this regime, as described in Section 5 of this report.

The influence of dam storage in tributaries is limited due to the relatively small capacity of irrigation dams compared to the significant water demands from conflicting users. More detail is given in the Water Resources volume of this study.

2.1.3 Mekong Delta Catchments overview

The Mekong Delta river basin group consists of 8 catchments (Table 2), stretching between Kratie and the Cambodia- Vietnam border (Figure 6). The basin consists of mostly low-lying land since large areas constitute the Mekong floodplain. However, two of the sub-catchments (Prek Chhlong and Prek Thnot) have mountainous areas in the upper parts of their sub-catchment. The Cardamom Mountains to the west create a rain shadow effect, which causes lower rainfall in Kampong Speu and areas of Battambang.

Table 2: Sub-catchments of the Mekong Delta river basin group

River Basin		Area (km^2)	River Basin		Area (km^2)
1	Stung Toan Han	1,765	5	Mekong Riverine (Upstream)	2,086
2	Stung Siakou	2,485	6	Mekong Delta Cambodia	8,723
3	Stung Prek Thnot	7,055	7	Mekong TS flood plain (Spean Troas)	1,508
4	Prek Chhlong	5,599	8	Tonle Vaico	6,618
Sub-Total Area of Mekong Delta: 35,839 km^2					

Like the Tonle Sap basin, a main driver of ecosystem functioning in the delta is water from the Mekong. The landscape is fragmented by population growth, infrastructure and development, which threaten the wetland ecosystems of the basin. These threats will intensify if irrigation projects are designed to maintain the natural functioning ecosystem.

2.1.4 Mekong Delta Flood Regime

The flood regime is a key factor in this RBG, which is primarily driven by the hydrology of the Mekong and Tonle Sap river system. Local runoff has a limited impact but is influenced by infrastructure such as roads, flood banks, canals and the raising of land for urban development. Close to the border, there is also influence from the extensive water infrastructure in the Vietnam part of the Mekong Delta. The average number of days of flooding per year recorded from satellite is shown in Figure 7.

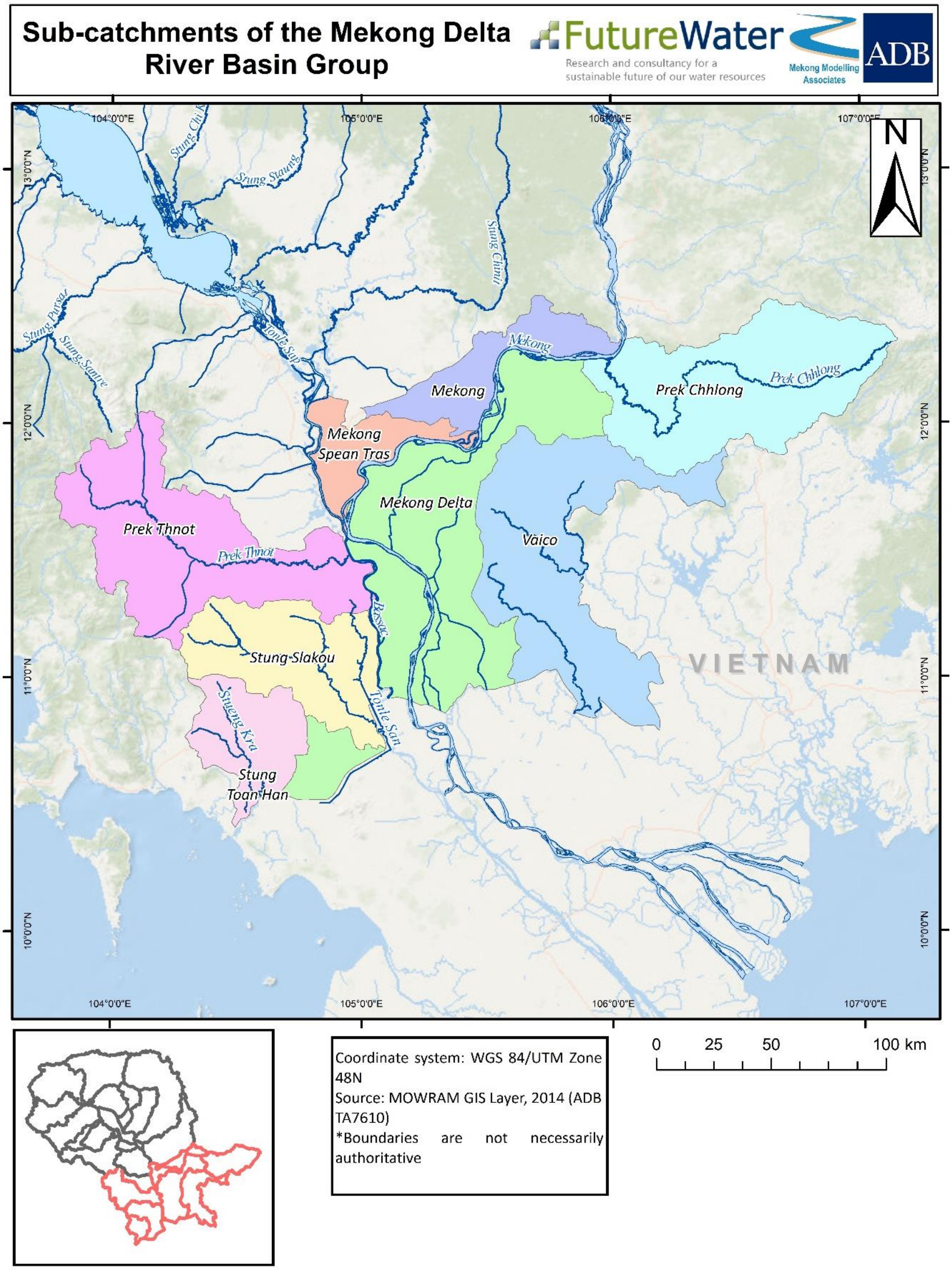


Figure 6: Sub-catchments of the Mekong Delta River Basin Group

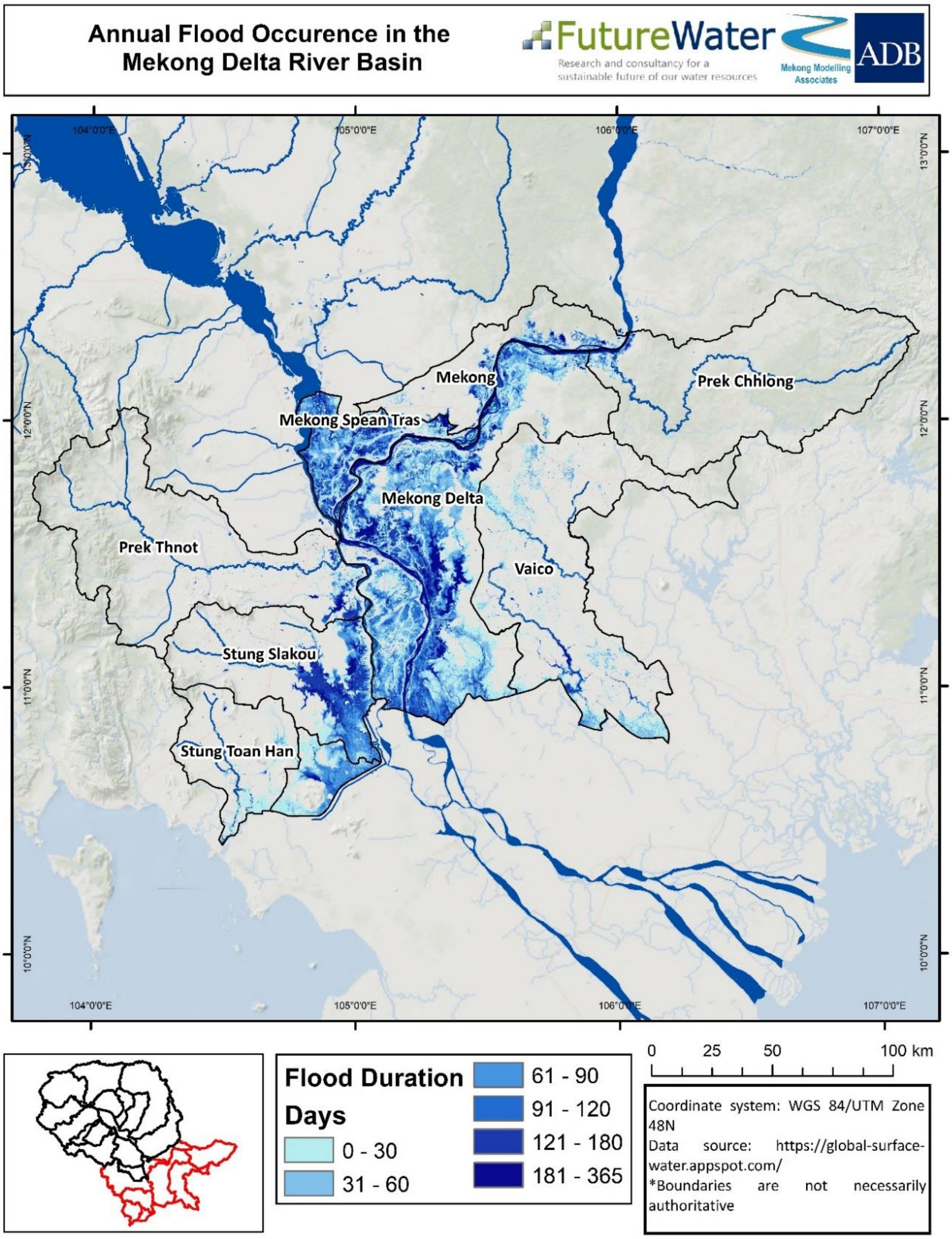


Figure 7: Average Flood Annual Flood Duration Mekong Delta RBG

2.1.5 Mekong Delta Dry Season Regime

The Mekong Delta Dry Season Regime is dominated by changes in water level and flow. The flow available at a given location is relative to ground elevation and river levels. Near to the border with Vietnam, connectivity is easier due to the relatively low level of the land and the tidal regime that has significant influence beyond the border of Cambodia. Such low-lying areas are however more prone to longer flood durations. This is explained further in the Water Resources report.

2.2 Environmental Flow Requirement Overview

This project attempts to make environmental flow requirement estimates for all of the 24 sub-catchments in the two RBGs. A review of the methods commonly used to estimate environmental flow demand and existing water frameworks relevant for Cambodia are outlined below.

2.2.1 Definitions of Environmental flow/ and ecological flow

An environmental flow (E-flow) is "the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated" (IUCN, 2003). Other definitions include 'the minimum flow needed to preserve existing river ecosystems" and the "hydrological regime required to maintain river biota jointly with social goods and ecosystem services "(Richter et al., 1996), including the water quality element. The flow for the maintenance of ecological processes and aquatic habitats is also referred to as Instream Flow Requirement (IFR), Environmental Flow Requirement (EFR) and Environmental Water Demand (EWD) (Karimi and Eslamian, 2012).

E-flows are a relatively new concept, especially in the context of a developing country such as Cambodia (Karimi and Eslamian, 2012). However, with increasing development and multiple competing water resource uses, maintenance of E-flows is essential to avoid any negative impacts to ecosystems that support biodiversity and the livelihoods that depend on them. Flows are modified by water infrastructure such as weirs and dams, hence, extractions for agriculture and other requirements must be balanced with the needs of ecosystems and their services.

2.2.2 Review of E-flow requirements in Cambodia

2.2.2.1 <u>Existing methods for estimating E-flow requirements</u>

Tharme (2003) reviewed over 200 methods for setting E-flow, which fall into 4 categories: 1) Rule based tables (e.g. the Tennant method); 2) Hydrological analysis (e.g. Richter method); 3) Ecosystem Functional Analysis, and 4) Habitat modelling (see Box 1 for further information).

According to this definition, the flow can be maintained at a less than 'pristine' condition to reach a compromise between water demands, and flow regimes can be modified to some extent without significantly altering the ecosystem (IUCN, 2003). With estimates ranging between the proportion maintenance of 65-95% of natural flow, which must be maintained to avoid impacts to ecosystems range between 65 and 95%.

This condition can be expressed in Environmental Management Classes (EMCs), commonly classified from A – F (Papadonikolaki et al., 2018). The method to assess E-flows is determined by factors such as the time and resources available and the type of issue at hand. The degree of flow allocated to environmental flow is determined by the stakeholders depending on the level of ecological heath that they want to be maintained at any given location (IUCN, 2003).

Box. 1. 4 categories of methodologies for determining Environmental Flows

1.**Rule based methods:**

These are normally presented at a percentage of mean annual flow (MAF) For example, the Tennent method and its derivatives use percentages of mean annual flow (MAF) that are considered to maintain an ecosystem at an agreed level, for example, 60-% of flow for 'good fish habitat' and 10%; lowest to sustain short-term survival of aquatic ecology maintaining a 'poor' condition (30% for maintaining 'moderate' quality). Other examples include 90% of Q95 for 'good ecological status' in sensitive rivers, as used in the EU Water Framework Directive as applied in the United Kingdom.

2. Hydrological Analysis:

This method analyses the flow regime from the past using at-site data tailored to a particular river. This method does not require biological data, as it assumes that the flow is the major control on the river ecosystem. It is considered one of the most holistic approaches to E-flow assessment.

3. Ecosystem Functional Analysis (e.g. the building block method)

Key flow regime elements are introduced according to the specific needs of an ecosystem. This method could be useful for example in dam reservoir operation when a dam controls the flow regime to ensure the flow 'mimics' that needed for ecosystem maintenance.

4. Habitat Modelling

This approach is much more complex, using additional variables known to effect ecology such as depth, velocity and substrate and habitat use data, combined into an Eco/hydraulic model. It is focused on habitat and hydraulics.

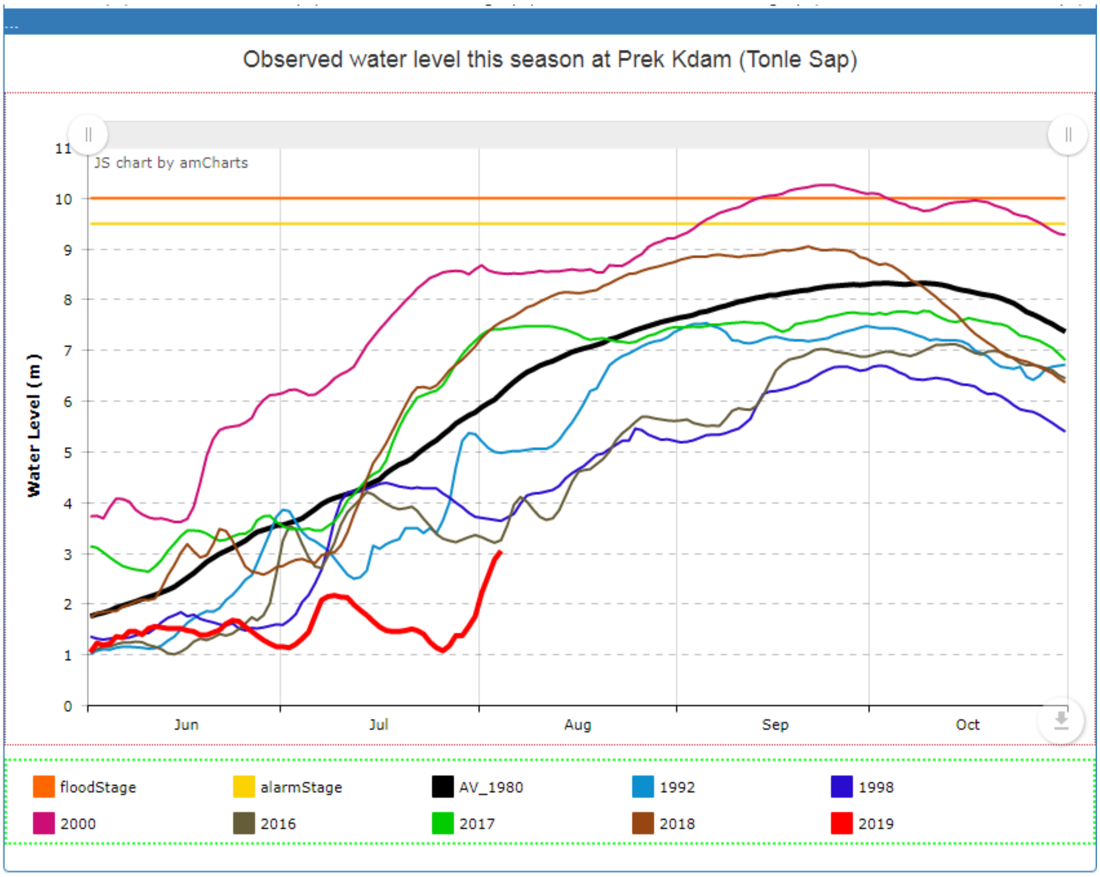


Figure 8: MRC Monitoring of Water Level under PMFM. Prek Kdam gauge on Tonle Sap.

2.2.2.2 Existing Flow Frameworks in Cambodia

MRC Procedures to Maintain Flow in the Mainstream (PMFM)

Under the PMFM, flow frameworks are provided for each selected hydrometric station (for monitoring mainstream), establishing flow thresholds that are considered acceptable by member countries. The flow framework for planning is intended to inform both national and transboundary planning and decision-making. Stations include Phnom Penh Port, Kratie, Prek Kdam and Kampong Luong, relevant to the Tonle Sap and Chao Doc, Chroy Changvar, and Tan Chau in the Mekong Delta region just across the border into Vietnam (for monitoring the transboundary flow regime form Cambodia to Vietnam).

Of relevance to this assessment is ***Article 6B*** of the Mekong Agreement (1995) there should be 'acceptable natural reverse flow of the Tonle Sap taking place during the wet season' (June-November) (MRC, 2018). Phnom Penh Port, Kratie, Prek Kdam and Kampong Luong stations monitor the reverse flow of the Tonle Sap lake during wet season. The flow framework is based on the total wet season volume at Kratie baseline scenario (1985-2000) and should be maintained within the upper and lower 90% Confidence Interval (= thresholds band) of probability of exceedance of the Baseline Scenario.

Mekong River Commission Procedures for Maintenance of Flow on the Mainstream: guidelines for planning purposes

- **Article 6A:** Of not less than the acceptable minimum monthly natural flow during each month of the dry season;
    - A considered development scenario or proposed project could **not be deemed acceptable** for planning purposes under the provisions of Section 5.1.1 of the PMFM, if the **simulated mean monthly flow** for the development scenario or proposed project is **below one or more of the minimum flow thresholds** for one or more months of the dry season at one or more selected hydrological stations.

- **Article 6B:** To enable the acceptable natural reverse flow of the Tonle Sap River to take place during the wet season;
    - A considered development scenario or proposed project could **not be deemed acceptable** for planning purposes under the provisions of Section 5.1.2 of the PMFM, if the **simulated total wet season flow volume at Kratie** for the development scenario or proposed project falls **outside the thresholds band**.

- **Article 6C:** To prevent average daily peak flows greater than what naturally occur on the average during the flood season.
    - A considered development scenario or proposed project could **not be deemed acceptable** for planning purposes under the provisions of Section 5.1.3 of the PMFM, if the **mean of simulated daily peak flows** for the development scenario or proposed project is **above the maximum flow thresholds** for one or more months of the flood season at one or more selected hydrological stations.

The MRC and WUP-FIN also carried out a 2-year project on 'Modelling the Flow regime and Water Quality of the Tonle Sap' (Sarkkula et al., 2003). Their methodology included the DRIFT model for quantifying mainstream ecosystem impacts of changes in the mainstream flow regime for flow, sediment and nutrients.

2.2.2.3 Other reported flow requirements

Global EFRs to maintain freshwater ecosystems were estimated by Smakhtin et al. (2004). An average EFR value of 24.7% of the Mean Annual Runoff (MAR) was calculated for Cambodia (Smakhtin et al., 2004). An EFR value of 43% of MAR by Sood et al. (2017) is estimated to maintain Ecosystem Management Class C. MARs are not very informative for a tropical climate, with pronounced wet and dry seasons when complex ecosystem processes are driven by specific hydrological regimes. IWMI provide an indicative Environmental Flow Requirement in raster form relative to the Mean Annual Runoff (Vorosmarty et al., 2010; Figure 9).

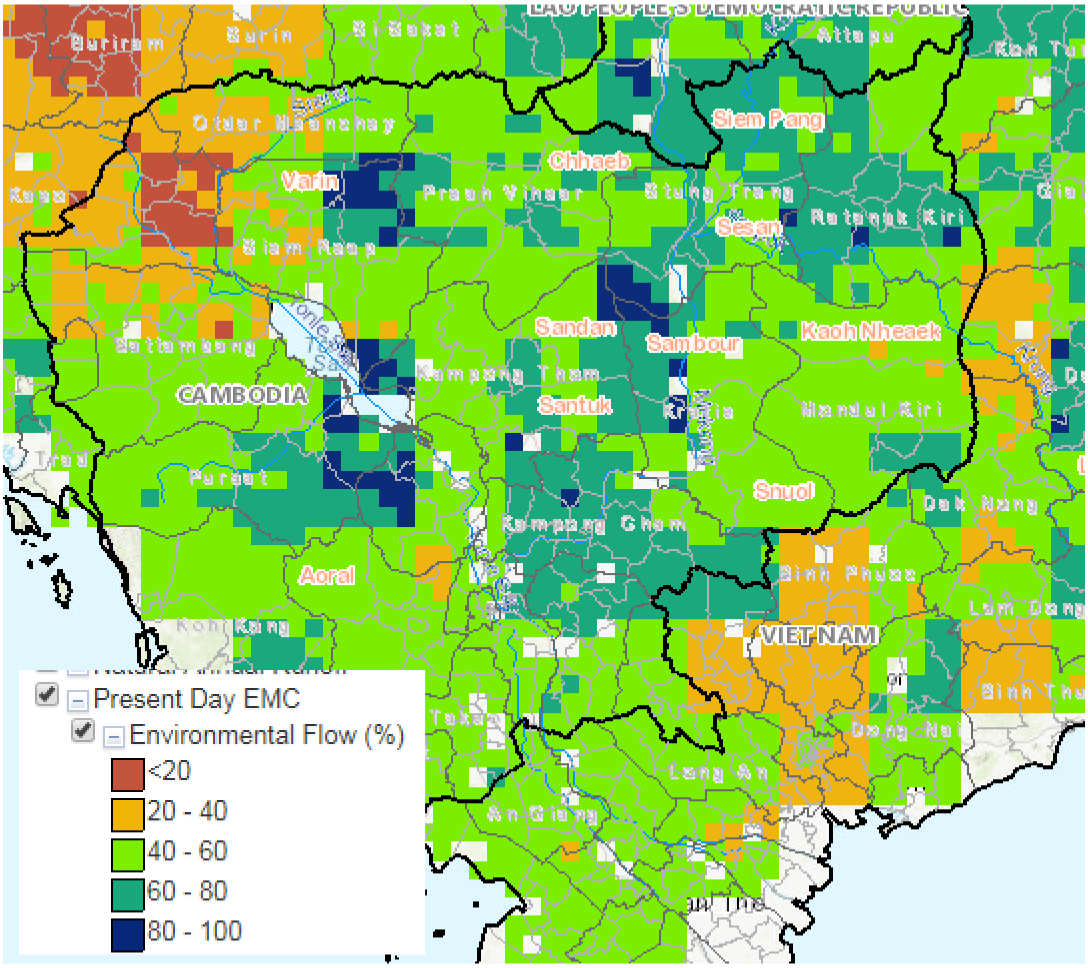


Figure 9: Proportion of Environmental flow in Cambodia according to IWMI Global Flow Information Tool (www.gef.iwmi.org)

Pastor et al. (2014) reviewed the different hydrological environmental flow methods applied worldwide and corroborated the results explicitly for low-flow and high-flow seasons. They reviewed two case-study applications in tropical areas in Asia (China and Vietnam), and computed EFR in the dry season at 67% and 51% of mean annual low-flow respectively. Wet season EFR were calculated at 32% of mean annual high flows in both cases. A dry season EFR of 40% of mean low flows was recommended for the Mekong mainstream (DHI, 2015).

Setting minimum environmental flow requirements in Cambodia is particularly relevant in the dry season. Chhuon et al. (2016) reported that the minimum EFR in Cambodia is 0.1 m^3/s per 100 km^2 of upstream catchment area. Hortle (2018) recommends a minimum dry season flow of 2 m^3/s for 4 diversion dam projects in Lao PDR, with catchment sizes varying between 595 and 1,039 km^2. This equals 0.2-0.3 m^3/s per 100 km^2 of upstream catchment area. A 1 L/second/km^2 E-flow was applied in the Kok River basin for ecological demand in the dry season (MRC, 2003). Estimates for the maintenance of the Mekong delta's freshwater regime is 2 L/second/km^2.

3 Methodology

3.1 General approach

The basis of the assessment is the characterization of ecosystems and their current condition, including their hydrology, intactness, vegetation types and status, aquatic ecology and fisheries and ornithological data.

- **Desk-based review** - Initial and review data collection of KBAs IBAs, Protected Areas (follow the methodology for E-flow requirements). Field site selection is based on a desk review to identify key environmental assets
- **Rapid assessment surveys** - were conducted over 2 weeks to assess habitat type, status and condition, and conservation requirements; as well as their water regime requirement and extent of flood. This included an assessment of fish and bird populations (including identification of threatened/rare species) and habitat requirements.
- **Identification of priority Ecosystems and Estimation of E-flows**

3.2 Data

3.2.1 Protected Areas

According to the IUCN definition, "A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."

Protected Area GIS information was sourced from the United Nations Environment World Conservation Monitoring Centre (UNEP-WCMC) with support from IUCN and its World Commission on Protected Areas. Data is accessible from the World Database on Protected Areas (WDPA): https://www.protectedplanet.net/. Protected Area data for Cambodia was provided by the Ministry of Agriculture Forestry and Fisheries (MAFF), Cambodia. This database includes marine and terrestrial protected areas that are recognized by governments, including areas designated under regional and international conventions, privately protected areas indigenous peoples' and community conserved territories and areas.

3.2.2 Important Bird areas and Key Biodiversity Areas

Important Bird Areas and Key Biodiversity Areas (IBA & KBAs) were from BirdLife international and data can be sourced from their data portal http://datazone.birdlife.org/site/factsheet/ . This database provides all the IBAs, as well as their most recent monitoring assessment in terms of threat and condition.

3.2.3 Ecological health monitoring

The MRC have an ecological health monitoring network, which is collected by the Cambodia National Mekong Committee (CNMC) in Cambodia and reported by the Mekong River Commission Secretariat (MRCS). The locations were sourced from the 2015 monitoring report and these locations were checked against the locations of the stations for the 2017 (most up to date) report. Samples of Benthic diatoms, zooplankton, benthic macroinvertebrates and littoral macroinvertebrates are taken biannually.

3.2.4 *Landcover*

Landcover SERVIR satellite data (downloadable at: http://data-servirmekong.opendata.arcgis.com/) provides landcover data until 2016. However, for the general LULC, this report chose to use Mekong River Commission (MRC), LULC 2010 dataset as it has a known and accepted method. Furthermore, this dataset has been used in region specific studies previously and therefore data is more comparable.

The Wetlands classification initially used was from the MRC and used the 2003 landcover dataset. It was realised however that some inconstancies exist between the MRC landcover 2010 and 2003 and they were therefore not deemed comparable. The MRC 2010 landcover data was then used to define wetland area, and the MRC inundation extent (2000 layer) to estimate the extent of wetland area.

3.3 Rapid Assessment Surveys

3.3.1 *Location of survey sites*

Locations were selected for fieldwork based on the initial desk-based review of information on landcover, Protected Areas, Important Bird Areas and Key Biodiversity hotspots. Sites that were selected are displayed in Appendix A.

3.4 Estimation of Environmental Flow requirements

3.4.1 *Selection of method for Initial phase of Eco-hydrology assessment*

Due to resources and time available, the method employed had to be relatively quick to implement. Therefore, complex methods were ruled out for the first phase of the project. Adding to this was the fact that many of the catchments are not gauged so it is difficult to be precise about the existing flow regime.

For general E- flows for each catchment, we assume for the first phase of this study that dry season EFR are a minimum of 0.2 m^3/s per 100 km^2 of catchment area in Tonle Sap and Mekong Delta RBG catchments. This approach can theoretically lead to unmet environmental demands in the current situation, and further assessment is required to relate the environmental flow to a natural condition in the dry season. For the wet season the conclusions of Pastor et al. (2014) and their presentation of five different methods for estimating EFR during the wet season can be used, a percentage of 30% of MAR is assumed as the EFR during the wet season months May – October. E-flows for the 5 specified Environmentally important sites of 5000 m^3 per hectare per year.

It is expected that in the detailed studies of Phase 2 the Environmental Flow requirements will build on Phase 1 work but be more broadly defined considering:

1. In channel flow requirements
2. Water demands of specific environmental sites that may need water control structures
3. Fish passage and fish refuges
4. Flood regime and flood pulse
5. Transboundary flow requirements including salinity control
6. Other requirements such as dilution of polluted water and acid sulphate soils

4 Ecological Classification, Assets, Processes and Values

4.1 Lowland wetland ecosystems

The focus of the ecological assessment is on lowland wetland ecosystems, since wetland areas in the lower parts of the sub-catchments in Tonle Sap and Mekong Delta river basin groups are the most vulnerable key (semi-natural) habitats, likely to be affected by the development of water resources in the main tributaries of the two RBGs. Not all tributaries have sensitive (wetland) habitats, therefore the assessment focused on key sub-catchments, as identified by MoE, WCS, BirdLife International, Wetlands International and other organizations.

4.2 Description of habitat types & vegetation

4.2.1 General description of wetland habitats

Wetland ecosystems in the lowlands of the Tonle Sap and Mekong Delta RBGs consist mainly of seasonally inundated forest and shrubland (17.7% of floodplain area), seasonally inundated grasslands (12.2%), rice fields (61.2%) and various water bodies (8.4%), including lakes, ponds and streams (Figure 10 and Figure 11). These are not uniformly spread across the various sub-catchments of the two River Basin Groups (RBGs), as some have no semi-permanent waterbodies (e.g. Stung Pursat, Stung Moung Russei), while others lack flooded forest/shrubland (e.g. Stung Toan Han, Stung Krang Ponley, Stung Slakou) (Figure 12).

In its most pristine form, the Tonle Sap floodplain vegetation consists of an almost closed canopy of small-to-medium sized (7-15m) trees, while at the other end of the spectrum it consists of herbaceous, seasonally inundated vegetation (Giesen, 1998). By far the largest part of the floodplain, however, consists of something intermediate, usually shrubland, with shrubs and short trees of less than 4-5 meters tall, and an occasional scattered taller tree, interspersed with patches of open vegetation dominated by grasses. According to Campbell et al. (2006) and Poole (2016) vegetation around the Tonle Sap can largely be divided into a gradient of wetland types from the permanent open waters to the forested uplands, including flooded forest around the perimeter of the open water surface of the lake, seasonally inundated grasslands located beyond the flooded forest; and permanent rice-field agriculture, mainly flood recession rice (planting rice as the flood waters recede), and increasingly, irrigated dry season rice (Figure 10).

The natural vegetation of the Mekong Delta includes five broad natural wetland types according to Tran (2016): mangrove forests, *Melaleuca* swamp forests, riparian vegetation, aquatic vegetation in permanent water bodies (lakes, reservoirs), and seasonally inundated marshes. The wetland communities among these natural vegetation types exhibit tremendous variation in floristic composition and structure. The seasonally inundated freshwater marsh, mangrove forest, and *Melaleuca swamp* forest are the three most extensive wetland types in the delta. Of these, only the aquatic vegetation of permanent waterbodies and seasonally inundated marshes occur widely in the Cambodian part of the Mekong delta, as natural riparian vegetation is largely lacking after a long history of clearing, agricultural conversion and settlement along the banks.

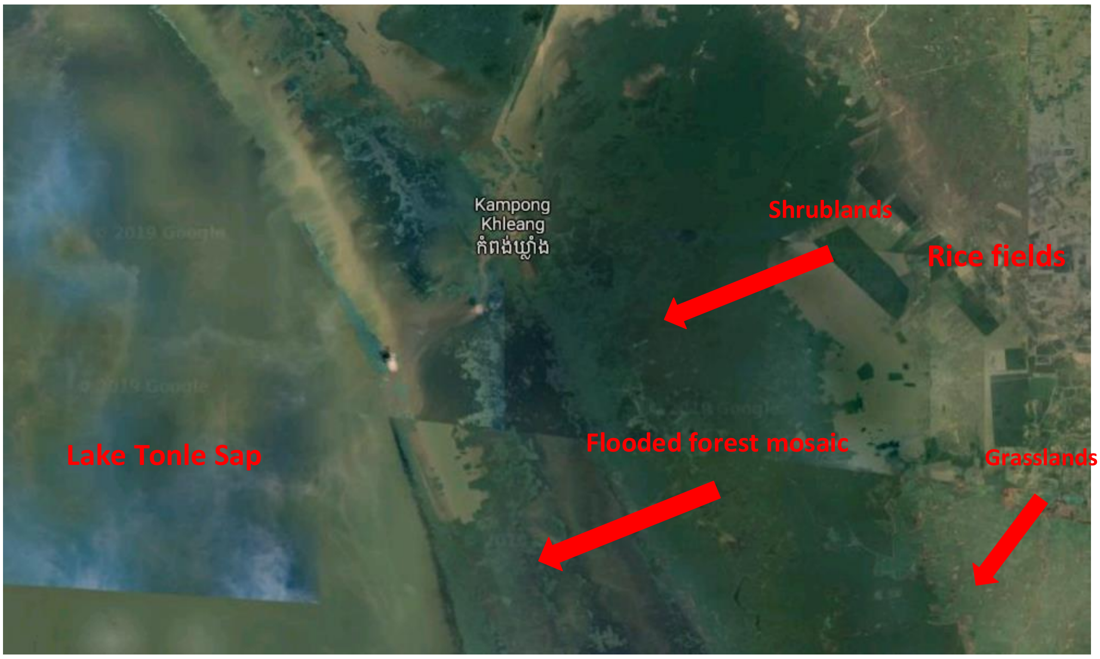


Figure 10: Patterns of vegetation in Siem Reap province, *with the sequence from left to right of lake/open water, flooded forest (mosaic), shrublands, grasslands and rice fields.* (image from Google Earth)

It can be seen in Table 3 that a significant area of Flooded Forest still existing in the 2010 Land Cover mapping and together with the seasonally flooded grassland and permanent water body make up all together over 850,000ha of wetland related area without even adding on the Rice fields which adds another 1.2m ha to 2.5 million ha, a significant total area of wetland which as shown in the next chapters is rich in fauna and flora.

Table 3: Land cover in the floodplains of the Tonle Sap and Mekong Delta sub-catchments.

Semi-permanent Water Body (ha)	**Flooded Forest** (ha)	**Seasonally flooded Grassland** (ha)	**Rice Field** (ha)	**Total area** (ha)
172,192	363,498	249,970	1,266,281	2,051,941
8.4	17.7	12.2	61.7	%

n.b.. Landcover areas (from landcover MRC 2010) within the flooded area (according to MRC flood extent 2000). The "flooded forest" category also includes flooded shrubland, and the latter may form the greater part.

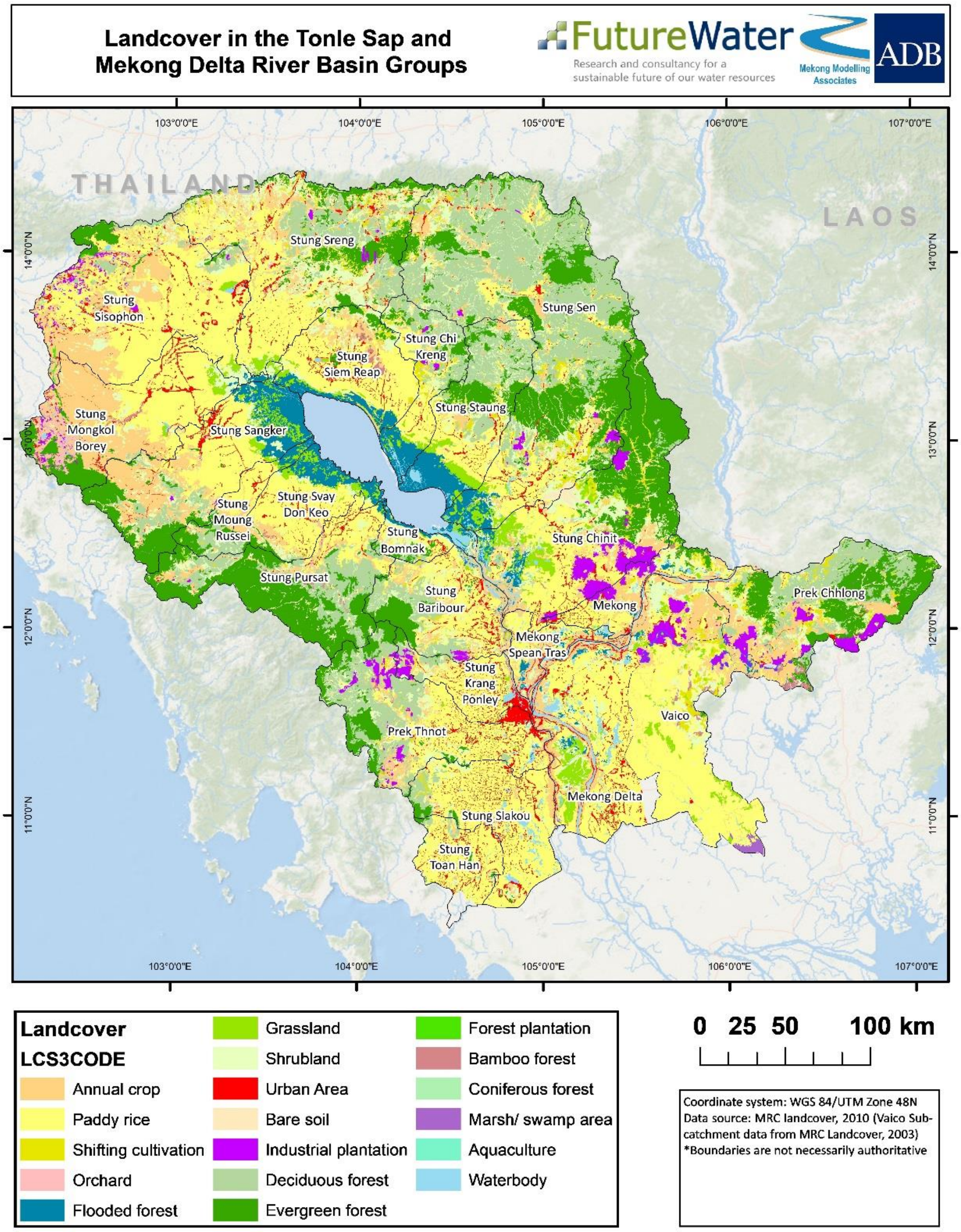


Figure 11: Land use land cover map of Tonle Sap and Mekong Delta River Basin Groups

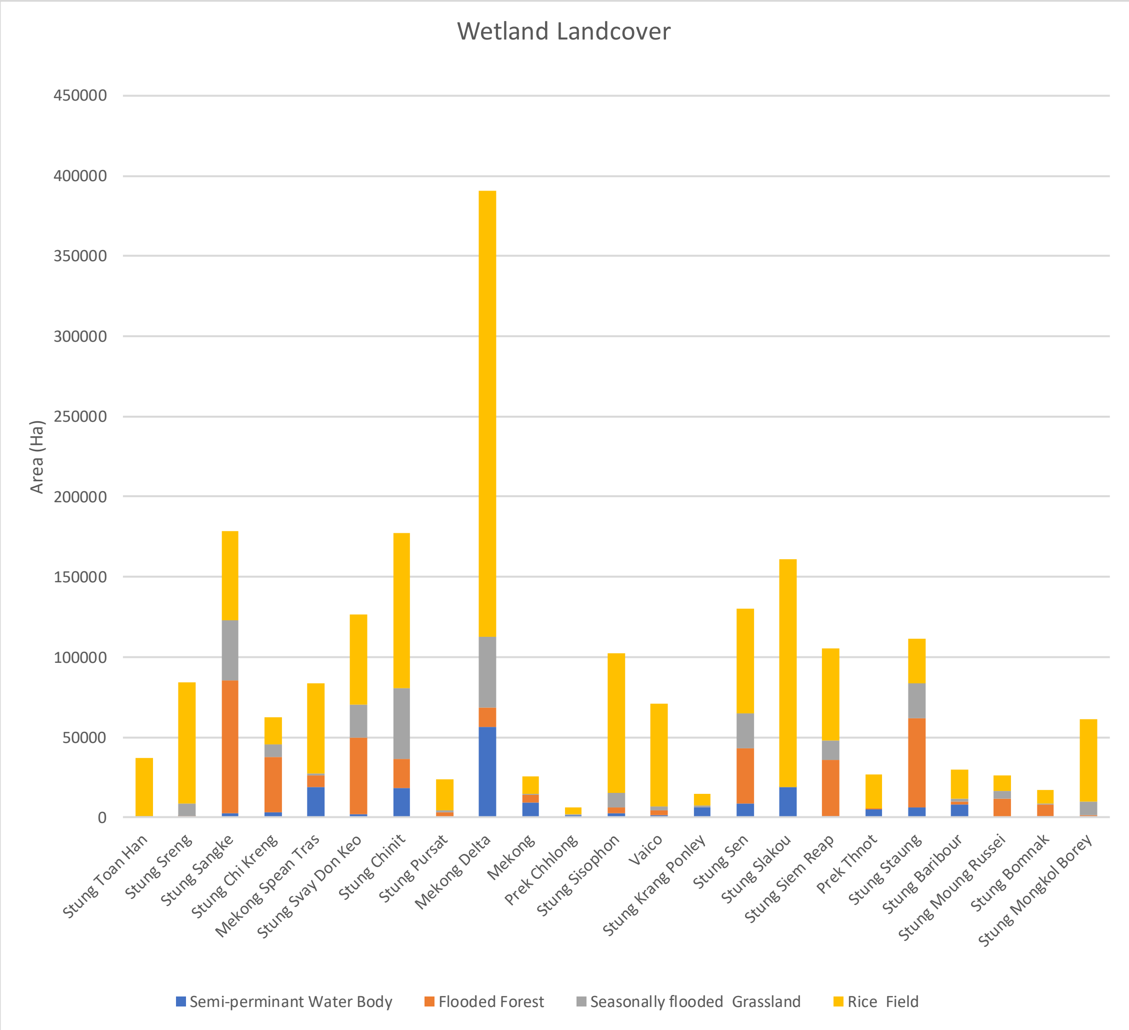


Figure 12: Land cover in the floodplains of the Tonle Sap & Mekong Delta sub-catchments

During the Phase-1 input (June-July 2019) the project team's ecologists visited most of the key lowland wetland sites both in the Tonle Sap and Mekong Delta River Basin Groups. Sites were pre-identified on maps and descriptions of Key Biodiversity Sites (as mapped by MoE) and Important Bird Areas (as mapped by BirdLife International) in the inundation zones indicating key wetlands. These locations are indicated on maps in Annex A, which also include the 2010 land cover. Note that there is no national wetland inventory for Cambodia, only a very general summary on key wetlands in the Directory of Asian Wetlands (Scott, 1989). The MRC has however been implementing a Wetland Management and Conservation Project for the Lower Mekong Basin (LMB) since 2016. Wetland inventory is one of the main activities under this project. A descriptive summary of habitat, land use and ornithological findings at these sites is recorded in Annex B, while details on ornithological observations are provided in Annex D. Table 4below provides a summary of the surveyed sites, based on field observations (sites 1-12) and descriptions by BirdLife International (sites 13-14; (http://datazone.birdlife.org/site/results?cty=36)

Based on field observations and literature (see below), one may summarize the following about the various wetland habitat types:

- **(Semi-) permanent water bodies.** These include lakes and ponds, some of which are fully permanent while others may dry out for several months each year. Vegetation of this habitat includes floating species, submerged-rooted species and emergent species along the margins.

- **Flooded forest.** The climax vegetation in much of the seasonally inundated lowlands of the two RBGs; remnants of these forests remain at mouths of rivers and at locations scattered around Tonle Sap, including Prek Toal, Boeng (Tonle) Chhmar and Stung Sen. Elsewhere, only a sprinkling of trees may remain – these are sometimes left as shade trees.
- **Flooded shrubland**. Cutting of trees for fuelwood and charcoal making, along with clearing and burning, followed by abandonment results in flooded forest being converted to a regularly flooded shrub-dominated habitat. This habitat may occur as a mosaic along with remnant forest, as patches of shrubland in a grassland environment, or as pure, large stands of shrubland.
- **Seasonally flooded grassland**. This habitat is formed as former flooded forest and/or shrubland is burned and grazed by cattle and buffalo, as a result of which woody vegetation disappears or remains as a minor feature in the landscape. This habitat usually occurs between a less elevated zone consisting of flooded forest/shrubland and a more elevated zone with rice fields.
- **Recession rice fields**. Areas within the flood zone but located at a high enough elevation to be dry for a long enough period (> 6 months) are usually converted to rice fields. Originally these areas were planted with recession rice, for example, rice planted as waters subside and otherwise being rainfed. More and more of these fields are being transformed to irrigated rice, which allows for one or more additional crops of rapidly maturing rice varieties.
- **Rain-fed rice-fields** and associated habitats. These anthropogenic habitats are the largest wetland class in the lower Mekong basin, and occupy about half of the seasonally inundated land in Cambodia. They are located up-slope of floodplains on formerly forested land, and comprise paddy fields, associated small waterbodies and local diversions, as well as some natural wetlands (small streams and marshes).

The vegetations of these wetland habitat types are described in more detail below. Section 4.9 of this report provides information about water quality of these habitats, while section 5 covers fish and fisheries and section 6 reviews ornithology.

Table 4:Summary of survey sites

Name of site	1 Boeng Prek Lapouv	2 Bassac marshes	3 Prek Chhlong	4 Lower Stung Sen	5 Chhnok Tru	6 Boeng Chhmar	7 Ang Tropeang Thmor	8 Preah Net Preah / Kra Lanh / Pourk	9 Stung/Chi Kreng/Kam pong Svay	10 Stung/ Prasat Balang	11 Veal Srongae	12 Stung Sen / Santuk / Baray	13 Dei Roneat	14 Prek Toal
Date surveyed	24/06/2019	25/06/2019	26/06/2019	27/06/2019	27/06/2019	28/06/2019	01/07/2019	01/07/2019	02/07/2019	02/07/2019	03/07/2019	03/07/2019	not surveyed	not surveyed
IBA number	**39**	**38**	n.a.	**19**	**18**	**15**	**1**	**2**	**16**	**17**	**20**	**21**	**4**	**3**
Key Biodiversity area (KMH)	**14**	**2**	**24**	**16**	**9**	**3**	**1**	**23**	**34**	**35**	n.a.	**33**	**10**	**25**
Coordinates (x,y) latitude (°N)	10.72	11.28		12.60	12.53	12.85	13.85	13.43	12.95	13.02	12.60	12.42	12.82	13.12
longitude (°E)	105.03	105.15		104.52	104.42	104.23	103.32	103.43	104.42	104.72	104.65	104.88	103.87	103.65
Area (ha, as offically recorded)	9,276	52,316	n.a.	12,390	2,357	39,405	12,659	69,570	53,543	100,675	5,873	109,081	7,251	39,873
(ha, as mapped)	9,325	52,103	18,273	12,758	3,453	39,730	12,900	70,520	52,000	105,011	5,434	110,114	6,936	39,720
Sub-catchment(s) 1	Mekong delta	Mekong delta	Prek Chhlong	Sen	Tonle Sap	Chikreng	Kampong Krasang	Kampong Krasang	Chikreng	Staung	Sen	Sen	Moung	Moung
2	Takeo					Staung		Sreng	Staung	Sen		Chinit		Sangker
3								Tanat	Sen					
4								Siem Reap						
Habitats Dryland forest										+++				
Flooded forest			+++	+++		+++							+++	+++
Flooded shrubland	+	+++	++	++	+	++	++	++	++	+	++	+	+++	++
Flooded grassland	+++	+++	+	++	+++	++	+++	+++	+++	+	++	+	+	++
(Semi)permanent water	++	+	++	+	++	++	+++	+	+		+	+	+++	++
Rice fields	+++	+++						+++		++	+++	+++		
Dryland agriculture										+++				
Flora/vegetation Trees	4	3	8	4	0	5	1	5	2	6	4	0	n.a.	n.a.
Shrubs	3	5	6	4	1	4	6	8	4	12	5	3	n.a.	n.a.
Herbs	18	13	8	4	4	10	9	15	11	3	9	12	n.a.	n.a.
Climbers/lianas	3	6	6	7	0	2	4	4	3	7	4	3	n.a.	n.a.
total # species	28	27	28	19	5	21	20	32	20	28	22	18	n.a.	n.a.
biodiversity value	7.0	7.5	7.0	8.5	5.0	8.0	7.0	7.5	8.0	8.5	6.0	6.0	7-8	9.0
Birds # species (T= threatened, NT = near-threatened)	110 (T5/NT5)	57 (T0/NT5)	33 (T0/NT0)	24 (T2/NT4)	23 (T2/NT4)	39 (T4/NT6)	58 (T8/NT10	19 (T0/NT0)	50 (T8/NT3)	25 (T0/NT0)	39 (T1/NT0)	36 (T7/NT2)	4 (T3/NT1)	94 (T6/NT7)
biodiversity value	8.5	6	5	7	7	8.5	9	5	9	5	5.5	8	7.5	9
Overall biodiversity score (0-9)	8.5	6.5	6.0	8.0	6.0	8.5	7.5	6.0	7.5	7.0	6.0	7.0	7.5	9.0
Land-use rice fields				++			+++	+++		++	+++	+++		
Grazing	++	++	++	++			+++	++	+++	+	++	++		
Dryland crops				++						++				
Tree-felling			++			+	+++	++		+++	+++	++		++
Burning	+		++	++	++	+	+	++	+++	+	+	+		+
Hydrology Maximum flooding (m)	2.0	3-3.5	8-10	2-3	5-7	2-3	4-5	2-3	2-3	1-2	2-3	2-3	n.a.	2-3
Duration of flood (required minimum months of flooding to maintain biodiversity)	2-3	3-4	5-6	1-2	3-4	1-2	4.0	2-3	4.0	<1	3-4	2-3	1-2	1-2

4.3 (Semi-) permanent water bodies

(Semi-) permanent water bodies vary from small pools to large lakes such as the Tonle Sap. Some of these are man-made, such as the 10,000+ ha Ang Tropeang Thmor reservoir, which is shallow and has a rich aquatic biodiversity. But also small, farm-level ponds used for aquaculture and rice crop irrigation that are usually deep, steep-sided and poor in aquatic life. Natural vegetation of this habitat includes floating species, submerged-rooted species and emergent species along the margins (Rollet, 1972, McDonald et al., 1997, Giesen, 1998, this report). In farm-level ponds, water spinach *Ipomoea aquatica* is commonly cultivated and at times is the main plant seen in these waters.

Floating species commonly found include herbaceous species such as waterhyacinth *Eichhornia crassipes,* pondweed *Lemna minor, Pistia stratiotes, Salvinia cucullata, Trapa natans* and bladderwort *Utricularia aurea.* Some herbaceous species such as *Ludwigia adscendans* and *Ipomoea aquatica* may be both terrestrial and floating, while the same holds for some shrubs such as *Mimosa pigra, Neptunia oleracea* and *Sesbania javanica.* Submerged rooted species found in this habitat include *Chara* sp., *Hydrilla verticillata, Nymphaea nouchali, Nymphoides indica, Ottelia alismoides* and *Potamogeton* species. Emergent vegetation found along margins and in shallower pools includes many sedges (*Actinoscirpus grossus, Cyperus cephalotes, Cyperus digitatus, Cyperus haspan, Cyperus imbricatus, Cyperus pilosus, Cyperus procerus, Cyperus sphaecelatus, Fimbristylis acuminata, Fimbristylis dichotoma, Fimbristylis miliacea, Fimbristylis tomentosa, Rhynchospora* sp. and *Scleria* species) and true grasses (*Brachiaria mutica, Echinochlora crus-galli, Echinochloa stagnina, Leersia hexandra, Leptochloa chinensis, Miscanthus fuscus Oryza rufipogon, Panicum repens, Panicum scrobiculatum, Paspalum scrobiculatum, Phacelurus cambogiensis, Phragmites karka, Pseudoraphis minuta, Rottboellia exaltata, Saccharum spontaneum, Sacciolepis interrupta, Sacciolepis myosuroides, Setaria pumila and Vossia cuspidata*), along with *Ceratopteris thalictroides,* taro *Colocasia esculenta, Hydrocharis dubia, Ludwigia hyssopifolia, Ludwigia peruviana, Marsilea crenata, Monochoria hastata, Monochoria vaginalis,* lotus *Nelumbo nucifera, Sesbania javanica* and a number of *Xyris* species.

4.4 Flooded forests & shrublands

As mentioned, flooded forest is the climax vegetation of the seasonally inundated floodplain (shrublands and grasslands are secondary vegetation types) and it harbours the greatest floristic diversity and number of unique species. It also provides a habitat for lowland forest dwelling wildlife and bird species, but also for colonial-nesting water birds such as egrets, darters and cormorants.

During the present survey, tree and shrub species observed in the flooded forests and shrublands include *Antidesma ghaesembilla, Barringtonia acutangula* (reang)*, Combretum trifoliatum, Crateva nurvala, Dalbergia cambodiensis, Dalbergia entadoides, Diospyros cambodiana* (tol), *Gmelina asiatica* (anchanh)*, Macaranga* sp., *Mallotus* sp., *Mimosa pigra, Morinda persicifolia, Phyllanthus reticulatus, Quassia harmandiana, Sesbania javanica, Sindora siamensis* and *Terminalia cambodiana.* In the shrublands woody species encountered include *Abelmoschus moschatus*, Aganonerion polymorphum, Antidesma ghaesembilla, Aporosa octandra, Barringtonia acutangula, Calotropis gigantea*, Combretum trifoliatum, Croton caudatus, Dalbergia cambodiana, Glochidion obscurum, Gmelina asiatica, Gossypium herbaceum*, Grewia asiatica*, Helicteres hirsuta*, Hiptage triacantha*, *Jatropha gossypiifolia*, Mimosa pigra*, Morinda* *persicifolia* and *Sesbania javanica.* Those marked with an asterix (*) are common weed species, often introduced exotics such as *Jatropha* and *Mimosa pigra.*

Rollet (1972) and McDonald et al. (1997) list a much greater number of tree species, including *Albizia lebbekoides, Alangium ridleyi, Brownlowia paludosa, Carallia brachiata, Careya arborea, Combretum quadrangulare, Cryptocarya oblongifolia, Cynometra dongnaiensis, Cynometra inaequifolia, Dasymaschalon lomentaceum, Drypetes thorelii, Dysoxylum excelsum, Elaeocarpus hygrophilus, Elaeocarpus lacunosus, Garcinia loureiroi, Garcinia schomburgkiana, Gardenia cambodiana, Homalium brevidens, Homalium dasyanthum, Hydnocarpus anthelminthicus, Hydnocarpus saigonensis, Lagerstroemia thorelii, Lophopetalum fimbriatum, Lophopetalum wightianum, Maerua decandra, Mimusops elengi, Mitragyna diversifolia, Mitragyna parvifolia, Nauclea officinalis, Peltophorum dasyrrhachis, Popowia diospyrifolia, Salix tetrasperma, Samandura harmandii, Schleichera oleosa, Syzygium cinereum, Syzygium sterrophyllum, Thevetia neriifolia* and *Xanthophyllum glaucum.* Prek Toal and central parts of Boeng (Tonle) Chhmar and Stung Sen flooded forests were inaccessible during the present survey due to low water levels, and this may be the reason that many of these additional species were not observed during present surveys.

4.5 Seasonally flooded grasslands

Seasonally flooded grasslands are habitats derived from flooded forest and shrubland by a combination of clearing, burning and grazing/browsing by cattle and buffalo. Grass is purposely kept short (often by regular burning) to provide good grazing, and at the same time this measure prevents shrubs and trees from recolonizing these areas. Nevertheless, patches of shrubs and small trees occur, often around remaining pools that are maintained to provide drinking water for livestock.

Observations in the Stung/Chi Kreng/Kampong Svay area (IBA 16) on the eastern shores of Tonle Sap indicate that these grasslands are highly varied in species composition and includes various sedges (*Cyperus cephalotes, Fimbristylis acuminata, F. tomentosa*), grasses (*Eleocharis ochrostachys, Eragrostis unioloides, Panicum repens, Rottboellia exaltata*) and a mix of herbs (e.g. *Decaschistia parviflora*, *Grangea maderaspatana, Murdannia macrocarpa*). Shrubs and tree(-lets) include *Antidesma ghaesembilla, Borassus flabellifer, Glochidion obscurum, Gmelina asiatica, Holarrhena curtisii* and *Hiptage* sp. Climbers include rattans *Calamus palustris, Calamus salicifolius, Cassytha filiformis* and *Uvaria rufa.*

Grasslands in the Mekong delta wetlands include grass species such as *Chloris barbata, Cynodon dactylon, Echinochloa stagnina, Eleusine indica, Ischaemum* sp., *Leersia hexandra, Phragmites vallatoria* and *Saccharum spontaneum*, along with sedges such as *Eleocharis dulcis* and herbs such as *Persicaria hydropiper, Merremia umbelata* and *Ipomoea nil.* The few tree and shrub species include the exotic *Mimosa pigra* and *Phyllanthus reticulata* (WWT *et al.* 2013).

4.6 Rice fields

Biodiversity in and around rice field is generally fair to moderate, but most plant species occurring in addition to rice are common species such as grasses, sedges, herbaceous weeds such as *Ageratum conyzoides, Alternanthea sessilis, Crotalaria striata, Eclipta alba, Grangea maderaspatana, Heliotropium indicum, Ludwigia adscendans, Ludwigia hyssopifolia, Melochia corchorifolia, Mimosa pudica* and *Polygonum pulchrum,* and woody weeds such as *Helicteres hirsute* and *Mimosa pigra.*

4.7 Status of vegetation types

4.7.1 Vegetation & land use

As mentioned in section 4.2, wetland ecosystems in the lowlands of the Tonle Sap and Mekong Delta RBGs consist mainly of seasonally inundated forest and scrub, seasonally inundated grasslands, rice fields and various water bodies, including lakes, ponds and streams. These lowland habitats have had a long history of change due to human disturbances and most can be regarded as secondary vegetation types derived from flooded forest, which appears to be the climax vegetation of most areas except in (semi-) permanent water bodies. As mentioned by Rollet (1972), the original abundance of species of the flooded forest flora is now difficult to specify because selective harvesting and clearing have profoundly affected the proportions of these species. This has resulted in more-or-less secondary formations, consisting of flooded thickets with large relict trees, often invaded by common and weedy species.

Flooded forests (or swamp forests) have declined from a pre-1930s cover of more than one million ha, to around 300,000-360,000 ha (2015 estimate, Poole 2016; Table 5). These forests have always been under significant pressure, as Rollet (1972) describes that in 1932, the flooded forest produced 85% of the fuelwood consumed in Cambodia (350,000 m³ out of 410,000) and 75% of the charcoal (10,000 out of 15,000 tonnes per year). During present surveys clearing of flooded forest was observed to be ongoing in the Stung Sen area, especially on the banks opposite the Ramsar Site and protected area, where clearing and burning activities could be clearly seen both on the ground and on drone imagery (see Appendix A). Thi et al. (2017) also report on extensive and ongoing clearing of the flooded forest for various reasons and sum it up in a quote from a village head: "The villagers are smart. Outside, the forest looks untouched – so when the environment officers from Phnom Penh check by boat, it looks protected! But actually, inside it is all cut! The forest is hollow, like a drum!"

Table 5: Area of flooded forest around the Tonle Sap

Date	**Flooded forest area** (ha)	**Notes**	**Reference**
Pre-1930s	1,000,000	Original area (estimate)	Rollet (1972)
1930s	<1,000,000	Exploitation for charcoal	Rollet (1972)
1940s	<<1,000,000	Population pressures	Rollet (1972)
late 1960s	614,000	Population pressures	Woodsworth (1995)
1970s	564,000	Conversion by Khmer Rouge	Woodsworth (1995)
1990	460,000	Economic development fueling conversion to agriculture	Woodsworth (1995)
1991	518,900	Includes 157,200 ha of degraded forest and associated types	Woodsworth (1995)
1992-3	349,303	Includes 229,093ha flooded forest, 22,623ha inundated forest regrowth, and 98,587ha inundated forest mosaic	FAO (2010)
1995	363,400	UNEP-GRID	Jones (1998)
1996-7	335,291	Includes 219,896ha flooded forest, 20,819ha inundated forest regrowth, and 94,582ha inundated forest mosaic	FAO (2010)
2010	372,600	Analysis of 2010 LULC data in TS basin	MRC 2010 data
2014	481,078		Min. of Environment (2018)
2015	300,000-360,000	Using range provided by previous authors	Poole (2016)
2016	477,813		Min. of Environment (2018)

Much of the remaining flooded forest vegetation (with trees of 7-15 metres) occurs along rivers and the lake shore. McDonald et al. (1997) conclude that the stature of this vegetation decreases further away from the lake edge due to the increase in drought stress, plus the increase in depth of groundwater levels. However, according to Giesen (1998) this pattern is more easily explained by the fact that fires do not readily spread into these forests when inundated, and the existing stunted swamp forest along the lake margin represents a remnant that was spared from burning.

McDonald et al. (1997) argue that the decrease in stature (with flooded forest giving way to flooded scrubland further from the permanent lake margin) coincides with an increase in biodiversity, which according to them is indicative that the shrubland is a climax vegetation. However, although these shrublands may harbour larger numbers of plant species than the taller flooded forest, many of the species found in this habitat are common species weeds that invade disturbed areas, a conclusion also reached by Rollet (1972). Local community members interviewed (by Giesen, 1998) mentioned that scrubland areas were formerly forested prior to the Pol Pot era, and that these areas were cleared for rice production but ultimately abandoned, thereby reverting to a secondary scrubland. This also agrees with Nao (1996) who reports that 5,000 ha of flooded forest was cleared for rice production in Siem Reap province alone in the Pol Pot era. In any case, the overall decline and loss of two-thirds of the area of flooded forest since the 1930s is evident (Table 5).

Seasonally flooded grasslands found in the zone between seasonally flooded forest/shrublands and rice fields are likely a fire climax, although shrubs and trees may also be partly suppressed by browsing livestock in these areas, including cattle and buffalo. Clumps of shrubs and an occasional tree, and the presence of clumps of rattan in the grass-landscape are also an indication that woody vegetation is the climax in this area and that grassland is secondary. During the surveys signs of burning were observed in many places in the grasslands, with grass recovery growth at various stages, indicating that fires were ignited at various times over the previous months.

Box 2. Fires in Cambodian lowland wetlands

Fires are an annual feature in Cambodia (Jones 1998, Tansey et al. 2004, Vadrevu & Justice 2011) and have left their impression on the lowland wetland landscape, especially around the Tonle Sap but also in the Mekong delta. During the present survey we observed fire being used to clear and convert flooded forest in the lower Stung Sen, being used in grasslands at Stung/Chi Kreng/Kampong Svay to encourage regrowth as fodder for cattle and buffalo, and at Stung Sen / Santuk / Baray for burning rice stubble post-harvest. This activity has been evident at least for decades, as Jones (1998) analysis of satellite imagery and fires for Cambodia showed that fire density was highest in pine forests, flooded forest and seasonally flooded grassland, and that fire activity was highest in the late dry season (March-April), "reflecting a period of greatest fuel flammability and fire-setting activities by man".

The area of cultivated rice fields dropped from 2.3 Mha in 1969 to 1.5 Mha in 1980, gradually increasing since 1980 to about 3.0 Mha in 2016. Rice fields account for 75% of cultivated land (Cheu & Heng 2018). Around the Tonle Sap, most of this was traditionally recession rice, which is planted as floodwaters drop. In recent years, however, the area of rice has increased as there is pressure to increase from a single harvest to 2(-3) rice harvests per year, which is possible with rapidly maturing IRRI rice cultivars and provision of water in the dry season. As a result, one can observe many pumps and pipelines along canals and rivers that are used to provide irrigation water to rice paddies.

In terms of ecological representativeness, the most important habitats in the two RBGs are the flooded forests and the seasonally-flooded grasslands. The former because flooded forest is the original climax vegetation of these floodplains, with many unique and specially-adapted species and associated wildlife and bird species, and is under significant threat (e.g. by conversion, tree felling, fires). The seasonally flooded grasslands are a secondary vegetation type, but nevertheless an important habitat as these grasslands support a large proportion of the world population of the globally endangered Bengal florican, and the endangered Sarus crane. The seasonally flooded shrublands are also important (albeit less so than flooded forest and grasslands), as flooded forest species (both of flora and fauna) may find refuge in this degraded, secondary habitat. Upstream along the tributaries there are also remnants of flooded forest and shrubland habitat, although these linear features are generally not well mapped.

The trends are strongly towards secondary habitat types and this seems unabated. Flooded forest is degraded by tree-felling (for fuel and charcoal production, but also (to a lesser degree) for timber) and fires and this may lead to conversion to seasonally flooded shrubland. If fires continue or is combined with grazing and browsing by cattle/buffalo, shrubland may be transformed into seasonally flooded grassland. If flooding is less pronounced (not that deep or prolonged), these areas may be brought under rice cultivation, with recession rice as floodwaters recede, or (if irrigation water is available), with irrigated IRII cultivars producing 2(-3) crops per year.

Expansion of irrigation and MOWRAM water resources projects will result in a further increase in conversion of grassland and other natural habitats to rice fields, as flooding of natural habitats becomes less pronounced and more water for irrigated rice fields is available.

4.8 Sensitive and rare/endangered plant species

To date, some 2,300 plant species have been recorded in Cambodia, but studies are incomplete, and some experts consider that the Cambodian flora may total around 3,000 species (Holden, 2010). Apart from a few exceptions, little is known about the status of individual plant species in Cambodia, as botanical research in Cambodia is limited. The herbarium in Phnom Penh was destroyed during the Pol Pot era, and only recently (2010) has the Royal University of Phnom Penh (RUPP) established a new herbarium (Theilade & de Kok, 2015). This currently houses about 8,000 specimens, some of which are duplicates that have been donated by Paris Herbarium. The RUPP herbarium has a curator and several MSc and PhD students of botany, and a programme of study that is partly being funded by Flora and Fauna International (FFI). The focus is, however, on upland forests (for example, the Cardamom Mountains) as these forest areas are currently perceived by RUPP and FFI as being botanically rich and under the greatest threat.

The flora of the lowland flooded forest and shrublands is not being studied, and hence species of these habitats are under-represented in the collection and there is little or no knowledge of the status of these species. Flooded forests have disappeared almost entirely in the Mekong Delta and at least two-thirds of these forests have disappeared around the Tonle Sap. Current figures on area of flooded forest (about 350,000ha) also include that of flooded shrubland, and it is possible that the greater part of this area consists of shrubland. Combined with a long history of tree felling for fuel and charcoal making and ongoing activities aimed at conversion, these habitats are under threat. It is highly likely that the status of various species is at least ‘Vulnerable’ (VU), and perhaps ‘Endangered’ (EN) for restricted range species that are also more sensitive, such as slow growing trees and epiphytes requiring old trees as a suitable ‘substrate’.

There is also a danger that species may disappear (i.e. become extinct) before they are even properly recorded. More in-depth botanical studies are likely to identify more species new to science, even in less remote locations.

Figure 13: The unusual Hiptage triacantha (Malpighiaceae) found in the Bassac marshes and the Stung/Chi Kreng/Kampong Svay grasslands

4.9 Water quality

As one of the Member Countries of the Mekong River Commission (MRC), Cambodia has established a Water Quality Monitoring Network (WQMN) to detect changes in Mekong River water quality and to take preventative and remedial action if any changes are detected. Since its inception in 1985, the WQMN has provided a continuous record of water quality in the Mekong River and its tributaries by routinely measuring a number of different water quality parameters (including temperature, pH, electrical conductivity, total suspended solid (TSS), total nitrite and nitrate (NO2-3-N), ammonium (NH4-N), total nitrogen (TOTN), total phosphorous (TOTP), dissolved oxygen (DO), chemical oxygen demand (COD), and biological oxygen demand (BOD)) at 48 stations throughout the basin. In 2016, 19 stations of these 48 were located in Cambodia, of which 6 are located on the mainstream, 3 on the Bassac River, and 10 on tributaries. Figure 14 shows the water quality stations located in the two basin groups, in which 15 stations have been indicated. The water samples of all stations have been collected every month (ranged from 16^{th} to 28^{th} of each month).

A Water Quality Laboratory under the Water Quality Analysis Office (Hydrology and River Works Department) of Ministry of Water Resources and Meteorology (MOWRAM) has been designated by the Cambodia National Mekong Committee (CNMC) as a unit to undertake the monitoring, sampling, and analysis of water quality. This laboratory is responsible for undertaking routine monitoring and measurements of water quality parameters. It's also responsible for analysing, assessing, and reporting water quality data on an annual basis. Its specific duties include: (i) conducting routine monthly water quality monitoring of the Mekong River and its tributaries as defined in its Terms of Reference; (ii) managing water quality data in accordance with the agreed format and submit the data to the MRC Secretariat for validation and sharing through the MRC data portal; and (iii) producing and publishing an annual water quality data assessment report, outlining the results of water quality monitoring, analysis, and assessment.

4.9.1 Water Quality Analysis

The maximum, mean, and minimum values of each water quality parameter for all stations in Mekong, Tonle Sap (including its tributaries), and Bassac Rivers (excluding Temperature, and pH), which are presented in Appendix E, were analysed for each monitoring station to show the status of water quality in 2016. The key water quality parameters monitored in the above stations are spatially and temporally analysed to reflect the status of water quality of the mentioned three groups below in 2017, and comparisons between 2017 and 2000-2016 have been analysed. The maximum, mean, and minimum values of each water quality parameter at each station are also analysed.

MOWRAM has not collected additional water quality samples from other stations apart from what it has collected and analysed for MRC. The Ministry of Environment has however collected additional water quality samples with additional parameters (such as Cr^{+6}) apart from pH, TSS, BOD_5, and COD_{mn} at some points located in Tonle Sap and its tributaries (Stung Sen, Stung Chinit, Stung Siem Reap, Stung Sankger, and Stung Pursat). The water quality data in five catchments in the Tonle Sap River Basin Group are presented in the tables below.

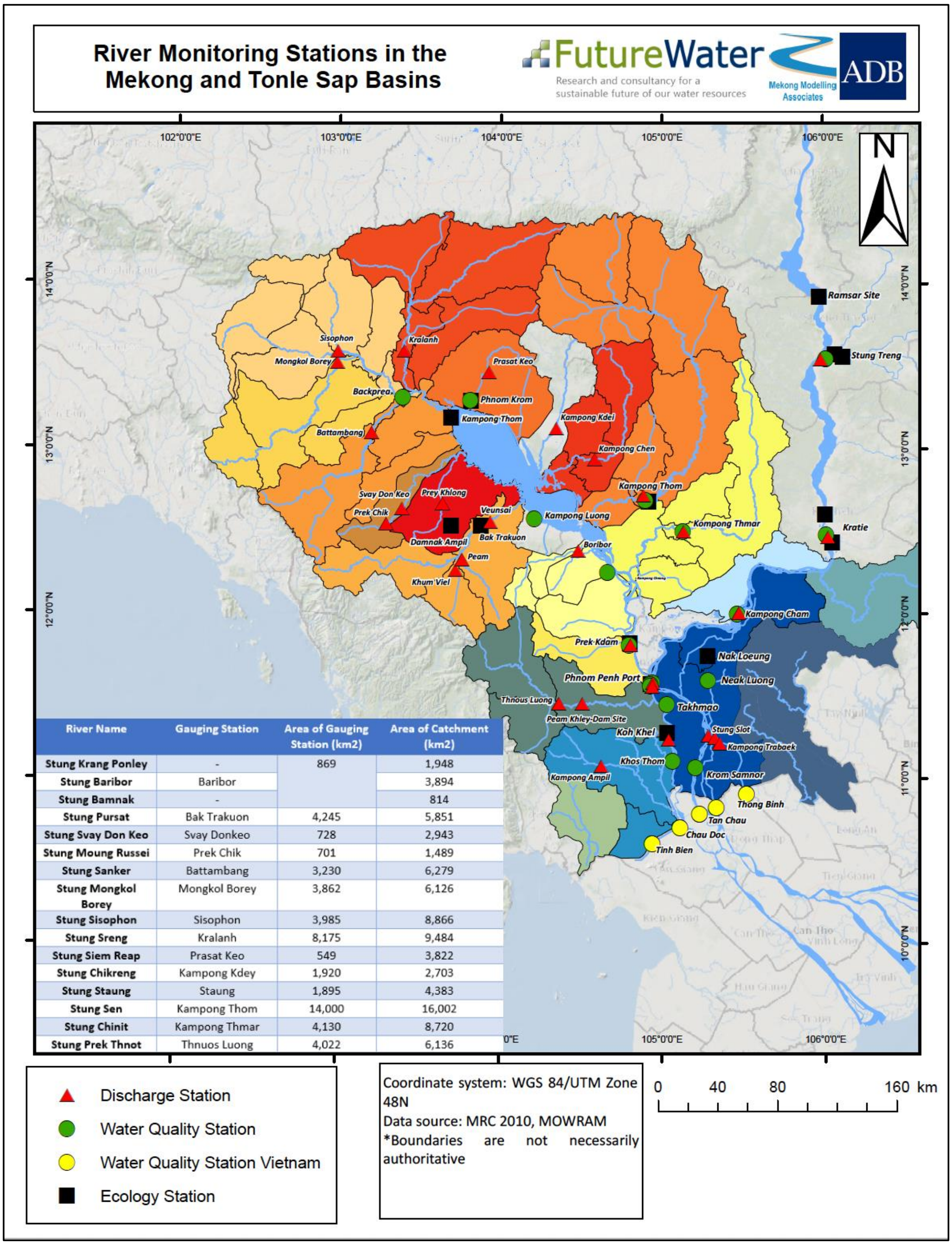


Figure 14: River Monitoring Stations in the Mekong and Tonle Sap Basins

4.9.2 Water quality monitoring stations on the Mekong, Tonle Sap, and Bassac River in 2016

Observed data indicates that the water quality concentrations for tested parameters (including pH, TSS, Cr^{+6}, TOTN, TOTP, COD, and BOD) in 2018 at the five catchments around the Tonle Sap River and Lake were below the thresholds of the MRC's Water Quality Guidelines and Cambodia's Water Quality Standards for public water areas (river). The COD concentration value (6.22 mg/L) in Stung Sankger however slightly exceeded the value of the MRC's Water Quality

Guidelines for protection of human health. The geographical locations of the water stations and dates for water sample collection were not reported by the MOE. It is difficult to make a conclusion on the state of water quality in the five catchments since long duration time series data is unavailable and DO concentration has not been measured.

Table 6: Water quality for some streams around the Tonle Sap Basin Group in 2018

Parameters	Unit	RC Water Quality Guidelin		Cambodia (*) Water Quality Standard	Stung Sen	Stung Chinit	Stung Siem Reap	Stung Sangke	Stung Pursat
		Protection of Human Health	Protection of Aquatic Life						
pH	-	-	-	6.5 - 8.5	7.28	7.14	7.16	7.16	7.28
TSS	mS/m	79 - 150	-	25 - 100	121.45	77.06	86.48	131.31	96.79
Cr^{+6}	µg/L	-	-	< 50	0.10	0.00	0.00	0.00	0.03
TOTN	mg/L	5	5	-	0.47	0.46	0.86	1.30	1.21
TOTP	mg/L	-	-	-	0.09	0.16	0.21	0.24	0.27
COD	mg/L	5	-	1 - 8	3.10	2.90	3.23	6.22	3.37
BOD	mg/L	-	-	1 - 10	1.11	1.30	1.05	1.95	1.44

Source: General Department of Environmental Protection (Ministry of Environment), 2018
n.b. (*) Water Quality Standard in Public Water Areas (River) for Biodiversity Conservation under Sub-decree on Water Pollution Control, which was adopted in 1999.

The comparisons between data of 2017 and 2000-2016 have been analysed in this section. Three river sections have been divided: (i) Mekong River, which includes five stations (Kratie, Kampong Cham, Chroy Changvar, Neak Loeung, and K'orm Samnor) located along the Mekong River from Kratie down to border between Cambodia and Vietnam; (ii) Tonle Sap River and Lake, which includes six stations (Bac Preah, Phnom Kraom, Kampong Luong, Kampong Chhnang, Prek Kdam, and Phnom Penh Port) located around the Tonle Sap River and Lake; and (iii) Bassac River, which includes three stations (Takhmao, Koh Khel, and Koh Thom) located along the Bassac River.

4.9.3 Mekong River Water Quality

In general, the water quality at the Mekong River stations in both dry and wet seasons in 2017 and during the period of 2000-2016 was consindered to be in a *'good'* or *'very good'* condition. Major observations arising from the analysis of the data set include:

Table 7: Comparison of water quality data in the Mekong between 2000-2016 and 2017 in the wet season

Parameters	Unit	MRC Water Quality Guidelines		Cambodia Water Quality Standard	2017			2000-2016		
		Protection of Human Health	Protection of Aquatic Life		Max	Mean	Min	Max	Mean	Min
TSS	mg/L	-	-	25 - 100	266.00	135.03	18.72	536.00	120.50	1.50
EC	mS/m	79 - 150	-	-	22.14	15.45	9.70	24.17	12.42	3.56
$NO_{3,2}$-N	mg/L	5	5	-	0.11	0.06	0.03	0.87	0.21	0.01
NH4N	mg/L	-	-	-	0.11	0.06	0.03	0.41	0.06	0.01
TOTN	mg/L	-	-	-	1.09	0.47	0.16	0.95	0.46	0.05
TOTP	mg/L	-	-	-	0.28	0.12	0.01	0.57	0.14	0.00
DO	mg/L	> 6	> 5	2.0 - 7.5	8.72	7.13	4.76	13.38	6.70	0.98
COD	mg/L	5	-	1 - 8	2.19	1.40	0.47	9.94	2.42	0.04
BOD	mg/L	-	-	1 - 10	1.20	0.58	0.03			

Source: MRC Database, 2000-2017

- The highest TSS concentration value (288 mg/L) was recorded at Kampong Cham station on 18 November 2001 (early dry season) and at Neak Leuong station (166 mg/L) on 24 August 2017.

- The COD concentrations in both dry and wet season of the historical period (2000-2016) were higher than those of 2017. The maximum value was recorded at Neak Loeung station on 13 September 2001 (wet season) and at Kampong Cham station (12.65 mg/L) on 23 February 2005 (dry season).

Table 8: Comparison of water quality data in the Mekong between 2000-2016 and 2017 in the dry season

Parameters	Unit	MRC Water Quality Guidelines		Cambodia Water Quality Standard	2017			2000-2016		
		Protection of Human Health	Protection of Aquatic Life		Max	Mean	Min	Max	Mean	Min
TSS	mg/L	-	-	25 - 100	116.45	35.83	8.04	288.00	25.81	0.67
EC	mS/m	79 - 150	-	-	22.12	18.46	13.48	24.70	16.43	2.02
$NO_{3,2}$-N	mg/L	5	5	-	0.31	0.07	0.03	0.39	0.09	0.00
NH4N	mg/L	-	-	-	0.31	0.07	0.03	0.30	0.05	0.01
TOTN	mg/L	-	-	-	0.56	0.30	0.13	1.06	0.29	0.04
TOTP	mg/L	-	-	-	0.26	0.09	0.03	0.56	0.05	0.00
DO	mg/L	> 6	> 5	2.0 - 7.5	9.83	7.77	4.68	13.85	7.52	2.57
COD	mg/L	5	-	1 - 8	3.05	1.47	0.24	12.65	2.18	0.04
BOD	mg/L	-	-	1 - 10	1.60	0.81	0.11			

Source: MRC Database, 2000-2017

4.9.4 Tonle Sap River Water Quality

In general, the water quality at the mainstream stations in both dry and wet seasons in 2017 and during the period of 2000-2016 was considered to be in a 'good' or 'very good' condition. Major observations arising from the analysis of the data set include:

- High and increasing TSS concentrations are observed in some stations located in the Tonle Sap River and Lake with an average of 221 mg/L and 126 mg/L in 2017 and 2000-2016 respectively in the wet season. The highest value (3,256 mg/L) was recorded at Phnom Kraom station on 23 May 2016 (early wet season) for 2000-2016 and 2,185 mg/L at the same station and followed by Kampong Chhnang station (1,061 mg/L) on 24 May 2017. The TSS concentrations were considerably high in the wet season at the Tonle Sap River and Lake.

Table 9: Comparison of water quality data in the Tonle Sap between 2000-2016 and 2017 in the wet season

Parameters	Unit	MRC Water Quality Guidelines		Cambodia Water Quality Standard	2017			2000-2016		
		Protection of Human Health	Protection of Aquatic Life		Max	Mean	Min	Max	Mean	Min
TSS	mg/L	-	-	25 - 100	2,185.40	221.35	8.50	3,256.00	126.15	1.50
EC	mS/m	79 - 150	-	-	21.90	14.22	7.37	25.70	11.45	3.56
$NO_{3,2}$-N	mg/L	5	5	-	0.36	0.15	0.02	1.41	0.20	0.01
NH4N	mg/L	-	-	-	0.39	0.08	0.02	0.64	0.07	0.01
TOTN	mg/L	-	-	-	0.95	0.47	0.17	3.62	0.48	0.05
TOTP	mg/L	-	-	-	0.35	0.13	0.01	1.90	0.16	0.00
DO	mg/L	> 6	> 5	2.0 - 7.5	11.80	6.78	2.26	11.09	6.16	0.98
COD	mg/L	5	-	1 - 8	8.59	3.46	0.63	13.62	3.05	0.12
BOD	mg/L	-	-	1 - 10	1.60	0.71	0.09			

Source: MRC Database, 2000-2017

- Similar to the Mekong River stations, the COD concentrations in both dry and wet season of the historical period (2000-2016) were slightly higher than those of 2017. High and increasing COD concentrations were observed for most stations for both dry and wet seasons. The maximum value of 55 mg/L was however recorded at Bac Prea station on 23 December 2009 (dry season).

Table 10: Comparison of water quality data in the Tonle Sap between 2000-2016 and 2017 in the dry season

Parameters	Unit	MRC Water Quality Guidelines		Cambodia Water Quality Standard	2017			2000-2016		
		Protection of Human Health	Protection of Aquatic Life		Max	Mean	Min	Max	Mean	Min
TSS	mg/L	-	-	25 - 100	804.20	152.93	30.74	1,190.00	73.16	1.00
EC	mS/m	79 - 150	-	-	24.60	13.99	7.52	36.80	10.72	2.13
$NO_{3,2}$-N	mg/L	5	5	-	0.34	0.18	0.03	2.83	0.17	0.00
NH4N	mg/L	-	-	-	0.48	0.13	0.04	0.83	0.10	0.01
TOTN	mg/L	-	-	-	0.86	0.50	0.25	2.38	0.54	0.06
TOTP	mg/L	-	-	-	0.34	0.16	0.02	2.22	0.12	0.00
DO	mg/L	> 6	> 5	2.0 - 7.5	8.07	6.51	4.89	10.18	5.90	1.63
COD	mg/L	5	-	1 - 8	13.11	4.03	1.16	54.98	4.63	0.21
BOD	mg/L	-	-	1 - 10	1.70	1.18	0.22			

Source: MRC Database, 2000-2017

4.9.5 Bassac River Water Quality:

In general, the water quality at the mainstream stations in both dry and wet seasons in 2017 and during the period of 2000-2016 was in a ‘good’ or ‘very good’ condition. The TSS and COD concentrations of stations in the Bassac River were more or less the same values of the those in the Mekong River. The highest COD values of the historical data were however recoreded at Takhmao station (12.72 mg/L) in the wet season (October 2001) and at Takhmao station (11.83 mg/L) in the dry season (November 2001).

Table 11: Comparison of water quality data in the Bassac River between 2000-2016 and 2017 in the wet season

Parameters	Unit	MRC Water Quality Guidelines		Cambodia Water Quality Standard	2017			2000-2016		
		Protection of Human Health	Protection of Aquatic Life		Max	Mean	Min	Max	Mean	Min
TSS	mg/L	-	-	25 - 100	167.96	86.69	14.90	448.00	109.73	1.50
EC	mS/m	79 - 150	-	-	22.41	15.11	7.65	25.10	12.96	6.10
$NO_{3,2}$-N	mg/L	5	5	-	0.38	0.18	0.02	0.81	0.21	0.01
NH4N	mg/L	-	-	-	0.43	0.08	0.03	0.80	0.09	0.01
TOTN	mg/L	-	-	-	1.05	0.59	0.37	1.45	0.53	0.06
TOTP	mg/L	-	-	-	0.47	0.15	0.05	1.24	0.14	0.00
DO	mg/L	> 6	> 5	2.0 - 7.5	8.94	6.87	4.28	9.33	6.49	1.79
COD	mg/L	5	-	1 - 8	2.57	1.53	0.35	12.72	2.36	0.12
BOD	mg/L	-	-	1 - 10	2.00	0.93	0.05			

Source: MRC Database, 2000-2017

Table 12: Comparison of water quality data in the Bassac River between 2000-2016 and 2017 in the dry season

Parameters	Unit	MRC Water Quality Guidelines		Cambodia Water Quality Standard	2017			2000-2016		
		Protection of Human Health	Protection of Aquatic Life		Max	Mean	Min	Max	Mean	Min
TSS	mg/L	-	-	25 - 100	68.90	39.33	11.75	139.33	24.18	2.00
EC	mS/m	79 - 150	-	-	21.55	14.82	8.70	23.20	11.57	4.75
$NO_{3,2}$-N	mg/L	5	5	-	0.29	0.21	0.12	1.99	0.16	0.00
NH4N	mg/L	-	-	-	0.56	0.18	0.04	1.13	0.13	0.01
TOTN	mg/L	-	-	-	1.11	0.59	0.22	3.45	0.68	0.11
TOTP	mg/L	-	-	-	0.21	0.13	0.04	0.75	0.10	0.00
DO	mg/L	> 6	> 5	2.0 - 7.5	8.02	7.15	5.57	12.25	6.56	1.91
COD	mg/L	5	-	1 - 8	4.68	2.13	0.79	11.83	3.64	0.14
BOD	mg/L	-	-	1 - 10	1.70	1.11	0.14			

Source: MRC Database, 2000-2017

4.10 Watershed health

Wetland ecosystems require healthy watersheds in order to fully maintain their ecological functions, and where catchments have been degraded, for example by deforestation or mining, wetlands and river systems also deteriorate. Rivers with deforested upper watersheds display changed hydroperiods, with floods often being more extreme and of shorter duration, while dry spells may lead to rivers that were once perennial streams drying out or becoming stings of pools with zero flow. Rivers and streams of degraded catchments due to deforestation also become more silt-laden, which can choke water ways and contribute to wetland loss. Watershed degradation can directly lead to loss of wetlands, loss of important wetland functions, and loss of biodiversity.

Watershed degradation also affects irrigation and other downstream infrastructure, as higher suspended sediment levels silt up irrigation canals and reduce life expectancies of dams and reservoirs or lead to expensive interventions such as desilting and other maintenance. More extreme flood pulses due to watershed degradation can also contribute to extensive damage to infrastructure, property and loss of human life. Large Infrastructure investments in dams and irrigation infrastructure should therefore be linked with watershed protection measures such as forest conservation and reforestation efforts.

5 Fish and fisheries

5.1 Fish diversity

The Lower Mekong Basin (LMB) supports one of the world's largest inland fisheries, with an annual catch estimated at more than 2 million tonnes of fish and other aquatic animals (Hortle 2007), which is possibly the highest yield from any river basin. The LMB supports about 850 species of fish in 24 orders and 87 families, making it one of the world's most species-rich river systems, and perhaps the richest in higher-level taxonomic diversity (Hortle 2009, Valbo-Jorgensen et al. 2009). About 560 species are primary freshwater fishes, mainly *Cypriniform* fishes and *catfishes (ត្រីអណ្តែង),* the remainder being catadromous or estuarine/marine species which enter freshwaters. While the fauna is generally similar to that of other regional river systems, about 220 species –or one third of the primary freshwater fishes– are endemic to the Mekong, and most of these are relatively specialised fish found in one or a few tributaries.

About 475 of the 850 LMB fish species occur or are likely to occur in the LMB in Cambodia (Rainboth 1996), and most of these would be found at sometime within the Mekong - Tonle Sap and their tributary rivers in the Study Area. About 200 species are important in catches from lowland rivers and floodplains, with a few species typically making up most of the biomass (Halls et al., 2013a, Halls et al., 2013b, Ngor et al., 2006, Ngor et al., 2005), and most of these are purely freshwater species that can be grouped broadly as white fish, black fish or grey fish, categorisations based on their ecology, including propensity to migrate (Hortle and So, 2017). The general characteristics of these groups are described below.

White fish typically inhabit rivers and are predominantly *catfishes (ត្រីអណ្តែង)*, *loaches (ត្រីកញ្ជ្រូក)* and *cyprinids* (*carps, barbs* and *minnows*). White fish include several of the world's largest freshwater fish species. They generally migrate within river channels and may also move onto flooded areas to feed and/or to breed. In Cambodia many white fish migrate between the Tonle Sap system, where they feed and grow during the wet season, and the Mekong River, where they seek shelter in deep pools and spawn in the early wet season (Hortle et al. 2004, Poulsen 2001, Halls et al. 2013b). Many also migrate up and down the tributary rivers of the Tonle Sap and Mekong e.g. Stung Chinit (Warren 1999), Stung Pursat (Marsden et al. 2018), and Prek Chhlong (Degen et al. 2005), so they are likely to be highly impacted by dams or other barriers, with consequent impacts on fish production and catches. Unlike black and grey fishes (see below), many white fish are adapted to life in running waters, and most require flowing water for breeding, so they do not persist in small reservoirs.

Black fish are relatively sedentary species such as snakeheads *(ត្រីដៀប/ឆ្តោ)*, walking catfishes *(ត្រីអណ្តែងរឹង)*, climbing perch *(ត្រីក្រាញ់)* and swamp eels *(អន្ទង់)*, which are typically found in still or slow-flowing waters. They can breathe air, so have minimal or no requirement for dissolved oxygen. Several species can 'walk' over land and can bury themselves in mud where they aestivate through the dry season. Black fish are most common in Cambodia in floodplains and rice-fields. Grey fish have been defined as an intermediate group of fish that migrate short distances between floodplains and rivers and between permanent and seasonal waters on floodplains; they include featherbacks *(ត្រីក្រាយ),* gouramies *(ត្រីរមាស)* and some gudgeons. In general, both black and grey fishes are likely to persist both upstream and downstream of dams, and may thrive in impoundments, such as typical Cambodian irrigation reservoirs.

As well as these three broad categories based on migration, the Cambodian LMB fish fauna includes diadromous fish, which migrate between the river and the sea; these are grouped as catadromous, living in fresh water, but migrating downstream to breed in the estuary or sea, and anadromous, spending most of their life in brackish or marine waters, but migrating upstream to breed in a river. The Mekong, especially in its lower reaches is also home to many fishes that move freely between marine and freshwaters (euryhaline species). There are also many small tributary species, specialised for life in smaller upland streams with diverse habitats, for which some degree of seasonal migration along tributaries would be expected. In general, diadromous, euryhaline and specialised tributary fishes are less likely to be directly exposed to and impacted by lowland tributary developments in Cambodia, though all fish are subject to the secondary effects of basin-wide land-use and water resource developments, which alter hydrology, water quality and nutrient flow downstream.

There is limited up-to-date information on the status of many individual fish species in the Study Area or elsewhere in Cambodia. Because of the large monsoonal flood and seasonal variation in extent and characteristics of aquatic habitats, most of the fish found in the lowlands are widespread species, tolerant of environmental variation. Catches at any site may show different proportions of different species, depending on the local influence of vegetated floodplain habitat (which favours black and grey fish) and proximity to the migration routes of fish along rivers. For example, along the Tonle Sap –Great Lake system, black and grey fish are more abundant in catches in the north-west, where there is still extensive flooded forest, while migratory white fishes are more abundant in the south-east and the Tonle Sap River, along which white fish migrate (Ngor et al. 2018b).

Many Cambodian fish species have been recorded at only a few sites, which might reflect actual rarity, lack of survey effort, that they are small or cryptic, or that they are ‘lumped’ with similar species by non-taxonomists. There is in particular little information on the status of species specialised for particular habitats on floodplains, or headwater (rhithron) fishes, which comprise a large proportion of Cambodia’s fish biodiversity, as most survey and monitoring has focused on the lowland river-floodplains or on the modified rain-fed rice-field environments, which together provide the common food fish to the bulk of the population (see below). Hence there is a need for review and field survey of the status and conservation needs of such species, in the light of the threats discussed below.

5.2 Fisheries habitat and yield

Many authors have noted that the inland fisheries of Cambodia are highly diverse and productive. At a landscape scale, fisheries yield[1] can be considered to originate from three broad classes of habitats (Hortle and Bamrungrach, 2015).

- The major flood zone (based on the Year 2000 flood), includes large rivers and their seasonally inundated and productive lowland floodplains, which provide a diversity of aquatic habitats and support highly visible fisheries. The most notable ‘fish factory’ of the Mekong basin is the Tonle Sap-Great Lake system, where commercial fishers at times catch many tonnes of fish per day, and which provides food and livelihoods for millions of Cambodians, as well as people upstream in Laos and Thailand, and downstream in Vietnam, to where fish migrate during the dry season.

- The rain-fed zone is a vast landscape of anthropogenic aquatic habitats, principally rice-fields and associated small water-bodies, which has been developed on formerly forested

[1] Yield is the proportion of biological production removed by people, often referred to as ‘production’ by non-biologists.

elevated land around floodplains. Fields which are dry for much of the year are during the wet season rapidly colonised by aquatic organisms, including black fish and molluscs and crustaceans. People harvest fish and OAAS on an individually small scale throughout the wet season, with catches peaking as water levels fall. Because catches are dispersed, seasonal, relatively small (per capita and per day), and mainly for household consumption, rain-fed habitats support an 'invisible fishery', which is generally ignored in development planning, as is generally the case in development of irrigation schemes around the Tonle Sap.

- Large water-bodies outside the major flood zone in Cambodia mainly comprise irrigation reservoirs, and some canals and large river channels. These systems may support significant fisheries, which can be augmented by stocking.

5.3 Fisheries Yield

Fisheries yield at a landscape scale has been estimated to be between about 50 and 300 kg/ha/year in these main habitats of the lower Mekong basin, based on a review of relevant yield-per-unit area studies (Hortle and Bamrungrach, 2015). The most productive habitats include deeper, nutrient rich floodplains which are inundated for several months, whereas less productive habitats include shallow rain-fed rice fields that are inundated for 1-2 months each year. Various other features which are correlated with fisheries productivity include nutrient status, habitat diversity, the presence of tributary rivers with intact forested catchments, and connectivity across the landscape.

To estimate the potential fisheries yield within the Study Area, the area of each habitat class was multiplied by a mid-range estimate of yield from Hortle and Bamrungrach (2015) as follows:

- Major river floodplain 150 kg/ha/year
- Rain-fed habitat 75 kg/ha/year
- Water-body outside the major flood 200 kg/ha/year

As shown in Table 13, the total yield estimate of 628,316 tonnes per year is more than adequate to support the 'official' national capture fisheries 'production' of about 500,000 tonnes per year, and higher yield estimates from consumption surveys. A significant proportion of the estimated yield is caught further downstream in Vietnam, to where fish migrate during the flood drawdown; a smaller proportion of the Cambodian yield is caught in Laos and Thailand, to where fish migrate during the dry season. Based on the yield and consumption-based estimates, and assuming conservative prices, wild capture fishery production from the Study Area is worth several billion dollars per year to Cambodia, so it clearly deserves more consideration in development planning.

Table 13: The main habitat classes which support fisheries production and their estimated yield

Habitat class	***Areas of habitat classes in the tributary river basins (km²)***		***Total Area***
	Tonle Sap River Basin	***Mekong Delta River Basin***	
1 Major river - floodplain within the major flood zone	*14,803*	*10,444*	*25,246*
2 Rain-fed habitat	*18,387*	*6,151*	*24,538*
3 Water Body outside the major flood zone	*241*	*87*	*328*
Sub-total wetlands	*33,431*	*16,681*	*50,113*
Total area	*83,267*	*29,321*	*112,589*
Habitat class	***Likely fisheries yield (tonnes/year) from production in the tributary river basins***		***Total Yield***
	Tonle Sap River Basin	***Mekong Delta River Basin***	
1 Major river - floodplain within the major flood zone	*222,043*	*156,654*	*378,697*
2 Rain-fed habitat	*137,902*	*46,134*	*184,036*
3 Water Body outside the major flood zone	*48,247*	*17,335*	*65,583*
Total yield	*408,193*	*220,123*	*628,316*

Assuming the yield-per-unit area estimates are accurate, Table 13 shows that 60% of the catch is believed to originate from the major-river/floodplain zone, 30% is from rain-fed habitats, and only 10% is from large water-bodies outside the major flood zone, including reservoirs.
Management interventions in each of these habitat classes could increase yields to at least double those shown. From the perspective of MOWRAM, more attention is needed to rain-fed rice-fields and reservoirs associated with irrigation schemes, noting that:

- the area of rain-fed rice-fields continues to expand, both up-slope into areas cleared of forest, and down-slope as flooding diminishes because of river regulation by reservoirs;

- it is technically and socially feasible to increase fish production within rain-fed rice-field systems (Brooks and Sieu 2016, Kim et al. 2019), as discussed below;

- reservoirs can be managed (physical measures, stocking and fishing regulation) to achieve much higher fisheries yields than those estimated.

5.4 The importance of Cambodia's inland fisheries

As a result of the high productivity and diversity of Cambodian inland fisheries, most rural people go fishing and/or collect other aquatic animals at least part-time, and Cambodians rely heavily upon inland fisheries for income and for food. In 2000, average annual per capita consumption was about 42.2 kg of freshwater fish and 9.2 kg of OAAs, which amounted to total national consumption of 482 kt/year of inland fish and 105 kt/year of inland OAAs in 2000 (Hortle, 2007). Based on an unpublished nationwide household survey (IFREDI, 2013), despite significant population increase since 2000, total inland fish and OAA consumption, and per capita consumption of all fishery products appear to have been stable, with the additional *per capita* requirements being met by increased production from marine fisheries and aquaculture. Recent official figures from MAFF for Cambodian inland capture fish production are 500 kt/year; which is consistent with consumption-based estimates and habitat-based assessments.
Aside from production for food, fish and other aquatic animals (OAAs) are the basis for recreational fishing and a significant aquarium trade, as well as supporting aquaculture by providing brood stock, fingerlings and 'trash fish' for feed (So et al., 2005). There is very little up-to-date information on these elements of Cambodia's inland fisheries, but they are important throughout the Study Area.

5.5 Threats to fisheries in Cambodia

The main threats to fish and fisheries result not only from competition for water resource but also from fishing pressure and environmental changes as discussed below.

5.5.1 Fishing pressure

Fishing by a wide range of legal and illegal methods appears to be having significant impacts on fish and other aquatic animals, especially in heavily fished places such as in and around the Tonle Sap and the Mekong delta Increasing exploitation results in 'fishing-down', as larger species and individuals become rare, and smaller species and younger fish become dominant (Halls et al., 2013b), with indiscriminate fishing nowadays taking all species and sizes of fish, causing significant changes in fish assemblages (Ngor et al., 2018a). Many interview-based surveys report that fishers complain of a reduction in their individual catches as a result of competition with other fishers (Hortle, 2009). However, based on limited evidence, total catches are generally considered to be stable or in a plateau phase, as the fish are adapted to a fluctuating monsoon environment, which favours high rates of reproduction and growth, so are extremely resilient to fishing pressure. Most threatened by fishing are large species which migrate long distances and take several years to mature. These include the giant catfish or *ត្រីរាជ* (*Pangasianodon gigas*) and giant carp or *ត្រីគល់រាំង* (*Catlocarpio siamensis*), as well as sawfish and stingrays or *ត្រីបបែល*, which have few offspring and are highly vulnerable to capture (Mattson et al. 2002); these are being supplanted in catches by small, fecund fast-maturing species (Ngor et al. 2018a). However, some specialised species found only in particular habitats, are likely threatened by the aquarium trade; these include fighting fish or *ត្រីក្រឹម* (*Betta* spp.), tiger fish or ត្រីខ្លា (*Datnioides* spp.) and some loaches and catfishes, but there is apparently little specific information on the status of such species as mentioned above.

5.5.2 Environmental changes

Despite concerns regarding overfishing pressure as discussed above, the main threats to productivity and biodiversity of inland fisheries in Cambodia result from the clearing and development of catchments and most importantly the development of infrastructure (especially hydropower and irrigation development) as discussed below.

The effects on fish and OAAs of forest clearance and agricultural expansion on the Tonle Sap and Mekong floodplains, as well as in the headwaters of the Cambodian tributary rivers, are not well-documented. It can be assumed that some specialised tributary floodplain species are directly threatened by the rapid environmental changes in Cambodia over the last two decades as mentioned above. The high-value wetland areas which are critical for conservation of plants, birds and other animals as discussed in previous sections, are also important for fish and OAAs, for which specific information is generally lacking. There is a clear need to survey the important wetlands and rithron (flowing water) reaches of tributaries so as to document the status of aquatic flora and fauna (including fish and OAAs), and to inform how best to conserve some of these unique habitats in the face of accelerating environmental change.

5.5.3 Species introductions

Introduction of exotic fish species and other pest organisms, intentionally or accidentally, is also a significant threat to biodiversity (Welcomme and Vidthayanon, 2003). Infrastructure and catchment changes which alter environmental conditions tend to facilitate introductions, which tip the balance in favour of exotic generalist invasive species.

5.5.4 Development of infrastructure

Development of infrastructure (such as dams, canals or roads), causes two types of primary impact: 1) alterations to flows, which may cause various higher-order changes, such as to water quality and habitat; and 2) creation of barriers to movement. Thousands of dams have been built throughout the Mekong basin, with significant effects on migrations of fish and OAAs. Since 2000, several major hydropower dams upstream of Cambodia have created very large reservoirs which have allowed significant regulation of the Mekong's flow – delay of wet season flows and reduction of flood peaks and increases in dry season flows (Räsänen et al., 2017). The effect of these flow alterations is considered to be generally negative for the diversity and productivity of fish and OAAs, which depend upon the extent and duration of annual flooding (Halls et al., 2013a, Halls et al., 2013b). However, some increase in dry season flows and water levels may also be beneficial, by allowing more survival of fish and OAAs through the dry season (Halls and Welcomme, 2004).

In Cambodia, development of hundreds of irrigation schemes on tributaries has caused major landscape-scale changes which affect fisheries in several ways. The most obvious impact is blockage that could prevent the migratory paths.of fish migration by dams, which is mentioned in some MOWRAM project documents, with fish passes built or planned at some dams to mitigate impacts (Table 14). Figure 15 demonstrates the current river blockages (according to satellite imagery). However, the majority of weirs, gates or dams in Cambodian tributaries have no mitigation for fish passage or any other physical impacts and only the Stung Sen and Stung Chhlong have clear passage. Given the importance of fisheries throughout Cambodia, improvements are needed in pre-project assessments and design of mitigation measures or offsets for fisheries. Infrastructure impacts and measures to mitigate or manage them are discussed further below.

5.6 Regional impacts from upstream dam projects

Hydropower dams on the Mekong mainstream and large Mekong tributaries upstream of the Study Area in China, Thailand and Laos (and to a minor extent irrigation schemes on tributaries in Thailand and Laos) have already altered Mekong River and Tonle Sap hydrology, with obvious delays in the timing of wet season flow increases, reduced wet season flood level and extent, and increased dry season water levels, notwithstanding the impacts of recent droughts in 2016 and 2019. These regional effects are likely to continue and intensify as more dams are built upstream (BDP, 2011, Räsänen et al., 2017).

Regional flow changes affect the ecology and fisheries of the lower reaches of the Tonle Sap and Delta tributaries; in general, the impacts are likely to be negative via disruption and obstruction of fish migrations and reduced fish production from flooded areas. From the perspective of MOWRAM, the reduction in average flood heights around the Tonle Sap will likely provide more opportunities for irrigation in the upper flood zone, which will increase the impacts of irrigation schemes and the need for mitigation as discussed below.

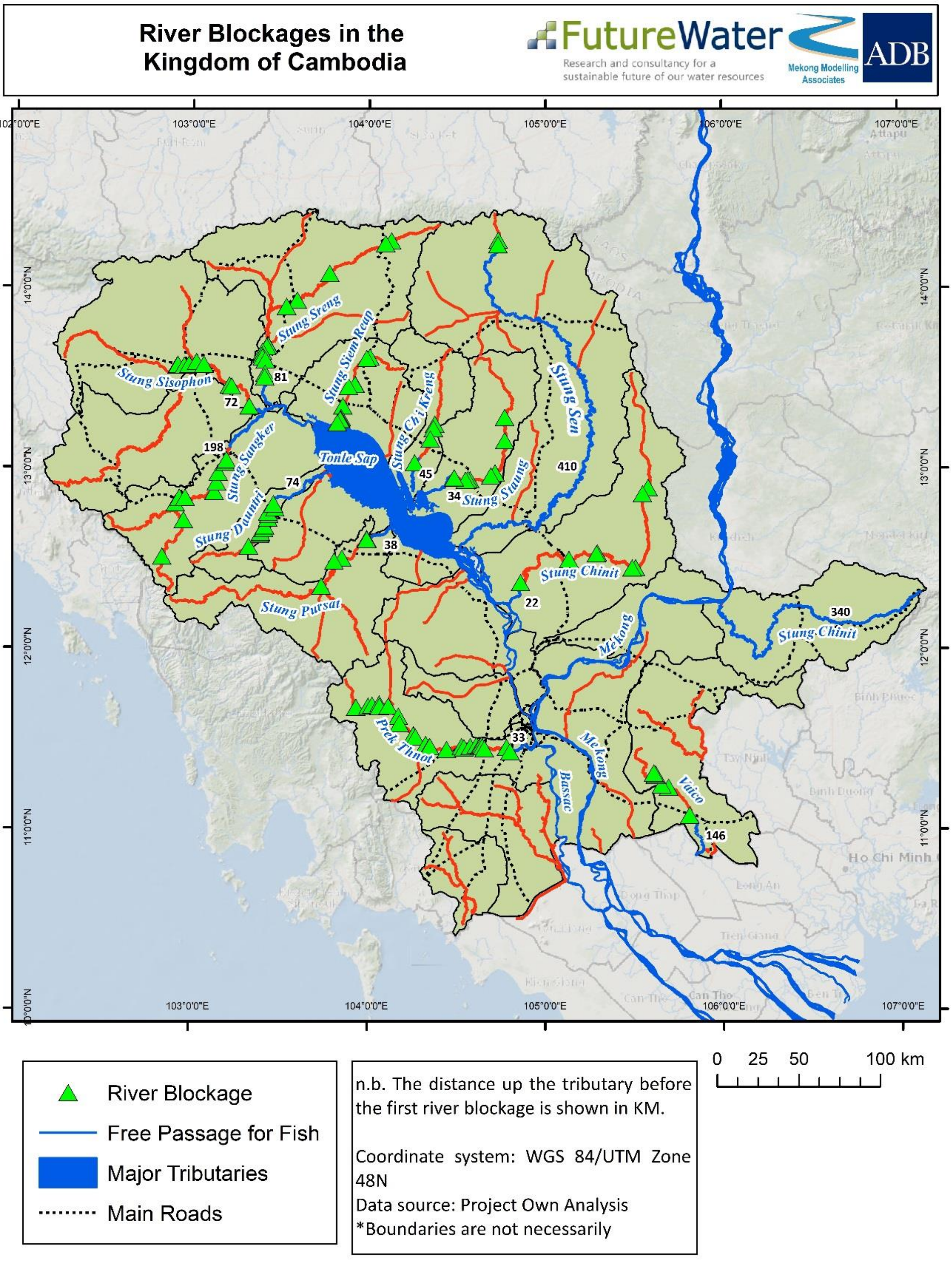


Figure 15: River blockages in the Tonle Sap and Mekong Delta river basin groups (RBGs) according to satellite imagery

5.7 Hydropower on the major Tonle Sap tributaries

On the study area tributaries, one hydropower project has been completed in 2017 on a Tonle Sap tributary, the Stung Sankger in Battambang Province. There appears to be no public information on the environmental impacts of this relatively small project, but based on experiences elsewhere, this and other hydropower schemes planned for the larger tributaries of the Tonle Sap will generally cause some negative impacts on riverine ecology and productivity.
Some of the predictable local impacts of larger hydropower projects should they be built in the upper reaches of Cambodian tributary Rivers such as being considered for the Stung Sen will include:

- the destruction of forest and soil erosion at the project site and along transmission lines and roads,
- inundation in a reservoir of diverse rhithron (flowing water) habitats which support specialised fish and other aquatic animals, and
- obstruction of migrations of fish and other animals.

Downstream impacts of tributary hydropower projects in the absence of mitigation will include:

- regulation of seasonal flows, which *inter alia* will affect fish migration and spawning, and reproduction and growth on floodplains;
- regulation of daily flows (if hydropower plants are used for hydro-peaking), which will create an unfavourable environment for most aquatic organisms,
- reduction of downstream transport of nutrients and particulate matter, which are essential for aquatic productivity,
- poor water quality, with reduced oxygen concentrations, and elevated concentrations of toxicants including hydrogen sulphide, methane, manganese and iron, which may affect uses of the water;
- increased dry-season flows, which may support irrigation and E-flows.

These and other impacts are discussed in Hortle and So (2015), who also review and discuss potential approaches to mitigating or offsetting negative impacts. Developers should recognise the scale of such impacts and the need for mitigation or offsets if hydropower is to be truly beneficial in improving people's lives. The benefits of cheap electricity and seasonal regulation of flows may be more than offset by negative impacts, which in Cambodia are likely to be very significant for downstream fisheries, given the importance of fisheries for nutrition and livelihoods of most rural people.
Each tributary hydropower dam will provide some seasonal storage and regulation, which will tend to increase the viability of additional hydropower and irrigation schemes further downstream. By providing cheap and available power, and raising river water levels, they also increase the viability of pumping for irrigation.

5.8 Irrigation projects: impacts and opportunities

5.8.1 Introduction

Irrigation schemes have been constructed throughout the Cambodian lowlands; by 1999 there were 666 reservoirs of total FLS area of 287 km^2 by 1999 (Hortle and So 2015). Many of these schemes were defunct and/or not officially recognised; MRC databases in 2003 only included 323 irrigation schemes. Since 2000 many Cambodian schemes have been rehabilitated, and the process continues with MOWRAM and donors working on upgrading and expanding irrigation systems.
The effects of irrigation projects depend upon their location, type and mode of operation. In general, barrier and flow effects are similar to those discussed above for hydropower dams: obstruction of fish migrations and disruption of the ecological system through flow changes and

secondary impacts. However, irrigation schemes also divert water out of rivers into irrigated command areas, which reduces flow of, and causes negative impacts in a dammed river; and also increases water in irrigated areas, which may have benefits for fisheries if properly managed.

5.8.1.1 Mitigating impacts of irrigation dams

As Irrigation dams are generally low head, it is possible with good design to allow for fish passage via fish ladders and attraction flows as implemented at the Stung Chinit. The increase in wetland environment in the tertiary canals and rice fields also offers opportunities for fisheries production especially if sensitively designed using canals that feature natural vegetation, fish friendly control structures and supply of water to fish refuges.

5.9 Environmental flows for Fish

Maintenance of adequate environmental flows is critical for survival of fish and OAAs, and to allow migration along river channels (See section on E-flows). Mitigation of fish passage impacts requires further consideration of both upstream and downstream fish passage, as well as other factors as discussed briefly below.

5.9.1 Upstream fish passage

While the need for upstream fish passage has been long recognised, it is only recently that effective fish passes have begun to be constructed for Mekong basin fish species. Several dams in the Study Area have functional fish passes (Table 14, Figure 16, Figure 17, and Figure 18), but all have shortcomings; while passing many species of fish at certain times, they probably have limited efficiency relative to the numbers and range of sizes and species of fish which are migrating throughout the year.
The limitations of these and other fish passes arise from their siting, design and/or size relative to flows as discussed by many authors (e.g. Marsden et al., 2018).

Siting of fish passes: a fish pass must take into account the way fish approach and accumulate at a barrier; in particular, the entrance (at the downstream end) must be in a location where fish are likely to find it and enter it. Fish migrating upstream will approach a fish pass's entrance only if it is close to the main flow of water and if there is sufficient flow through it to attract the fish. Fish must be able to swim through quickly – the fish pass cannot be too long – and exit from the fish pass (upstream of the dam) in a location where they will not be swept back downstream over spillways or diverted into irrigation off-takes. Many fish passes are well designed hydraulically, but have still failed because they have not adequately considered the optimal positions of the entrance and exit and the need to guide fish to safely enter and exit the fish pass.

Design of fish passes: many factors need to be considered in designing a fish pass which will pass a significant proportion of the species and sizes of fish attempting to migrate upstream in different seasons (Thorncraft and Harris 2000, Marsden et al. 2018). The head-loss across a barrier, seasonal change in water levels and flows, and the wide variety and size of migrating fish in Cambodia must all be taken into account, and may limit the effectiveness of any particular design of fish pass, with more than one system needed at many sites, as discussed in detail by Marsden et al. (2018).
While most fish passes require a purpose-built engineered structure, at a low-level diversion weir, fish may be able to swim upstream across the structure if the spillway and/or apron can be designed to allow such passage.

Size of fish passes: Engineered fish passes typically pass less than 1 m^3/s of discharge (Table 14). As a result of the large size of tributary rivers in the Study Area, and the timing of peak fish migrations during the early flood, the entrances to fish passes may not be found by fish, which then accumulate below barriers where they are caught by fishers. Flow through a fish pass (or multiple passes) will also function as an environmental flow, so should be as large as practically possible relative to the river's discharge (See section on E-flows).

Other features: Fish passes may need to be covered with mesh to prevent people fishing in them or falling into them and must be regularly maintained to remove debris or sediment. Fishing must be prevented within the approach and exit zones of the fish pass. These and other factors must be considered if fish passes are to function effectively.

Fish pass design is constantly improving and being adapted, and readers are referred for further information to documents referenced in Hortle and So (2015) Schmutz and Mielach (2015) and Marsden et al. (2018).

Table 14: Fish passes in Cambodia, existing and planned

Province	River	Fish pass location	Type	Design discharge (m^3/s)	Environmental flow (m^3/s)	Status
Kampong Chhnang	Boribo River	Lum Hach headworks	Half cone	0.88	0.74 m3/s + 0.14 domestic/industrial	Completed 2019 but not operating yet.
Pursat	Stung Pursat	Damnak Ampil Weir	Half cone	4.71	nd	Completed 2019
		Kbal Hong Weir	Cone	0.02-0.36	nd	Completed 2019
		Damnak Choeur Krom	Vertical Slot	nd	2.17	Under construction
Battambang	Stung Dountri	Ream Kon Headworks	Half cone	>=0.79	0.79	Completed 2019
Stung Svay Don Keo	Boeung Khnar	Wat Chre	Half cone	>=0.18	>=0.18	Completed 2019
Kampong Thom	Stung Chinit	Stung Chinit Dam	Vertical Slot	0.668	2	Completed 2007
Stung Treng	Sesan River	Lower Sesan II Hydropower project	Nature-like	nd	nd	Completed 2017

Note: other fish passes may not be included because their status is unknown.

Figure 16: Stung Chinit Weir in Cambodia, downstream of the main dam wall

A water gate and flume (left centre) provide an environmental flow release, and a vertical-slot fish pass (right centre) supports fish passage upstream. This fish pass is a modern design that passes many fish, but the flow through it is small relative to both the environmental flow and the main dam overflow, which runs over a long spillway to the right of the photo. Most fish that are swimming upstream (left to right) would miss the fish pass entrance and continue towards the right where they are targeted by fishers.

Figure 17: Inside the vertical-slot fish pass at Stung Chinit Weir looking upstream

Fish swim upstream through each slot in the baffles, resting in the pools. The entire structure is covered by a steel mesh grid to prevent access. The photo was taken underneath the grid.

Figure 18: Cone fish pass at Kbal Hong Irrigation Weir in Pursat in 2019

Source: A Photo by Australasian Fish Passage Services

5.9.2 Downstream fish passage

To complete their life cycles, most adult fish which swim up a Mekong or Tonle Sap tributary river in the early wet season must migrate back downstream, as must their larvae or fry which result from spawning in the tributary. Downstream fish passage may be obstructed or prevented in several ways, with mitigation possible as follows:

1. At a weir, fish which are migrating downstream may pass below undershot gates, where they will be injured or killed by barotrauma, shear or strike. Overshot gates may provide safe passage downstream (Figure 19, Figure 20, Figure 21 (Baumgartner et al. 2006)).
2. Spillways may be too steep, may include injurious energy dissipaters, or may have water levels which are too shallow for successful fish passage. Spillways should be designed to take account of fish passage down them.
3. Weirs may divert fish laterally into irrigation areas, where they may die or be caught by fishers. Fish can be prevented from passing into irrigation canals by screens (e.g. www.awmawatercontrol.com.au/products/fish-exclusion-screens). However very small fish (larvae and juveniles) cannot be effectively screened and a proportion will enter irrigation system off-takes.
4. Fish which are dispersed via canals and into rice-fields may enhance rice-field fisheries. To protect fish and OAAs, overshot water-gates should be installed on canals. An additional benefit is that such gates allow downstream drift of floating aquatic weeds such as water hyacinth *Eichhornia crassipes*, and salvinia *Salvinia molesta*, which may otherwise choke irrigation systems in Cambodia, and increase water loss through transpiration (Figure 22).

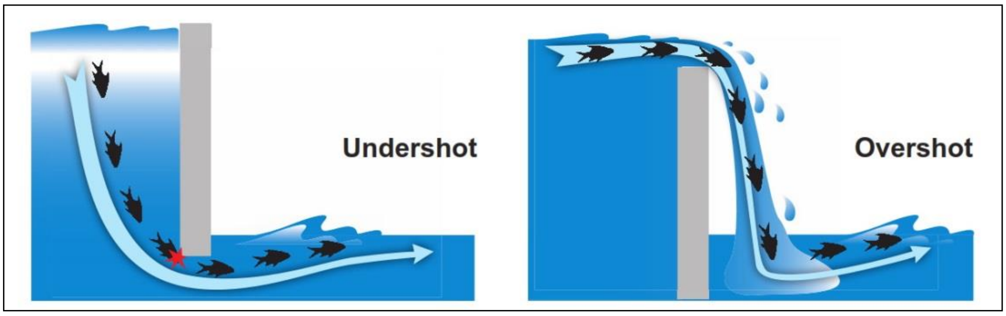


Figure 19: Schematic view of fish passage through undershot and overshot water gates

From Hortle and So (2015); drawing by Chut Chheana.

Figure 20: Overshot “lay-flat” water gates which can pass debris and pass fish safely

Source: Photo by AWMA Water Management Solutions

Figure 21: Overshot water-gates on Tumnub Makak Dam, Kampong Thom, Cambodia

The water gate in the centre of the spillway is open, allowing fish and floating weeds to pass.

The photo was taken in 2013 in January - the dry season - so the other gates are closed.

Figure 22: Boeng Kampeng, a small irrigation reservoir choked with aquatic plants.

Water is 3-4 m deep at this location. Part of Boeng Kampeng is a CFR.

Based on field visits to several irrigation systems, and reviews of the available reports (by the ADB, MOWRAM, JICA, KOICA and ACIAR) about irrigation schemes in the Cambodian lowlands, downstream fish passage issues have not been generally considered, and mitigation measures have rarely been applied in Cambodia. The effects on fish and fisheries within the tributary rivers and in the Tonle Sap and Mekong are unknown, but presumably quite serious, given the large numbers of such schemes throughout the basin and known fish migrations within the tributaries.

Pumping water from rivers also extracts fish larvae and food organisms (insects and crustaceans) which may be killed or injured within pumps or transferred to irrigated rice-fields. The cumulative impact of thousands of pumps on a river system's fauna and productivity could be very significant. The impact could be greatly reduced by fish-friendly screens on intakes, which also prevent organic debris clogging the pumps (Baumgartner et al., 2009).

5.9.3 Impacts of irrigation of command areas and downstream flows

Increasing the distribution of irrigation water to rice-fields is likely to favour increased fisheries production in a traditional rice-farming system, as discussed by (Lahmeyer et al., 2003) for Stung Chinit. However, if the irrigation system supports intensification of shallow-water, fast-growing rice varieties, which require increased use of pesticides, the overall impact on fish and OAA is likely to be negative. Channels and roads may also create barriers to fish movement through the landscape, exacerbating negative impacts, as discussed in detail by (Arthur et al. 2006) for the Tonle Sap system. Drainage from irrigation areas to the parent river or to adjacent catchments should also be considered.

These impacts can be managed by support for IPM (integrated pest management), careful design of the system, and working with the CFR and CFi members to support water supply to their systems and fish passage across and through the irrigated landscape, as discussed below.

5.10 Integrating fisheries with water resources development in Cambodia

5.10.1 Institutional arrangements for fisheries management in Cambodia

Within Cambodia, fisheries management is the responsibility of the Fisheries Administration (FiA) within the Ministry of Agriculture, Forestry and Fisheries (MAFF). The FiA consists of nine departments, including Planning, Administration, Marine Fisheries, Fisheries Affairs and Post-harvest Departments.

Four other FiA departments are of most relevance in considering impacts and management of capture fisheries, as discussed below, together with the main areas of responsibility relevant to water resources developments.

5.10.2 Inland Fisheries Research and Development Institution (IFREDI) and fish passage

IFREDI is responsible for general research, monitoring and development, especially of the wild capture fishery, and works with the MRC and other organisations, having produced many reports on Cambodia's inland fisheries. IFREDI is responsible for planning, design and monitoring of fish passes. With support from donors more fish passes are being planned at present. Water resource developers and MOWRAM should consult with IFREDI to integrate fish passage in projects. IFREDI also needs to consider measures for downstream and lateral fish passage (via irrigation canals), which has not been done to date, probably because of a lack of awareness of the importance and potential of rice-field fisheries.

5.10.3 Community Fisheries Department and CFis

National Fisheries Reform in 2000 and in 2012 involved the closure of most of the large commercial fishing lots around the Tonle Sap-Great Lake and elsewhere, with about one million hectares (mainly floodplains reclassified as to be managed by newly formed Community Fisheries groups (CFis). The CFis are authorised to manage fisheries at a local scale, with support from

the FiA. There are now about 516 registered CFis with 407 of those within the Study Area provinces (
Figure **23** and Table 15). Their performance has been mixed, as discussed by (Ly, 2018), who surveyed 292 CFis nationwide, and found that only 9% were performing well, 61% were operational but under-performing, and 40% were not functioning at all. The best CFis were in coastal areas, where they had strong support from NGOs and also could earn money from tourists who like to visit their protected areas.

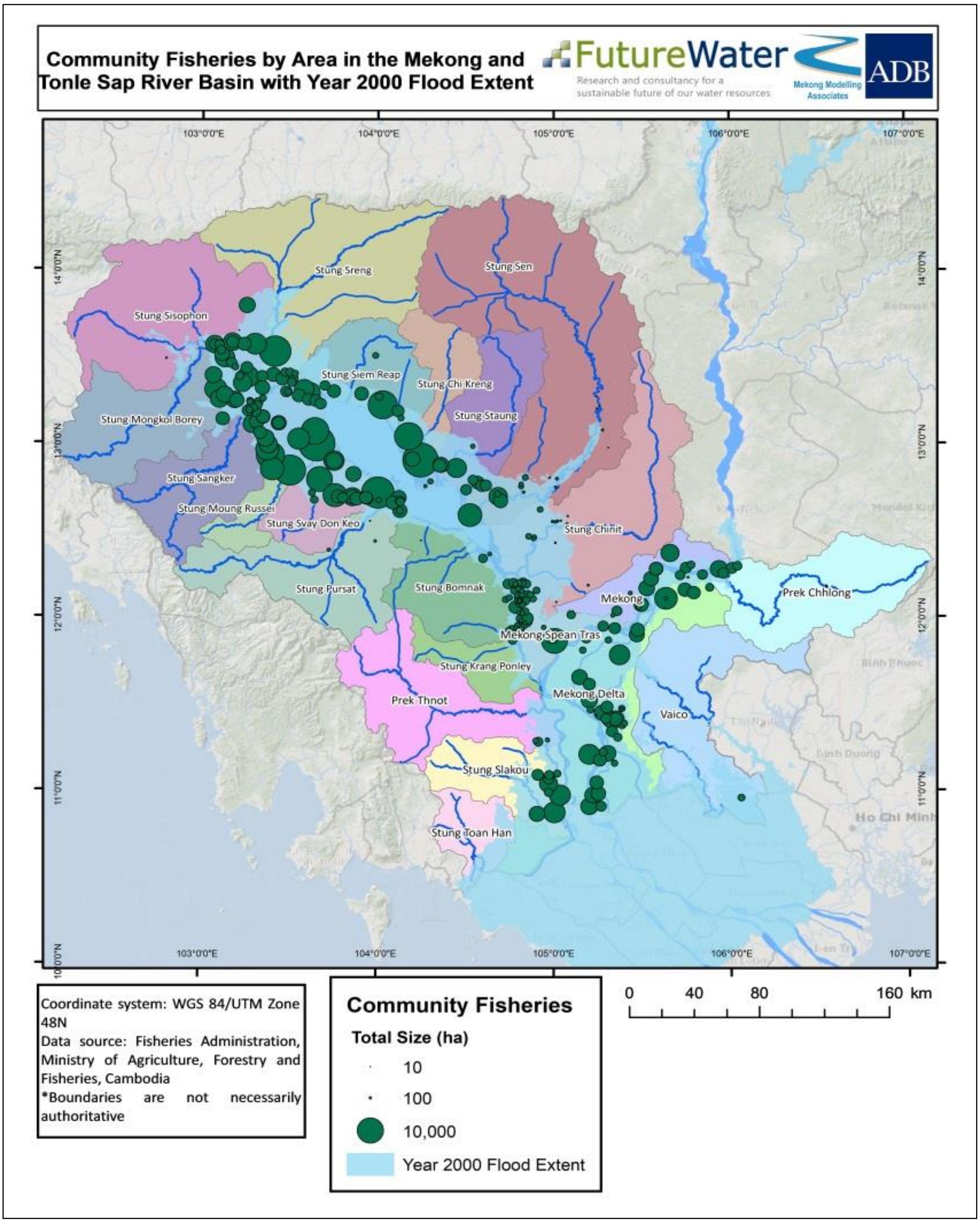


Figure 23: Location and area (ha) of 292 Community Fisheries groups for which data are available

In fact, most CFis cannot perform well, as the fish and OAAs are common property and people are not willing to pay for access, so the CFi receives no income for enforcement or other fisheries management. As shown in

Figure 23, the CFis are mostly within the major flood zone, so for much of the year they at least partly flooded, which makes enforcement of any regulations expensive and difficult, as does the large size of many CFis, the largest of which is nearly 20,000 ha in area (Table 15).

Table 15: Community Fisheries groups registered in the Study Area provinces

Province	*No. of CFis*	*No. with no data for Area*	*Total CFis Area (ha)*	*Min. CFi Area (ha)*	*Max. CFi Area (ha)*
Bantey Meanchey	*19*	*0*	*64,764*	*23*	*14,300*
Battambang	*47*	*4*	*174,127*	*660*	*19,044*
Kampong Cham	*22*	*2*	*36,169*	*36*	*9,788*
Kampong Chhnang	*58*	*4*	*52,973*	*178*	*6,740*
Kampong Thom	*43*	*3*	*44,177*	*23*	*8,110*
Kandal	*29*	*24*	*6,816*	*37*	*6,380*
Kratie	*68*	*14*	*46,968*	*11*	*4,413*
Prey Veng	*28*	*1*	*70,648*	*158*	*7,508*
Pursat	*35*	*5*	*88,693*	*31*	*15,230*
Siem Reap	*23*	*1*	*109,583*	*574*	*19,796*
Svay Rieng	*1*	*0*	*771*	*771*	*771*
Takeo	*19*	*7*	*36,582*	*461*	*6,840*
Tbong Khmum	*15*	*2*	*30,225*	*9*	*7,430*
Total	*407*	*67*	*762,495*	*9*	*19,796*

n.b. areas are under-estimates, as there are no area data for 67 CFis.

Competition between the many fishers in a CFi leads to use of illegal gears, including electro-fishers, poisons and explosives, with the problem exacerbated by fishing by outsiders, who have no interest in local conservation efforts. Added to this is the lack of consultation between CFi members and FWUC members, and consequent disruption to fisheries due to allocation or extraction of water for agriculture.

However, the CFi groups do provide a potentially very useful framework for managing fisheries impacts and enhancing fisheries, so should be included in development planning, especially to improve the supply of water for critical dry season refuges and to set up systems to prevent and resolve conflicts.

5.10.3.1 Fisheries Conservation Department and State Fish Conservation Areas

This department is responsible for the large State-owned conservation areas which were former fishing lots; these now cover about 120,000 ha in the Study Area, as shown in Figure 24; the largest area is flooded forest in Battambang. Fishing continues within these areas but is heavily regulated and the habitat is protected. In these areas the fishers and FiA have a strong incentive to protect the natural vegetation, especially flooded forest, which could be very significant overall for nature conservation in Cambodia. Hence the impacts of any water resource development on these areas should be carefully considered.

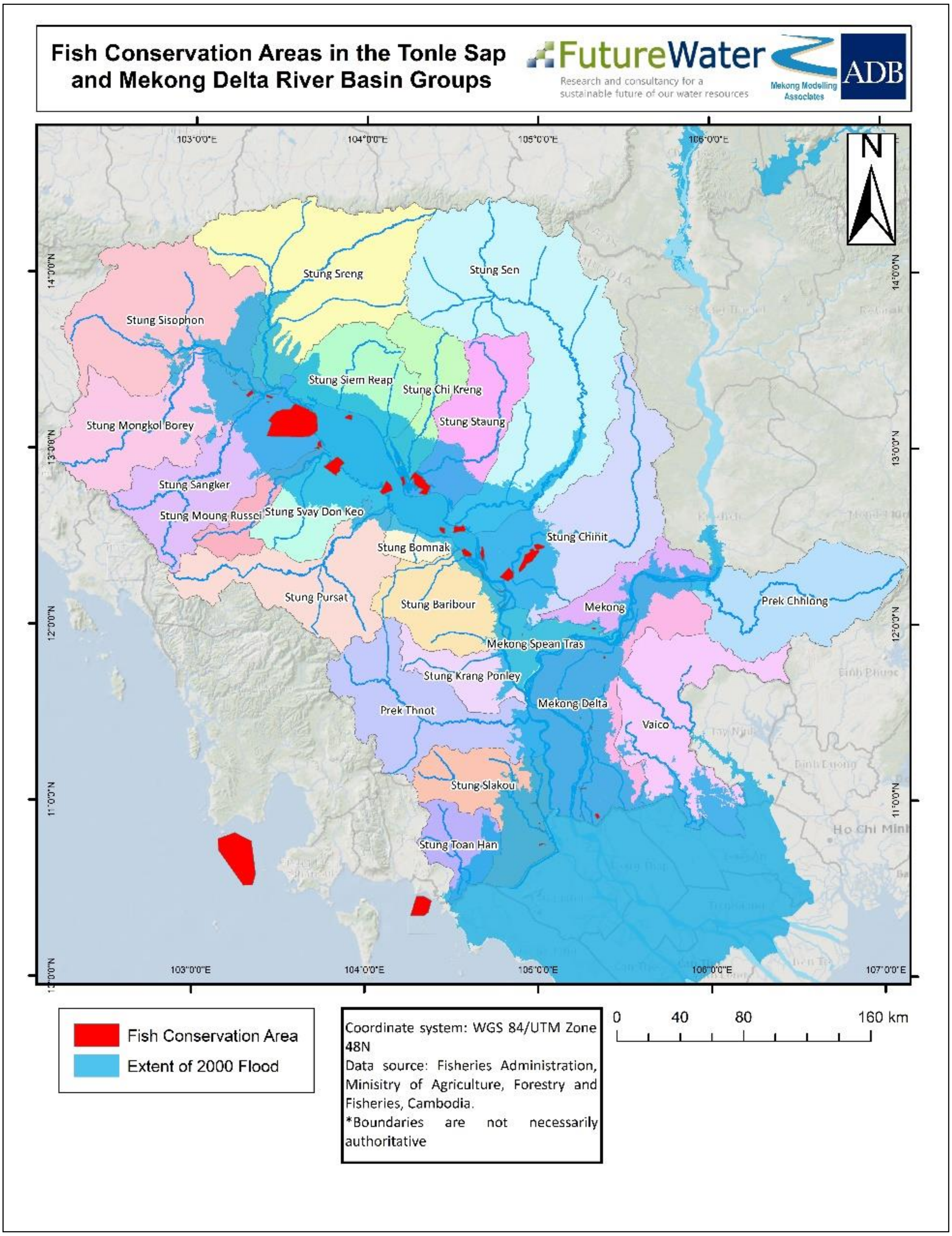


Figure 24: State Fish Conservation Areas in Cambodia

5.10.4 Aquaculture Department and Community Fish Refuges

Aquaculture is strongly promoted by MAFF to improve nutrition and livelihoods and to complement the wild capture fishery. The department runs several hatcheries and regulates and promotes aquaculture throughout the country. Inland commercial aquaculture has been increasing and is now about 68,200 tonnes per year, with most of the production from Kandal, Phnom Penh and some of the provinces around the Great Lake Figure 25). Most of the commercial production is from cage culture or large ponds in the lowlands, with integrated livestock-fish culture being common. The official figures do not include small-scale household production, which is significant.

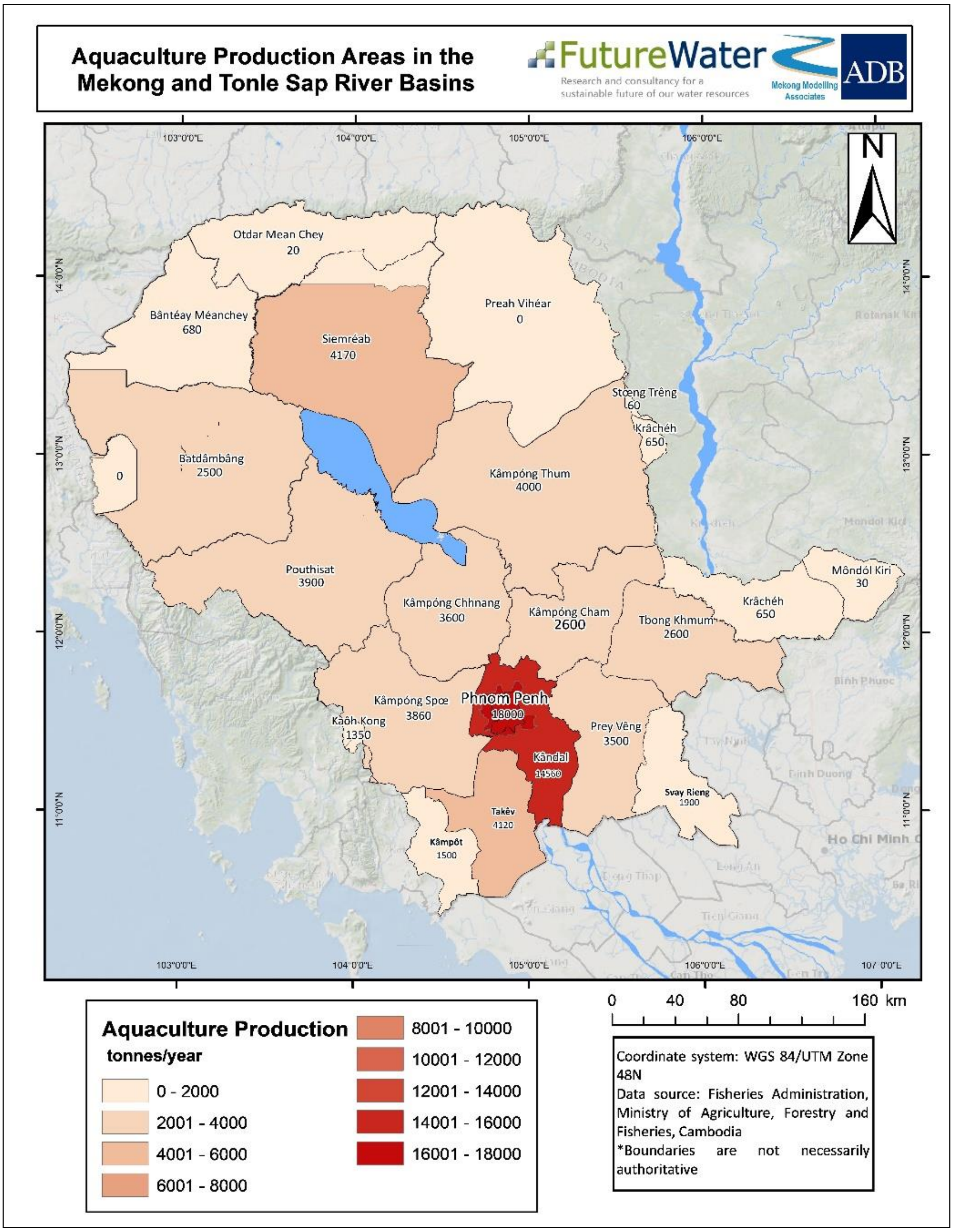


Figure 25: Aquaculture production within the Study Area, showing annual tonnage of fish produced commercially in each province

The Aquaculture Department also oversees Community Fish Refuges (CFRs), which support primarily wild capture fisheries, but as they are located within a highly modified and farmer-managed landscape they are considered by the FiA to be a form of aquaculture.

There are about 840 community fish refuges registered in Cambodia, but for most there are no accurate data available. Figure 26 shows the location of 215 CFRs for which data are available. In contrast to the Community Fisheries (CFis) (Figure 25), the CFRs are on average smaller and most are outside the major flood zone and within rain-fed rice-field ecosystems. Because of their smaller size and location in proximity to the households who benefit from them, they are more manageable and less subject to the problems as mentioned for CFis.

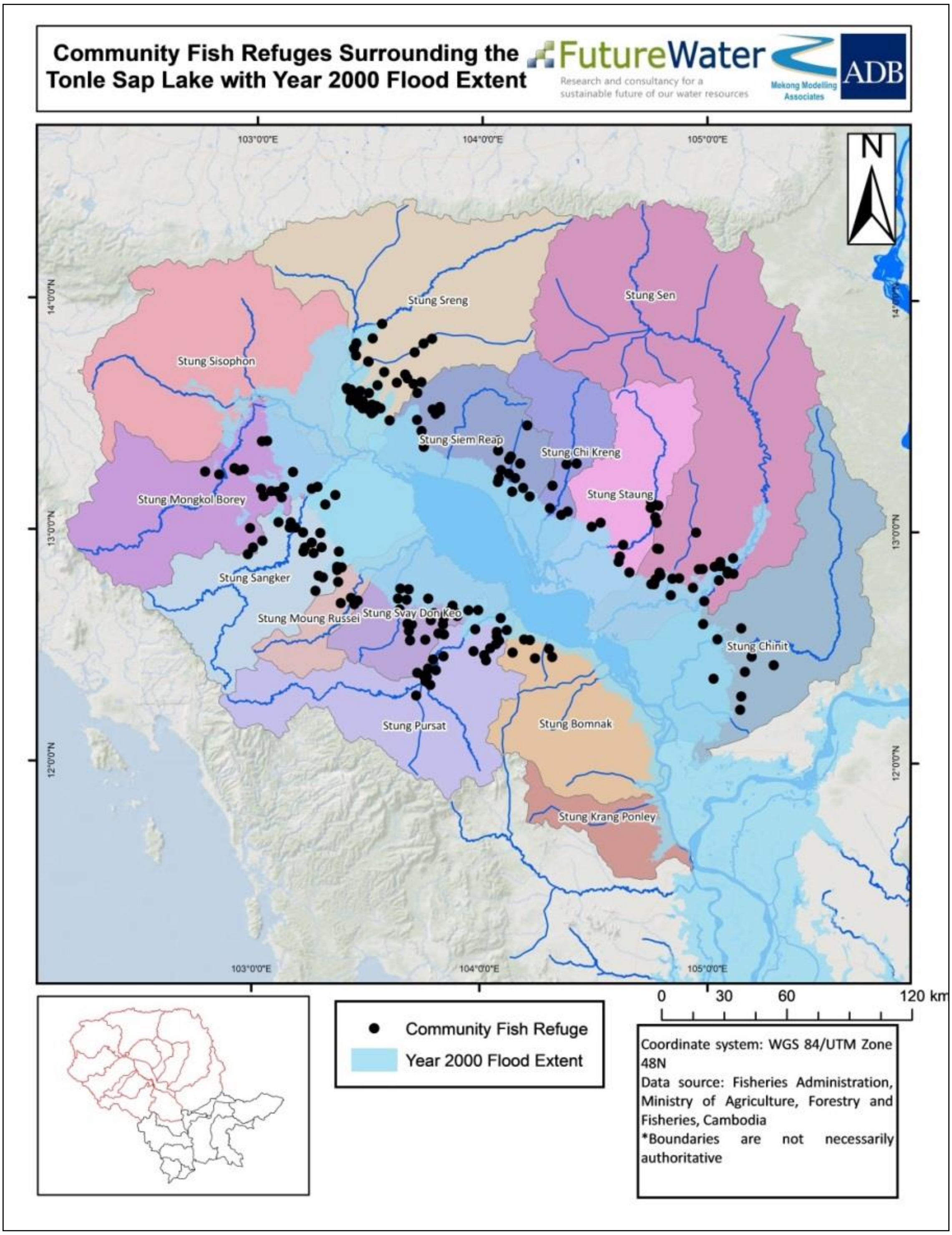


Figure 26: Community Fish Refuges (CFRs) surrounding the Great Lake

The main element in a CFR is a protected dry-season refuge (Figure 27), which is either a large pond or part of a reservoir. The refuge is connected through low-lying areas or channels to rice-fields and to other smaller refuges dispersed through the rice-field environment (Figure 28). Fish and OAAs can survive through the dry season in the refuges, where they breed in the early wet season, and from there, they and their offspring can rapidly colonise rice-fields where water levels are increasing. During the wet season, if water levels in rice-fields fall, fish and OAAs may move back temporarily to the refuges. Interventions to create CFRS and improve their management have been well-studied in Cambodia, where Brooks and Sieu (2016) show that CFRs can significantly increase the production and value of fish and OAAs from the nearby rain-fed rice-field environment. WorldFish Cambodia is continuing to expand the application of the management system developed from experience over several years working on 40 CFRs to others in Cambodia (Kim et al. 2019).

As well as CFRs increasing fisheries production, the yield of rice can also be increased, as a result of pest control and fertilisation by the fish (Viseth et al., 2008, Vromant and Chau, 2005, Xiao, 1992). More intensive ‘rice-fish’ culture (which requires stocking and other measures) is often promoted, and may be applicable depending upon economics, but it should be emphasised that wild capture fisheries are self-sustaining, with no need for stocking or other inputs.

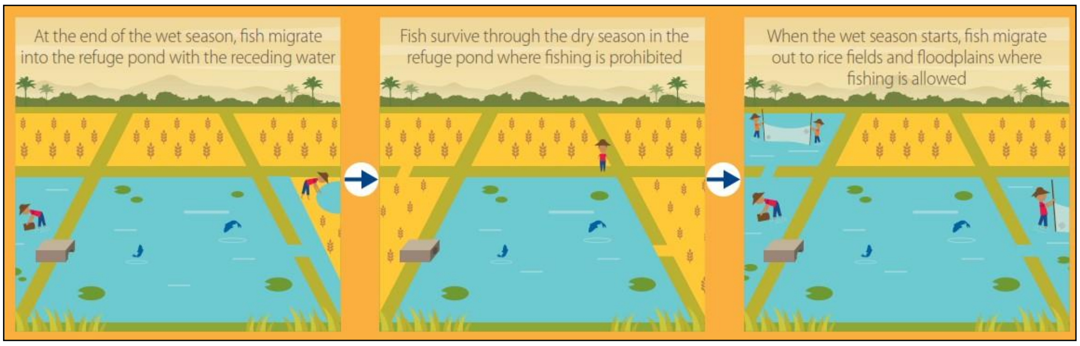


Figure 27: The basic concept of a CFR as a dry-season refuge (Kim et al., 2019)

Figure 28: The main elements of a CFR ecosystem (Kim et al. 2019)

Figure 29: Typical new community fish refuge (CFR) pond, protects fish and other animals

Figure 30: CFRs can support rich aquatic communities

Figure 31: A trap pond in the corner of a rain-fed rice-field provides refuge habitat

Dehydration has been a problem at some CFRs during recent dry seasons. In some cases, the water supply to a CFR has been cut off when irrigation canals were constructed. Given the importance of rice-field fisheries and that it has been demonstrated that CFRs can be managed to increase fisheries production, integration of water resource development projects and supply of water to CFRs should be a priority for MOWRAM and project developers.

6 Ornithology

6.1 Introduction

Eight of the twelve sites visited during the rapid ecological assessment field surveys have been designated as Important Bird Areas (IBAs) (BirdLife International, 2013). Extreme time constraints meant that surveys were brief, and often IBAs were largely inaccessible. Further to this, the seasonality and timing of the surveys were not ideal for observing bird populations. Field visits were conducted outside the breeding season for many species and therefore breeding populations that normally use the IBAs were dispersed over large areas. There were no congregations of migratory species, which had presumably left to their breeding grounds elsewhere. Surveys began late morning which was not ideal for carrying out an exhaustive bird survey. Nevertheless, the survey still provided a general perception of landscapes and bird populations, with further information obtained through interviews with residents and officials.

A list of bird species observed in the rapid assessment survey is provided in Appendix C. Goes (2013) was used to determine the localities of bird species. It was noted that some of the more common species were not always listed in this publication, although the localities of all uncommon to rare species have been listed, as well as localities for major concentrations of common species. Unpublished bird reports were also used to collect additional data on bird populations.

6.2 Description of bird assemblages & species per habitat & habitat dependence

6.2.1 Forest

A total of 95 species are known to dwell in deciduous dipterocarp, or savannah ***forest**, which is* inundated during the wet season. Overlap occurs with the riparian assemblage, since refuge is often sought by some species during the high-water levels in the wet season. Woodpeckers, babblers, and forest bulbuls are just some of the species that are not commonly found elsewhere. The large water bird colonies are exclusively found in the swamp forest, mainly at high water levels.

6.2.2 Shrubland

A total of 41 bird species were recorded in ***shrubland**.* This was not a very specialized assemblage, with birds also found in associated grasslands and remaining forest stands.

6.2.3 Marshland

In ***marshlands***, a total 131 bird species have been recorded. The inundated forest and grasslands give refuge to a rich assemblage of waterbirds, notably rails, crakes, ducks (eight of which are winter visitors) and cormorants (3 species).

6.2.4 Grasslands

A total of 85 species were reported in ***grasslands*** and adjacent to rice fields, which serve as a refuge during flooding of grasslands. Species recorded included the critically endangered Bengal Florican *(សត្វខ្សឹប ឬក្រមាក់អណ្ដើក)* (Goes, 2013, Mahood et al., 2019). Additionally, 3 species of lark are restricted to the grasslands.

6.2.5 River Channels

A total of 93 bird species were reported around ***riverine channels***, in the two RBGs. The riparian forest assemblage shows considerable overlap with dry deciduous forest, and the levees offer refuge to several species, especially ground-dwellers, such as Blue-winged Pittas *(ប៉ាក់ខ្មៀវស្លាបខៀវ)*.

6.2.6 Freshwater Wetlands

Freshwater wetlands in the area include permanent open water bodies and inundated grasslands in the wet season (August-December). The duck family is well represented in the Tonle Sap biosphere with 12 species. Eight of these species are migratory and were absent during the survey period. The survey only recorded 3 species of duck.

6.2.7 Open Countryside

Many of the 87 species of the ***open countryside*** assemblage observed are opportunists, widely found in open country, city parks and other general locations. These included Magpie Robins (*Copsychus saularis* or *ល្វាចេក*), Common Myna (*Acridotheres tristis or សារិកាកែវគោ*), and three species of Sparrow *(ចាប)*.

Some species originate from outside of Cambodia such as the Collared Kingfisher (*Todiramphus chloris or កងបខៀវ ស*), Pied Fantail (*Rhipidura javanica or កញ្ឆាក់ស្លាវ័ណ្ឌកខ្មៅ*), and Golden-bellied Gerygone (*Gerygone sulphurea or ចាបដូនតាថ្ងាស ស*), with the latter species only recently expanding its range. Other species find suitable habitat in the vast rice fields, when their preferred natural habitat is temporarily not available, (e.g. Bengal Florican *or សត្វខ្សឹប*, Blue-breasted Quail *or ក្រួចទ្រូងខៀវ*). Some species are visitors from their winter quarters, such as the Brown Shrike (*Lanius cristatus or ចាបដូនតាខ្នងត្នោតឆ្នូតក្រចៀកខ្មៅ*), which is common throughout Cambodia, occurring even in city parks. Occasionally birds are observed on passage, (e.g., Eurasian Wryneck) but there are only a few records of this.

A number of bird species are strongly associated with elements in the open landscape, such as palm trees, for example the Indian Roller (*Coracias benghalensis or ទៀវខៀវ*) and Asian Palm Swift (*Cypsiurus balasiensis or ត្រចៀកកាំដើមត្នោត*).

6.3 Status and threats to bird assemblages per habitat

6.3.1 Lakes

The visited sites at Lake sides in the southern part of the Tonle Sap water body, had large numbers of cormorants and Asian Openbills *or ចង្កៀលខ្យង*. The large waterbird colony of **Prek Toal** is well protected nowadays and, as a major tourist attraction, its value is much appreciated. Where unmonitored and unprotected, breeding colonies are depleted by the collection of eggs and chicks, especially during the wet season when accessibility is greatly enhanced by the high-water level. The large lake in the south of **Ang Tropeang Thmor IBA was strikingly empty of birdlife**. The entire area was busily visited by fishermen and disturbance could be considerable. This year the water level in the reservoir was exceptionally low and this may have a major impact, emphasizing the need for investigation into ecological flow to maintain water levels in the reservoir for bird (and potentially fish) species.

6.3.2 Rivers

The vegetation on riverbanks visited during the survey were greatly impacted by encroachment. For example, Prek Chhlong river exhibited a rich remnant bird population, but a large degree of encroachment had occurred further inland. River specialists such as the River Tern (*Sterna* *aurantia* or *រំពេទន្លេ*), River Lapwing (*Vanellus duvaucelii or ក្រដេវវិចទន្លេ*), and Mekong Wagtail (*Motacilla samveasna or ខ្ទប់ដីមេគង្គលើ*) are naturally rare, or absent in our survey area. Potentially, species like the Masked Finfoot (*Heliopais personata or ពពូលទឹក*) may be threatened by the use of gill nets, and lines of fishing hooks along riverbank vegetation.

6.3.3 Rice fields

The scarcity of birds in the vast rice fields, (particularly the *Granivorous munias*) was striking. Furthermore, cattle egrets, pond herons and others were far less common than expected, especially considering old reports of the abundance of herons and storks throughout the country. The use of pesticides may be a potential cause for this and warrants further investigation.

6.3.4 Inundated grasslands

Inundated grasslands become marshes during the wet season, forming wintering quarters for a large number of waterbirds (e.g. ducks, pelicans). Seven grassland passerines birds in particular are threatened in Cambodia by the merit-bird trade.

These species are:

- Streaked Weaver *Ploceus manyar or ចាបពូកទ្រូងឆ្នូត* (En)
- Baya Weaver Ploceus philippinus *or ចាបពូកទ្រូងត្នោត* (NT)
- Asian Golden Weaver *Ploceus hypox*anthus *or ចាបពូកទ្រូងលឿង* (En)
- Red Avadavat *Amandava amandava or ចាបមាស ឬចង្រ្កង់ក្រហម* (En)
- Chestnut Munia Lonchura atricapilla (En)
- Chestnut-eared Bunting *Emberiza fucata* (NT)
- Yellow-breasted Bunting *Emberiza aureola or ចាបព្រៃវែង* (En)

Bird trapping has extirpated local populations of wintering Yellow-breasted Bunting (ចាបព្រៃវែង) and resident Chestnut Munias. A special case is the globally near-threatened Rufous-rumped Grass Babbler (*Graminicola bengalensis or ចាបដូនតាចុងខ្នងប្រេះ*), discovered in Cambodia as recently as 2013, found in Pursat, with suitable habitat in Kampong Thom, but not (yet) recorded in one of the survey areas.

Grassland is being converted to large-scale intensive agriculture, mainly through building dams to enable rice cultivation in the dry season (Goes, 2013). Species such as the Bengal Florican (*សត្វខ្សឹប ឬក្រមាក់អណ្តើក*) need vast grasslands, and when total grassland areas fall below a certain threshold, their populations rapidly decrease in size (Mahood et al, 2019). Sarus Cranes also congregate on grasslands. The remaining birds reside in dry deciduous forest in the dry season. IBAs under threat, with large areas of important inundated grassland include Stung / Chi Kreng / Kampong Sva and Boeung Prek Lapouv which are both considered threatened by BirdLife International (2019).

6.3.5 Sensitive and rare/endangered bird species

Appendix C (Annex 3) lists all bird species that have received a global conservation status, based on actual declining numbers, or potential threats (e.g., small range, small population size).

A number of species with a global conservation status have been recorded previously at the survey sites, including 4 Critically Endangered, 3 Endangered, and 7 Vulnerable species, as well as 13 species that have a Near-threatened status. Listed species that are reliant on the provision of habitat from the Tonle Sap and Mekong delta river basins are detailed in the following section and summarised in Table 16.

Table 16: Listed species of bird reported in areas of the Tonle Sap and Mekong Delta River Basin, their requirements and Key habitat sites

Status	Requirements	Key habitat sites
Critically Endangered		
White-shouldered Ibis (*Pseudibis davison or ត្រយ៉ងចង្កំកស*)	Sufficient grassland in the dry season	Baray BFCA
Bengal Florican (*Houbaropsis bengalensis or សត្វខ្សឹប ឬត្រមាក់អណ្ដើក*)	Sufficient grassland	Stung Chikreng Bengal FLorical Conservation Area
Endangered		
Masked Finfoot (*Heliopais personata or ពពូលទឹក*)	Breeding in wet season Sep-Nov	Preak Toal Boeng Chhmar
Greater Adjutant (*Leptoptilos dubius or ត្រដក់ធំ*)	Breeding in swamp forest-Dec-April	Dey Roneat, Prek Toal, post breeding congregations at Boeng Chmar
Vulnerable		
Sarus Crane (*Grus Antigone or ក្រៀល*)	Breeding during wet season -Jul- Sep	North eastern plains, largest post breeding population at ATT; BPL
Greater Spotted Eagle (*Aquila clanga or អកខ្មៅដីសើម*)		Tonle Sap grasslands
Milky Stork (*Mycteria cinerea or រនាលស*)		Prek toal, ATT
Lesser Adjutant (*Leptoptilos javanicus or ត្រដក់តូច*)	Breeding Dec-Jun	Preak Toal and other unmonitored locations around the Tonle Sap floodplain
Manchurian Reed Warbler (*Acrocephalus tangorum or ចាបដូនតាវាលស្រែ*)	Visits Jan-May	Stung Chikreng BFCA
Yellow-breasted Bunting (*Emberiza aureola or ចាបព្រៃវែង*)	Visits Nov-Apr	Largest population at Stung Chi kreng, BFCAs and ATT

6.4 Critically endangered Bird Species

6.4.1 Bengal Florican (Houbaropsis bengalensis or សត្វខ្សឹប ឬត្រមាក់អណ្ដើក)

A 2018 survey estimated the number of displaying male Bengal Floricans at approximately 104 (89–117) individuals, which is lower than the estimated 216 (156–275) individuals in 2012. The number of sites where displaying male Bengal Floricans were reported reduced from 10 sites to 4 between 2012 and 2018. The only site with a stable population is Stung-Chi Kreng Bengal Florican Conservation Area, where 44 (25–63) displaying males were recorded in 2018. Incidentally, this is the only site that has an ongoing NGO-government conservation programme. However, Birdlife International (2019) has marked this IBA as under threat. Recent data indicated that Bengal Floricans are lost from sites when the area of grassland falls below 25 km^2.

Figure 32: Image of the Bengal Florican (*Houbaropsis bengalensis) (IUCN, 2017).*

6.4.2 White-shouldered Ibis (Pseudibis davisoni or ត្រយ៉ងចង្កំកស)

The already small, fragmented population of White-shouldered Ibis (*Pseudibis davisoni*) is in decline in Cambodia due to hydrological changes, hunting, habitat loss and disturbance as well as other unknown factors (BirdLife International, 2019). Population decline is set to continue with these ongoing pressures and the conservation of key sites in Cambodia is key to the species' survival. Typical habitat includes deciduous dipterocarp forest with wetlands and grassland. The main site is located at Western Siem Pang forest (north-western Cambodia and outside of study area), and within our catchments the species is known to breed at Baray BFCA and ATT from December-May.

Figure 33: Image of a White Shouldered Ibis (*Pseudibis davisoni*) (BirdLife International, 2019).

6.5 Endangered Bird Species

6.5.1 Masked Finfoot (Heliopais personata or ពពូលទឹក)

The Masked Finfoot (*Heliopais personata)* is known to breed at some sites in the study area, including Prek Toal and Boeung Chhmar, with breeding occurring in the wet season from September-November (Goes, 2013). The population is declining rapidly largely due to the degradation of wetlands.

Figure 34: Image of Masked Finfoot (*Heliopais personata*) (Birdlife International, 2016).

6.5.2 Greater Adjutant (Leptoptilos dubius or ត្រដក់ធំ)

Most of the Cambodian population of Greater Adjutant (*Leptoptilos dubius)* is found in the Tonle Sap swamp forest and breeds from December-April in large waterbird colonies (Dey Roneat, Prek Toal). Post-breeding congregations are found at Boeng Chhmar and scattered throughout the country (Goes, 2013), and the Cambodian population is estimated at 150-200 individuals. Cambodia hosts one of the only remaining breeding grounds in the world for Greater Adjutant (only other breeding grounds are in north-east India), mostly in the Tonle Sap Biosphere Reserve (WWF, 2019).


Figure 35: Image of Greater Adjutant (*Leptoptilos dubius) (Birdlife International, 2016).*

6.6 Vulnerable Bird Species

6.6.1 Sarus Crane (Grus antigone or ក្រៀល)

There is an estimated 800-1000 Sarus Crane individuals between Cambodia, Laos and Vietnam. In Cambodia, populations are mainly found in the northern and north-eastern plains. Most birds remain in dry deciduous forest in the dry season, with Ang Tropeang Thmor (ATT) being the most important non-breeding site in Cambodia. Smaller populations are scattered on the grasslands of the Tonle Sap floodplains. Boueng Prek Lapouv (BPL) hosts the second largest population of Sarus Crane in Cambodia. Numbers have apparently recently dropped at BPL, and conservation measures are being taken.


Figure 36: Image of Sarus Crane (*Grus Antigone*) (Birdlife International, 2019).

6.6.2 *Greater Spotted Eagle (Aquila clanga or អកខ្មៅដីសើម)*

The Greater Spotted Eagle is an uncommon visitor to Cambodia, having declined substantially since historical times. Now it is only commonly seen at a few sites, with a stronghold in the Tonle Sap grasslands.

Figure 37:Image of the Greater Spotted Eagle (*Aquila clanga*) (IUCN).

6.6.3 *Milky Stork (Mycteria cinerea or រនាលស)*

Small breeding Milky Stork populations exist at Prek Toal and Ang Tropeang Thmor. They commonly disperse in small numbers, pairs and singles, and associate with Painted Storks.

Figure 38: Image of the milky Stork (*Mycteria cinereal).*

6.6.4 *Lesser Adjutant (Leptoptilos javanicus or ត្រដក់តូច)*

This species is fairly common and widespread, breeding from December to June at Prek Toal. There is also an unknown number of unmonitored colonies present on the Tonle Sap floodplain.

Figure 39: Image of the Lesser Adjutant (*Leptoptilos javanicus)*

6.6.5 Manchurian Reed Warbler (Acrocephalus tangorum or ចាបដូនតាវាលស្រែ)

The Manchurian Reed Warbler (*Acrocephalus tangorum) is an* uncommon winter visitor, which occurs at low densities on the Tonle Sap grasslands, usually from January to May. The species is able to use a variety of habitats, and it is therefore unclear as to the causes of its decline since 2005. Now the species is only infrequently recorded in Stung Chikreng BFCA (Goes, 2013).

Figure 40: Image of Manchurian Reed Warbler (*Acrocephalus tangorum).*

6.6.6 *Yellow-breasted Bunting (Emberiza aureola or ចាបដូនតាព្រៃវែង)*

This species is an uncommon visitor, occurring between November and April, mainly Tonle Sap floodplain. There can be huge concentrations of several thousands of birds at Stung Chikreng and smaller numbers can be observed at the BFCAs and Ang Tropeang Thmor. There is immediate threat from trapping for food and merit-bird release trade.

Figure 41: Image of Yellow-breasted Bunting (*Emberiza aureola) (IUCN redlist)*

6.7 Migratory birds Species

About 93 (35%) out 265 species that have been recorded in the survey areas only have migratory or vagrant populations in the survey areas. Some species that are both resident and migratory have not been included.

Table 17: Number of species found in different habitats across the two RBGs

	Total # spp	# migratory spp
Swamp forest	95	20 (21%)
Swamps	131	58 (44 %)
Shrubland	41	11 (26 %)
Grassland	85	30 (35 %)
Riverine	94	26 (28 %)
Open country	87	23 (26 %)

Although some of these species occur extremely seldomly in Cambodia, or are presumed to do so, the occurrence of huge numbers of Whiskered Terns in Bassac Marshes, and Yellow-eared Bunting in Stung-Chikreng show the importance of the swamps and grasslands as wintering quarters for a large number of migratory species.

6.8 Birds with special local conservation status

There are 20 species which are more threatened in Cambodia than elsewhere in the world, amongst which critically endangered Masked Finfoot, River Tern, Milky Stork and Black-necked Stork. Six more species need more study before their conservation status can be assessed.

Three species of Weaver deserve special mention, as they are all under threat because of the merit-bird trade (i.e. the practise of purchasing then releasing birds to gain merit).

6.9 Summary of Sensitive Habitats and Species

The Important Bird Areas shown in Appendix A were visited and the observations at each site including endangered, vulnerable and sensitive species are given in Appendix C. It is clear that many species found in the IBA areas of Cambodia are diverse and need to be protected including ensuring the suitable management of wetlands. Defining the ecological flow requirements needs consideration of a range of aspects of the yearly flood pulse and dry season cycle which will be described further in the next chapter. Furthermore, ensuring the health of the ecosystems that the bird depend on also offers significant benefits to the country in terms of Ecotourism and cultural benefits.

7 Eco-hydrology

7.1 Hydrological features of the Tonle Sap and Mekong Delta River Basin Groups

7.1.1 Seasonality of the Flood pulse

One of the most important hydrological features that drives ecosystem processes in the Tonle Sap and Mekong Floodplain is the Flood pulse regime (Junk et al., 2006). This refers to the cyclical changes between high and low water levels and originates largely from water from the Mekong river driven by the monsoon (Kummu et al., 2014). It starts in April-May, when water levels in the Mekong mainstream rise and waters flow into the Tonle sap lake via the Tonle Sap river (Blackham, 2017). This amounts to an enormous degree of hydrological variability, with surface area ranging from 2,500 km^2 in the dry season to 15,000 km^2 in the peak flood and water levels varying between 1.4-10.3 m. Recent dam development upstream of Cambodia may have affected the reversal and dry season levels of the Great Lake and this may be investigated further in Phase 2 and hydrology is described further in the Rapid Assessment of Water Resources.

7.1.2 Importance of tributaries

Most work on future hydrological regime changes has been carried out on the Mekong mainstream as well as the reverse flow of the Tonle sap. The Mekong mainstream plays a key role in Tonle Sap ecosystem, providing around 50-60% of water and therefore flow regime changes in the Mekong Basin have a great impact on the water levels in the lake. Assessment of future changes to hydrology of the Tonle sap lake as result of Upper Mekong Basin development (e.g. MRC) predicts higher water levels in the dry season and decreases in water level in the wet season. Climate change Impacts on flow from the Mekong are uncertain but significant change will affect the Tonle Sap ecosystems (Kummu et al., 2014).

The tributaries (11 major) of the lake also play an important role, providing 25-35% of the annual streamflow (Oeurng et al., 2019). These tributaries have been poorly monitored and studied. The tributaries are important in maintaining dry season lake levels, being the sole contributor to lake water for 6 months of the year (from November to May). This is particularly relevant since the lake ensures the adequate provision of water the to the Mekong delta during dry season, providing approximately half of the delta's discharge in this period (Kummu et al., 2014).

The tributary flows are very variable, following the rainfall regime, and very low flows can be experienced during the dry season (negligible to zero in some cases) (MOWRAM-ADB, 2013). Generally, the northern catchments are wettest in October, whereas the Southern catchments of the Tonle Sap experience the most rain in September. Oeurng et al. (2019) predicted that climate change would reduce Tonle Sap tributary flows both in the wet season and dry season but also noted that changes to flow are affected by other factors, including land use change, with some catchments experiencing high levels of deforestation.

7.1.3 Biogeochemical processes

Potential biogeochemical changes are likely to be affected by changes in the lake's own sub-catchments (Kummu et al., 2006).

7.1.4 Sediment

The Tonle Sap has a sediment flux into the Tonle Sap during the wet season and outflux roughly in balance during the recession period and in the dry season when wind and local storms may mobilise lakeside deposition (Sarkkula et al., 2003). Although a large amount of the sediment is from the Mekong (70%), a proportion is also carried overland via the tributaries (Sarkkula et al., 2003). One of the main sedimentation areas is around the Lake and the tributaries where sediment is tramped by vegetation, particularly in flooded forests. This sediment is an important source of nutrients when generally phosphorous is the limiting nutrient for Primary Production (Sarkkula et al., 2003). The floodplain ecosystem has been found to retain up to 80% of the received nutrients adsorbed to sediment which enters and is used along with terrestrial nutrient sources by the ecosystem processes (Sarkkula et al., 2003).

7.1.5 Morphology and riverbank erosion

The development and movement of meandering rivers is a natural process that can benefit the environment through exposure of sand banks and fresh outer bend habitats suitable for nesting birds and other fauna. The development of flood control, irrigation and hydropower infrastructure however can block the sediment fluxes and disturb the equilibrium of the river bed affecting the ecosystems and rates of bank erosion. This is apparent in a number of locations and is especially critical for development of connections to the Mekong in the Mekong delta RBG.

7.1.6 Ecosystems adapted to water fluctuations

Ecosystems are highly adapted to large water level fluctuations around Tonle sap and on the floodplain, and therefore the hydrological regime of the basin must remain intact in order the sustain the functions of these important wetland ecosystems (Kummu et al., 2014).

Seasonally inundated vegetation requires this cycle between being inundated and not to survive. The floodplain vegetation provides numerous ecosystem services including the provision of fish (facilitated by the replenishment of oxygen and nutrients from the hydrological regime), wood and fertile agricultural land, flood protection through water retention.

7.2 Eco-hydrological risks

7.2.1 Overview

For the Tonle Sap ecosystems, connectivity and seasonal flooding are important. Infrastructure projects are likely to affect ecosystem structure and function, with most changes in fish populations in the tropics being related to changes in flow. Many of the Tonle Sap sub-catchments have planned and operational projects that have the potential to negatively impact key environmental areas on the Catchment. However, it is difficult to determine the impact of structures on ecology in the Tonle Sap river basin, largely due to the fact that it covers a large percentage of the country (44% according the CNMC World fish study), structural features differ, and data inconsistencies exist.

Irrigation structures are being rapidly developed in the sub-catchments and there are many plans for further irrigation rehabilitation projects and hydropower. Although the Mekong is the major player in flow alterations as a result of water infrastructure developments, the tributaries also have an important role in maintaining flow regimes with 30% of water into the Tonle Sap Lake coming from tributaries. It has been suggested in some studies that existing small scale reservoirs do not have much impact on water flow and water quality in the Tonle Sap. However, the cumulative impact of small structures could be significant. A study by Baran et al. (2007) suggested that irrigation and dam projects in the Tonle sap basin would substantially increase the impacts on the hydrological regime of the Tonle Sap Lake than analysis with upstream Mekong developments alone, with impacts being felt earlier from projects on Tonle sap tributaries, reducing inflows in the wet season and increasing them in the dry season.

7.3 Key Catchments likely to undergo changes:

There is a rapid rate of change within Cambodia for urbanisation and for agricultural improvement. Thus, many of the natural areas studied will be under threat of change and habitat loss. It will be important to continue the identification of key areas in Phase 2 of the project and develop how the water regime can be protected. Likely catchments with known pressures for change are:

- *Stung Sen* has several irrigation and reservoir systems both in operation and at planning stages, and hydropower projects in Upper Stung Sen region are being considered in the sub-catchment. A study by Theara et al. (2019) predicted a 42% increase in dry season flow and an average decrease in wet season flow of 46% at the outlet of Stung Sen basin as a result of Stung Sen Dam construction
- *Pursat,* and *Sankger* both have strong development pressures from hydropower and irrigation flood control and although this offers opportunities if not designed correctly there are risks of negative ecological impact.
- *Chinit* is a key fish area with continuing development and proposed rehabilitation of irrigation works.
- *Prek Chlong* is a largely natural catchment that is likely to undergo significant change.
- The *Basaac* marshes are a large border area with extensive flooding that are likely to be subject to agricultural pressure for flood control and irrigation development.
- The *Vaico* system is already becoming part of the larger irrigation system in the area and the upper part of the river used for conveyance such that the occasional flood flows from the Mekong may be diminished.
- The Canal 98 development has potential to improve the protection given to the nearby wetland and Sarus Crane reserve if designed in the right way.

7.3.1 Main Eco-hydrological risks

1) *<u>Water infrastructure on the tributaries will affect migratory fish species</u>*

- Several fish species spend time in tributaries, for example in Stung Chinit and Stung Pursat. Therefore, are likely to be affected by infrastructure in these catchments. Tributary developments are likely to have the biggest impacts in dry season and the start of wet season.
- Mitigation measures like fish passes in hydropower dams have generally been ineffective in the region, largely due to ecological factors. Stung Chinit has a fish pass- though the design shows features that may be improved upon in future designs.
- Most dams and infrastructure projects lack acceptable baseline studies and EIAs (Baran et al., 2007).

2) *<u>Flooded forest and other floodplain vegetation will be lost if they are permanently flooded</u>*

- Reduced flood pulses in floodplains results in reduced recharging of groundwater, reduced fisheries production and less favourable circumstances for wetland associated wildlife/birdlife.

- Equally important is that if such reduced flood levels prove to be stable, this would encourage further habitat conversion, and current grassland areas around the Tonle Sap, for example, are likely to be converted to agriculture (esp. rice cultivation).

3) *Future irrigation could lead to increased nitrate, phosphate and pesticides from farming activities into the river systems.*

- Stung Chinit irrigation study showed impact on flows, sediment and nutrients was not significant. However, this was based on short study and therefore was not able to assess long-term impacts (World fish).

4) *Delayed onsets of floods that are potentially influenced by competing water uses in tributaries could affect biota due to delaying the DO and nutrients that arrive in flood waters*

- Could affect the survival of fish larvae and juveniles and other biota that rely on this biogeochemical cycle
- However, some irrigation areas have been seen to develop into new fishing grounds,- reservoirs with good level of Dissolved Oxygen
- Other relevant examples will be sought in Phase 2.

5) *Catchment degradation impacting infrastructure lifespan*
- E.g. deforestation of Prey Lang forest effecting eco-hydrology in Chinit Catchment
- Catchments with high levels of deforestation/ catchment degradation include Mongkol Boray.
- Cardamom and Dangrek mountain range forest areas are under pressure
- Samlaut evergreen forests in Sankger basin, loss of trees through mining operations- severe erosion and increase sedimentation to the river and the Tonle Sap Lake- an important area for biodiversity

6) Ecosystem degradation due to agricultural expansion and hunting
- For example, Lower Stung Sen Ramsar site is under threat from agriculture as well as most other sites surveyed
- Wetland areas are converted into agriculture though irrigation development. Agricultural activities can impact upstream and downstream areas.
- Under IWRM principles we should aim for a balance between the benefits of agriculture and maintaining ecosystem processes.

7.4 Calculation of Environmental Flow Requirements for each sub-catchment for Initial Rapid Assessment

7.4.1 Dry Season Minimum Flows

The determination of in-stream water demand for ecosystems is important to wetland ecosystems and aquatic biota. Environmental flow requirement estimations for phase 1 assumed that dry season EFRs are 0.2 m^3/s per 100 km^2 of catchment area in Tonle Sap and Mekong Delta RBG catchments. Low flow requirements were focused on for this initial analysis. A percentage of 30% of MAR is assumed as the EFR during the wet season months May – October. For sites determined as environmentally important, a flow requirement of 5000 $m^3 S^{-1}$ per hectare was allowed. Flow requirements per catchment based on this method are presented in Table 18 & Table 19.

Table 18: Modelled Environmental flow requirements for each Sub-catchment in the Tonle Sap RBG according to the application of 0.2 m^3 /s per $100km^2$ for dry season, 30% of MAF for wet season and $5000m^3$ per hectare per year for specified environmentally important sites. (as determined in the water resources assessment). Fish passage requirements are not currently well known but can be incorporated at Phase 2.

no.	Catchment	E-flow requirements (MCM/yr)	Current Fish Pass Requirement
Tonle Sap RBG			
1	Stung Krang Ponley		N/A
		129.36	
2	Stung Baribour		N/A
	BAR.1	181.27	
	BAR.2	89.83	
	BAR.3	80.41	
	BAR.4	45.69	
	TOTAL	**397.2**	
3	Stung Bamnak		N/A
		45.56	
4	Stung Pursat		2m3/s
	PUR.1	176.59	
	PUR.2	572.07	
	PUR.3	198.38	
	TOTAL	**947.04**	
5	Stung Svay Don Keo		N/A
	SVA.1	161.03	
6	Stung Moung Russei (Dauntry)		N/A
	MOU.1	60.08	
7	Stung Sankger		N/A
	SAN.1	86.82	
	SAN.2	45.87	
	SAN.3	189.44	
	TOTAL	**322.13**	

8	Stung Mongkol Borey		N/A
	MON.1	141.8	
	MON.2	318.43	
	MON.3	47.43	
	TOTAL	**507.66**	
9	Stung Sisophon		N/A
	SIS.1	47.36	
	SIS.2	127.8	
	SIS.3	157.89	
	SIS.4	67.9	
	SIS.5	22.09	
	SIS.6	271.4	
	TOTAL	**694.44**	
10	Stung Sreng		N/A
	SRE.1	143.62	
	SRE.2	213.09	
	SRE.3	157.77	
	SRE.4	408.81	
	TOTAL	**923.29**	
11	Stung Siem Reap		N/A
		316.89	
12	Stung Chikreng		N/A
		164.12	
13	Stung Staung		N/A
	STA.1	72.57	
	STA.2	190.84	
	STA.3	265.13	
	TOTAL	**528.54**	
14	Stung Sen		
	SEN.1	151.49	
	SEN.2	602.75	
	SEN.3	336.01	
	SEN.4	99.35	
	SEN.5	905.6	
	SEN.6	149.85	
	TOTAL	**2245.05**	

15	Stung Chinit		2m3/s
	CHI.1	100.9	
	CHI.2	350.06	
	CHI.3	540.99	
	CHI.4	91.46	
	TOTAL	1083.41	
16	Boeng Tonle Sap Sap		Tonle Sap Reversal under Mekong Agreement

Table 19: Modelled Environmental flow requirements for each Sub-catchment in the Mekong Delta RBG according to the application of 0.2 m^3 /s per 100km^2 for dry season, 30% of MAF for wet season and 5000m^3 per hectare per year for specified environmentally important sites. (as determined in the water resources assessment). Fish passage requirements are not currently well known but can be incorporated at Phase 2.

no.	**Catchment**	**E-flow requirements (MCM/yr)**	**Current Fish Pass Requirement**
1	Stung Toan Han		N/A
		189.1	
2	Stung Siakou		N/A
		351.4	
3	Stung Prek Thnot		N/A
	THN.1	108.8	
	THN.2	252.1	
	THN.3	455	
	TOTAL	**816**	
4	Prek Chlong		N/A
		970	
5	Mekong Riverine		N/A
		0	
6	Mekong Delta Cambodia		N/A
	DEL.1	0	
	DEL.2	486.7	
	DEL.3	97.7	
	DEL.4	0	
	TOTAL	**584**	

7	Mekong TS floodplain (Spean Troas)		N/A
	SPE.1	163.8	
	SPE.2	52	
	TOTAL	**216**	
8	Tonle Vaico		N/A
	VAI.1	403.4	
	VAI.2	263.1	
	TOTAL	**667**	

7.4.2 Ecological Requirements for Flood Regime

The hydrological characteristics of the various wetland habitats have yet not been studied in detail, as the present brief surveys exclude any in-depth study, although in a second phase this would be both desirable and necessary. Nevertheless, an attempt has been made to quantify the hydrology, based on simple characteristics such as flood marks left by the previous wet season's floodwaters. Flooded forests visited generally show such marks on trees at heights of 2-3 metres, and it can be assumed that such floods are normal given that floods in 2018 were average and not an abnormal event such as in 2000. Directly around the Tonle Sap and at Ang Trapeang Thmor reservoir, maximum flooding levels are 4-5 and 5-7 metres, respectively. While at the Stung/ Prasat Balang site this is usually not more than 1-2 metres. Most other sites appear intermediate.

Whether such a flood is an ecological necessity can be debated, but it is known that such flood pulses trigger flowering and fruiting and are certainly important for fish populations as it triggers spawning and provides extensive feeding grounds for floodplain fish. Receding floodwaters then form the basis for Cambodia's very substantial inland fisheries, but also receding rice cultivation and extensive verdant grasslands that support wildlife, key bird species (including endangered species such as the Sarus crane and Bengal florican) and livestock grazing. Reduced flood pulses in floodplains results in reduced recharging of groundwater, reduced fisheries production and less favourable circumstances for wetland associated wildlife/birdlife. Equally important is that if such reduced flood levels prove to be stable, this would encourage further habitat conversion, and current grassland areas around the Tonle Sap, for example, are likely to be converted to agriculture (esp. rice cultivation). Similarly, flood pulses along the Prek Chhlong prevent widespread conversion of the river valley riparian vegetation.

1. **Prek Toal (9) (Stung Sankger):** requires annual flooding (2-3 m in flooded forest, for at least 1-2 months)
2. **Boeng Chmar (8.5):** requires annual flooding (2-3 m in flooded forest, for at least 1-2 months)
3. **Lower Stung Sen (8):** requires annual flooding (2-3 m in flooded forest, for at least 1-2 months)
4. **Ang Tropeang Thmor (7.5):** requires annual flooding (up to 80%), but needs to be dry for at least 4 months = Bengal Florican breeding season.
5. **Stung Chi Kreng (7.5):** requires annual prolonged flooding (will otherwise be converted to agriculture and no longer be a grassland habitat), but needs to be dry from March to June (at least 4 months/year = Bengal Florican breeding season)
6. **Chnok Tru-** requires annual flooding (5-7m for minimum of 3-4 months)

7. **Prek Net Preah/ Kra Lanh/ Pour: -** requires annual flooding- 2-3 m for minimum of 2-3 months
8. **Stung Prasat Balang**- 1-2 m for <1 month
9. **Veal Srongae** 2-3 m for 2-3 months
10. **Stung Sen/Santuk/ Baray**- 2-3 m for 2-3 months
11. **Dei Roneat** – unknown depth necessary but min flooding of 1-2 months

7.5 Sites selected as Environmentally Important

Site selection was based on a biodiversity scoring decided though the rapid ecological assessment surveys. The selected sites are not the only important sites in the Tonle Sap river basin group but were considered important due to their high levels of biodiversity and other field observations. Further assessment of the environmental water demand for these catchments is recommended and only initial guidance to their EFR is provided in this report. These sites include the following:

1. **<u>Lower Stung Sen</u>**
    - Designated as a RAMSAR site in 2018 and supports many threatened bird species (see section 4).
    - Retains water in the wet season and prevents nearby settlements from flooding
    - Filters water through plants and recharges ground water (BirdLIfe International, 2019)
    - 30% of water supply is from tributaries of Tonle Sap Lake (Cambodia Water Resource Profile),

2. **<u>Ang Tropeng Tamor, (Stung Sisophon)</u>**
    - Man-made reservoir made in the Pol Pot regime, intended to provide irrigation and storage for cultivation of rice in the down-stream region. However, the structure was never completed.
    - In 2004, it was renovated and now the dam is closed during wet season. The timing of this event is always contended.
    - Staging ground for 300 Sarus crane and many other bird species.

3. **<u>Boeng Chmar, Kampong Thom and Siem Reap provinces</u>**
    - North-east fringe of Tonle sap lake
    - Consists of a permeant lake – creek systems feed groundwater to surrounding wetland (RAMSAR site information), and inundated forest
    - Receives water from Stung Staung and Stung Chikreng, as well as reverse flow of the Tonle Sap (RAMSAR)- during inundation water depths are 4-5 m.
    - Plays an important Biological and hydrological role for Stung Staung and Stung Chikreng.
    - Nutrient dynamics make the site ecologically diverse. It traps sediment from 2 rivers
    - Habitat for rare species
    - A main threat is the conversion of flooded forest and population growth

4. **<u>Prek Toal, Battambang Province (Sankger Catchment)</u>**
    - Situated at the Mouth of the Sankger river at the NW end of Tonle Sap lake (RAMSAR, 2015).

- Catchment includes Dong Rek mountains and Cardamom mountains.
- Water travels through Battambang via the Sankger river.
- Considered the best example of flooded forest and gallery forest on the Tonle sap lake.
- Large breeding ground for large water birds including globally threatened species.
- Floods up to 7-8m in wet season (only tail tree canopies remain above water; dry season site is dry covered with swamp forests (0.5-1.5 m depth).
- Forests trap sediments and nutrients giving rise to high levels of biodiversity – rise and fall of the flood brings the biological richness.
- Biggest threats include the changing flow of the Tonle Sap and conversion of forest to agriculture.

5. **Boeng Prek Lapouv**

- Accurate measurements rarely occur, but at the Boeng Prek Lapouv crane conservation area the guards keep track of flood water levels and that of 2018 was measured to be 1.87m above the average surface level.
- A summary of estimates of maximum flooding and minimum flooding required to maintain biodiversity is available.
- The area is only used by non-breeding Sarus Crane, in Oct – March, when soil is not too dry (BPL Management Plan 2014-18). This non-colonial, ground nester breeds elsewhere in Cambodia in wet meadows within the dry deciduous forest, from Jul – Sep (Clements et al., 2013).
- The ‘buffer area’ is important to consider as the core protected area is relatively small.

6. **Prek Chhlong**,

- Consists of riparian ‘forest’ in a narrow, fairly steep-sided valley and flood pulses there are likely to often be 8-10 metres.
- Whether such a flood is an ecological necessity can be debated, but it is known that such flood pulses trigger flowering and fruiting and are certainly important for fish populations as it triggers spawning and provides extensive feeding grounds for floodplain fish.
- Similarly, flood pulses along the Prek Chhlong prevent widespread conversion of the river valley riparian vegetation.

8 Conclusions and way forward

8.1 Ecosystems

The major wetland ecosystems of the Tonle Sap and Mekong Delta River Basin Groups have been appraised using both a review of available literature and data and a rapid field assessment covering ecology, fisheries and Birds. The characterisation is believed to be appropriate for the eco-hydrological study and specifically for an initial estimation of the ecological flow requirements that could be used in the rapid water resource assessment.

There are two broad objectives for setting Ecohydrological -flows, to prevent alteration from the natural flow regime or designing a flow regime based on the preservation of ecological processes or ecosystem services (Acreman et al., 2014).

Natural flow is either not altering flow indicators of a flow regime by more than a threshold against either historic baseline conditions or ‘naturalised’ with an attempt to remove the anthropogenic impact. This apprach assumes that every aspect of a flow regime is important to the functioning of an ecosystem, including magnitude, frequency, timing duration and variability. This is a relevant approach if the objective is to maintain a river at near pristine condition, or to maintain areas of high conservation value (and some of our areas are).

However, in the context of Cambodia, with multiple competing water resources, some extent of a change in flow regime is inevitable. A more designer approach could be the way forward, e.g. ensuring the annual flood and recession periods are not altered dramatically.

Average annual flow can be the least important aspect of the hydrological regime for ecosystems of the Tonle Sap and Mekong Delta though. For example, in the Tonle Sap it was found that even relatively small increases in dry season lake water level has the potential to destroy floodplain vegetation and thus ecosystem productivity (Kummu and Sarkkula, 2008).

Therefore, for the Tonle Sap and Mekong Delta River Basin groups, considering their complex eco-hydrological relationships, a site-specific method that considers all aspects of the hydrological regime would be more suitable, including magnitude, timing, frequency, duration and variability. This can be integrated into the next phase of the project when assessing selected catchments and specific environmental assets.

8.2 Fish and Fisheries

Based on brief reviews of several recent planning or monitoring reports from ADB-MOWRAM and aid agencies, fisheries issues are not well considered (or mentioned at all), despite such projects significantly modifying the aquatic environment (as is commonplace, see also Lorenzen et al., 2007, Nguyen-Khoa and Chet 2006, Nguyen-Khoa et al., 2005).

Previously, where fisheries are mentioned in irrigation scheme development in Cambodia, the authors of environmental assessments or monitoring refer cursorily to fish or fishing, and only in permanent water-bodies such as rivers and canals. They often ignore the fact that the rain-fed environment (mainly seasonal rice-fields) in Cambodia, is a very extensive wetland habitat and the main source of fish and OAAs in Cambodia. Such project documents also recommend no mitigation or management measures, apart from, in a few cases, fish passes for upstream fish passage which are unlikely to be very effective in the absence of various other measures (e.g. see JICA and NK 2009, MOWRAM 2018a, 2018b, 2019). There is a significant potential to enhance rice-field and reservoir fisheries through simple interventions and via existing institutional arrangements as discussed above. Apart from improving the outcomes for both irrigation and fisheries, improved dialogue may lessen the potential for conflicts over water allocation, especially conflicts between users, particularly fishers and farmers.

Overall, the issues identified in this report, and consequent recommendations with respect to fisheries include:

1. Most lowland fishes appear to be widely distributed, as a large and predictable monsoon flood drowns out any barriers in the rivers and connects the rivers to their floodplains over vast areas, allowing warm-water species to migrate freely to feed, reproduce and grow. Other aquatic animals (OAAs) which are also highly diverse and exploited by millions of people throughout the LMB include vertebrates (reptiles, amphibians) and invertebrates (including crustaceans, molluscs and insects) (Hortle 2007). The main threats to the large river-floodplain fishery are regional impacts from major hydropower developments upstream of the Study area, as well as irrigation development within the Study Area, which need to be understood and addressed to avoid serious negative impacts on fisheries production and biodiversity.
2. Specialised upland tributary fish species are likely to be threatened by catchment clearance and hydropower dams, and fish species specialised for life on floodplains are likely to be threatened by clearance of flooded forest as well as irrigation and other lowland developments. There appears to be little or no up-to-date information available on the distribution of such species; further review and field work are required to improve our understanding and to inform conservation measures.
3. There is a general lack of awareness of the size and importance of inland fisheries, especially the 'invisible' rain-fed rice-field fishery, and key documents need to be made widely available.
4. Apart from fish passes constructed on a handful of hundreds of irrigation projects in Cambodia, there has apparently been very limited attention to fisheries in irrigation and hydropower planning or implementation. Developers should fully consider threats and opportunities for integration of fisheries, which would provide mutual benefits and enhance the viability of schemes.
5. Experts who prepare project documents (such as EIAs and monitoring reports) should be provided with a handbook and guidelines to use in EIA or other assessments, so they can take full account of the importance of seasonally inundated areas (floodplains and rain-fed rice-fields) and small local refuges and the need to integrate irrigation systems with other uses of aquatic systems, including fisheries.
6. The Fisheries Administration (FiA) through MAFF has excellent institutional arrangements and well-qualified staff and consultants who can facilitate such integration; through Community Fisheries (CFi), Community Fish Refuges (CFRs), State Conservation Areas (SCAs), and fish passage management. Dialogue between MOWRAM should and MAFF should be improved. As a minimum, E-flows for these systems should be considered in all water resource projects.
7. Rapid assessments as planned for the 5 selected catchments should address in more detail these issues and refine these recommendations.

8.3 Next Steps

This rapid assessment phase has delivered important information on the extensive and rich diversity of the wetland environment in the two river basins studied. Linked with the hydrological and water resource study this has enabled a first pass of the ecological flow requirements to be made. In the past the knowledge and practise regarding linkages between the environment, fisheries and water resources development has not been strong enough and this project has shown how important this is for the rapidly changing development situation in Cambodia.

In the Phase 2 of the project, a smaller number of specific catchments will be selected for more detailed study and further work to integrate all the different aspects of the terrestrial and aquatic ecology will be made to define the Hydro-Ecological flow requirements for Catchment specific assessment. This must be supported by further data collection and a more closely linked hydrological modelling assessment that was not possible during the Rapid Assessment phase.

9. References

Acreman, M. C. (2014). Environmental flows for natural, hybrid, and novel riverine ecosystems in a Changing World. Frontiers in Ecology and the Environment, 466-473.

Acreman, M. C., Arthington, A. H., Colloff, M. J., Couch, C., Crossman, N., Dyer, F., Overton, I., Pollino, C. A., Stewardson, M. J., Young, W. 2014. "Environmental flows for natural, hybrid, and novel riverine ecosystems in a Changing World." Frontiers in Ecology and the Environment 466-473.

Anonymous (1996) - Cambodia Wetlands- Ornithologial Survey. Report prepared for Wetlands International: Asia Pacific & Institute of Advanced Studies, Un of Malaya, Kuala Lumpur.

Anonymous (2014) - *Boeung Prek Lapouv management plan January 2014 – December 2018 Part 1: Description and Evaluation*.

Arias, M.E., Cochrane, T., Norton, D., Killeen, T. J., Khon, P. (2013). REPORT The Flood Pulse as the Underlying Driver of Vegetation in the Largest Wetland and Fishery of the Mekong Basin. f. 42 (1), 864-876.

Arias, M.E., Piman, T., Lauri, H., Cochrane, T. A., Kummu, M. (2014). Dams on Mekong tributaries as significant contributors of hydrological alterations to the Tonle Sap Floodplain in Cambodia. Hydrol. Earth Syst. Sci.. 18 (1), 5303-5315.

Arthur, R., Baran, E., So, N., Leng, S.V., Prum, S. and Kura, Y. (2006) Influence of Built Structures on Tonle Sap Fish Resources, p. 55, Cambodia National Mekong Committee and WorldFish Center Phnom Penh, Cambodia.

Baran, E. P., Starr, P., Kura, (2007). Influence of built structures on the Tonle Sap Fisheries . Phnom Penh, Cambodia : World Fish.

Bartrug, B. (2007) - *Birdwatching Trip Report – Cambodja 14.2.2007 – 28.2.2007*. At Travelllingbirder.com.

Baumgartner, L.J., Reynoldson, N. and Gilligan, D.M. (2006) Mortality of larval Murray cod (Maccullochella peelii peelii) and golden perch (Macquaria ambigua) associated with passage through two types of low-head weirs. Marine and Freshwater Research 57, 187-191.

Baumgartner, L.J., Reynoldson, N.K., Cameron, L. and Stanger, J.G. (2009) Effects of irrigation pumps on riverine fish. Fisheries Management and Ecology 16, 429-437.

BDP (2011) Basin Development Plan Programme, Phase 2. Assessment of Basin-wide Development Scenarios. Main Report April 2011, p. 228, Mekong River Commission, Basin Development Plan Programm, Vientiane.

BirdLife International (2003) - *Saving Asia's Threatened Birds: a Guide for Government and Civil Society*. Cambridge UK, BirdLife International.

BirdLife International 2016. *Heliopais personatus*. *The IUCN Red List of Threatened Species* 2016: e.T22692181A93340327. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22692181A93340327.en. Downloaded on 06 September 2019.

Bird Life International. (2019). Protected status secured for Cambodia's Stung Sen wetlands. Available: https://www.birdlife.org/worldwide/news/protected-status-secured-cambodia%E2%80%99s-stung-sen-wetlands. Last accessed 20/07/2019.

BirdLife International (2019) Important Bird Areas factsheet. Downloaded from http://www.birdlife.org on 06/09/2019.

Blackham, G. V. (2017). Wise Use Guidence for Freshwater Wetlands in Cambodia. wildfowql and Wetlands Trust .

Brooks, A. and Sieu, C. (2016) The potential of community fish refuges (CFRs) in rice field agro-ecosystems for improving food and nutrition security in the Tonle Sap region. Report 2016-10, p. 27, WorldFish, Penang, Malaysia.

Campbell, I.C., C. Poole, W. Giesen & J. Valbo-Jorgensen (2006) – Species diversity and ecology of Tonle Sap Great Lake, Cambodia. Aquatic Science, 68: 355-373. DOI 10.1007/s00027-006-0855-0.

Cheu, P. and S. Heng (2018) – Overview of the Cambodian Rice Market - Challenges and the way forward. http://ap.fftc.agnet.org/ap_db.php?id=886&print=1
Chheng, P., Un, S., Tress, J., Simpson, V. and Sieu, C. (2016) Fish productivity by aquatic habitat and estimated fish production in Cambodia, p. 23, Inland Fisheries Research and Development Institute, (Fisheries Administration) and WorldFish, Phnom Penh, Cambodia.
Collaerts, P. (2007) - Thailand and Cambodia, February 17th – March 8th 2008. At Birdtours.co.uk
Davidson, P. (2004) - The Distribution, Ecology and Conservation Status of the Bengal Florican Houbaropsis bengalensis in Cambodja. MSc Thesis Un of E Anglia.
Degen, P., Chap, P., Swift, P. and Hang, M. (2005) Upland Fishing and Indigenous Punong Fisheries Management in Southern Mondulkiri Province, Cambodia, p. 75, Wildlife Conservation Society and Danida, Cambodia.
DHI (2015) Study on the Impacts of Mainstream Hydropower on the Mekong River Impact Assessment Report: Volume 1.
Eaton, J.A., S.P. Mahood & J.C. Eames (2014) - Chinese Grassbird *Graminicola striatus* in South-East Asia: lost, forgotten and re-found. *BirdingASIA* 22: 19-21.
FAO (2010) – Global Forest Resources Assessment 2010. Country Report Cambodia, 49 pp..
Giesen, W. (1998) – Environment in the Tonle Sap Area. Natural Resources-based development strategy for the Tonle Sap area, Cambodia. (CMB/95/003). Mekong River Commission Secretariat/UNDP. Final report, volume 2. Sectoral Studies. Phnom Penh, February 1998. 416.3109.1. Cambodian National Mekong Committee, NEDECO, in association with MIDAS Agronomics Bangkok, Thailand, 126 pp.
Goes, F., Hong Chamnan, Davidson, P. and Poole, C.M. (2001) - Bengal Florican (*Houbaropsis bengalensis*) Conservation in Kompong Thom Province, Cambodia. Phnom Penh: Wildlife Conservation Society Cambodia Program.
Halls, A.S. and Welcomme, R.L. (2004) Dynamics of river fish populations in response to hydrological conditions: a simulation study. River Research and Applications 20, 985-1000.
Halls, A.S., Paxton, B.R., Hall, N., Hortle, K.G., So, N., Chea, T., Chheng, P., Putrea, S., Lieng, S., Peng Bun, N., Pengby, N., Chan, S., Vu, V.A., Nguyen, N.D., Doan, V.T., Sinthavong, V., Douangkham, S., Vannaxay, S., Renu, S., Suntornratana, U., Tiwarat, T. and Boonsong, S. (2013a) Integrated analysis of data from the MRC fisheries monitoring programmes in the Lower Mekong Basin. MRC Technical Paper 33, 1-130.
Halls, A.S., Paxton, B.R., Hall, N., Peng Bun, N., Lieng, S., Pengby, N. and So, N. (2013b) The stationary trawl (dai) fishery of the Tonle Sap-Great Lake, Cambodia. MRC Technical Paper 32, 1-142.
Holden, J. (2010) – Introducing some charismatic species of Cambodian flora. Short communication. Cambodian Journal of Natural History, 2010 (1): 12-14.
Hortle, K.G., Lieng, S. and Valbo-Jorgensen, J. (2004) An introduction to Cambodia's inland fisheries. Mekong Development Series 4, 1-41.
Hortle, K.G. (2007) Consumption and the yield of fish and other aquatic animals from the lower Mekong basin. MRC Technical Paper 16, 1-88.
Hortle, K.G. (2009) The Mekong: Biophysical Environment of an International River Basin. Campbell, I.C. (ed), p. 432, Elsevier Publishers , Amsterdam, the Netherlands.
Hortle, K.G. (2015) Mitigation of the impacts of dams on fisheries - a primer. Mekong Development Series 7, 1-74.
Hortle, K.G. and Bamrungrach, P. (2015) Fisheries habitats and yield in the lower Mekong Basin. MRC Technical Paper 47, 1-69.
Hortle, K.G. and So, N. (2017) Mitigation of the impacts of dams on fisheries — a primer. Mekong Development Series 7, 1-86.
Hortle KG (2018) NHI Mitigation and Eflows report on Section 9-6 KGH
IFREDI (2013) Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia. Synthesis report of the FiA/Danida/WWF/Oxfam project “Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia”, p. 47,

Inland Fisheries Research and Development Institute, Fisheries Administration, Phnom Penh, Cambodia.
IUCN (2003). *The Essentials of Environmental Flows* . Cambridge, UK: IUCN. 11-31.
IUCN. (2017). *Protecting the Critically Endangered Bengal florican in Cambodia.* Available: https://www.iucn.org/news/cambodia/201703/protecting-critically-endangered-bengal-florican-cambodia. Last accessed 15/07/2019
JICA and NKCL (2009) Basin-wide Irrigation and Drainage Master Plan Study in the Kingdom of Cambodia. Final Report, Volume-1 Main Report, Japan International Coperation Agency & Nippon Koei Co. Ltd. Report to MOWRAM and MAFF, Phnom Penh, Cambodia.
Jones, S.H. (1998) – Vegetation fire and land use in Southeast Asia: The interpretation of remotely sensed data for Cambodia. Geocarto International, 13:3, 63-73, DOI: 10.1080/10106049809354653
Junk W, Brown M, Campbell IC, Finlayson M, Gopal B, Ramberg L, Warner BG (2006) Comparative biodiversity values of large wetlands: a synthesis. Aquat Sci 68:400–414
Karimi, S. S., Yasi, M., & Eslamian, M. (2012). Use of hydrological methods for assessment of environmental flow in a river reach. *Int. J. Environ. Sci. Technol.*, 549–558
Kim, M., Mam, K., Sean, V., Try, V., Brooks, A., Thay, S., Hav, V. and Gregory, R. (2019) Guidelines for community fish refuge-rice field fisheries system management in Cambodia, Fisheries Administration and WorldFish Cambodia, Phnom Penh, Cambodia.
Kummu, M., Sarkkula, J., Koponen, J., Nikula, J. (2006). Ecosystem Management of the Tonle Sap Lake: An Integrated Modelling Approach. *International Journal of Water Resources Development* . 22 (3), 497-519.
Kummu, M., Tes, S., Yin, S., Adamson, P., Józsa, J., Koponen, J., Richey, J., Sarkkula, J. (2014). Water balance analysis for the Tonle Sap Lake–floodplain system. *Hydrological Processes* . 28 (4), 1722-1733.

Lahmeyer, I., Smec and Smec Cambodia Consulting, L. (2003) Stung Chinit Irrigation and Rural Infrastructure Project. Potential for Fisheries and Aquaculture Development at Stung Chinit, pp. 1-23.
Lorenzen, K., Smith, L., Nguyen-Khoa, S., Burton, M. and Garaway, C. (2007) Management of Impacts of Irrication Development on Fisheries, p. 161, WorldFish, Penang, Malaysia.
Ly, V. (2018) The Baseline Assessment of the Effectiveness of Community Fisheries in Cambodia, p. 20, Community Fisheries Development Dept, Fisheries Administration, Cambodia.
Mahood, S. (in press) - Finding Cambodian Tailorbird *Orthotomus chaktomuk. Birding ASIA.*
Mahood, S., A. John, J. Eames, C. Oliveros, R. Moyle, Hong Chamnan, C. Poole, H. Nielsen & F. Sheldon (2013) – A new species of lowland tailorbird (Passeriformes: Cisticolidae: *Orthotomus*) form the Mekong floodplain of Cambodia. *Forktail* 29: 1-14.
Mahood, S.P., Hong Chmanan, Son Virak, Sum Phearun & S.T. Garnett (2019) – Catastrophic ongoing decline in Cambodia's Bengal Florican *Houbaropsis bengalensis* population. *Bird Conservation International*. doi:10.1017/S0959270919000157.
Marsden, T., Mallen-Cooper, M., Rice, I.S., Thorncraft, G. and Baumgartner, L. (2018) Stung Pursat Barrage Fishway: Proposed Fishway Design Criteria and Concept for Damnak Chheukrom Irrigation Scheme, p. 23, Australasian Fish Passage Services Pty Ltd.
McDonald, A., B. Pech, V. Phauk, and B. Leeu (1997) – Plant communities of the Tonle Sap Floodplain. Final Report in contribution to the nomination of Tonle Sap as a UNESCO Biosphere Reserve. UNESCO, IUCN, Wetlands International and SPEC (European Commission), Phnom Penh, 30 pp. + appendices, figures & maps.
Mattson, N.S., Buakhamvongsa, K., Sukumasavin, N., Nguyen, T. and Ouk, V. (2002) Mekong giant fish species: on their management and biology. MRC Technical Paper 3, 29.
Ministry of Water Resources and Meteorology, Cambodia. Asian Development Bank, Phnom Penh, Cambodia.

Moore, G., McGuire, K., Troch, P., Barron-Gafford, G. (2015). cohydrology and the Critical Zone: Processes and Patterns Across Scales. *Developments in Earth Surface Processes*. 19 (1), 239-266.
MOWRAM (2018a) Initial Environmental Examination (IEE). CAM: Uplands Irrigation and Water Resources Management Sector Project (UIWRMSP) (MOWRAM-CW05) - O' Kra Nahk Irrigation System Part 1, July 2018. ADB Loan 3289-CAM., p. 64, Asian Development Bank.
MOWRAM (2018b) Second Quarterly Environmental Monitoring Report April 2018. CAM: Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation Project. Project No.: 40190, Loan and Grant No: L2970-SF, G0330-SCF, L8262-SCF, p. 29, Asian Development Bank, Manila.
MOWRAM (2019) Initial Environmental Examination. Cambodia: Irrigated Agriculture Improvement Project. Kamping Puoy, Prek Po, and Canal 15 Subprojects (RRP CAM 51159-002) p. 143, Ministry of Water Resources for Asian Development Bank, Phnom Penh, Cambodia.
MOWRAM-ADB (2013). Report on the Water Environment of Cambodia. Phnom Penh, Cambodia.
Mekong River Commission (MRC) (2018). Procedures for the Maintenance of Flows on the Mainstream (PMFM): Comprehensive Information Report. Mekong River Commission, Vientiane, Lao PDR.
Na**o**, Thuok (1996) – Fishery Management in Siem Reap Province. Paper presented at the Tonle Sap Technical Workshop, Phnom Penh, 26 March 1996, 8 + viii pp.
Ngor, P., Aun, S. and Hortle, K.G. (2006) The Dai Bongkong fishery for giant river prawns, Macrobrachium rosenbergii, in southeastern Cambodia. MRC Conference Series 6, 3-32.
Ngor, P., McCann, K.S., Grenouillet, G., So, N., C., B., McMeans, Fraser, E. and Lek, S. (2018a) Evidence of indiscriminate fishing effects in one of the world's largest inland fisheries. Scientific Reports 8:8947, 1-12.
Ngor, P.B., Aun, S., Deap, L. and Hortle, K.G. (2005) The dai trey linh fishery on the Tonle Touch (Touch River), southeast Cambodia. MRC Conference Series 5, 35-56.
Ngor, P.B., Grenouillet, G., Phem, S., So, N. and Lek, S. (2018b) Spatial and temporal variation in fish community structure and diversity in the largest tropical flood-pulse system of South-East Asia.
Nguyen-Khoa, S. and Chet, P. (2006) Review of Tonle Sap built structures environmental impact assessments (EIAs) with regard to fisheries. TA 4669-CAM, p. 38, WorldFish Center and Ministry of Environment.
Nguyen-Khoa, S., Lorenzen, K., Garaway, C., Chamsingh, B., Siebert, D. and Randone, M. (2005) Impacts of irrigation on fisheries in rain-fed rice-farming landscapes. Journal of Applied Ecology 42, 892–900.
Papadonikolaki G, Martinez-Capel F, Munoz-Mas R, Papadaki C (2018) Determination of environmental flows in rivers using an integrated hydrological-hydrodynamic-habitat modelling approach Determination of environmental fl ows in rivers using an integrated hydrological-hydrodynamic-habitat modelling approach. J Environ Manage 209:273–285. doi: 10.1016/j.jenvman.2017.12.038

Pastor A V., Ludwig F, Biemans H, et al (2014) Accounting for environmental flow requirements in global water assessments. Hydrol Earth Syst Sci 18:5041–5059. doi: 10.5194/hess-18-5041-2014
Penny, D. (2006). The Holocene history and development of the Tonle Sap, Cambodia. *Quaternary Science Reviews*. 25 (3-4), 310-322.
Poole**,** C. (2016) – Tonle Sap Lake: Mekong River Basin (Cambodia). *In:* C.M. Finlayson et al. (eds.), The Wetland Book, DOI 10.1007/978-94-007-6173-5_42-2; 8 pp.
Poulsen, A.F. (2001) Fish Movements and their implication for River Basin Management in the Mekong River Basin, Mekong River Commission, Vientiane, Lao PDR.
Rainboth, W.J. (1996) Fishes of the Cambodian Mekong, FAO, Rome, Italy.

Räsänen, T.A., Someth, P., Lauri, H., Koponen, J., Sarkkula, J. and Kummu, M. (2017) Observed river discharge changes due to hydropower operations in the Upper Mekong Basin. Journal of Hydrology 545, 28-41.

Rheindt, F. (2004) – *Birding in Cambodia, 10-27 February 2004*. Worldtwitch.

Richter, B.D., Baumgartner, J.V., Powell, J., Braun D.P. (1996). A Method for Assessing Hydrological Alteration within Ecosystems in Conservation Biology 10(4) 1163-1174

Rollet, B. (1972) – La Végétation du Cambodge. Revue Bois et Forêts des Tropiques, No. 144 July-August 1972, p: 3-15.

Sarkkula, J. K. (2003). Ecosystem processes of the Tonle Sap Lake. Full paper for 1st Workshop of Ecotone Phase II, Phnom Penh, Cambodia.

Scott, D. (1989) – A directory of Asian wetlands. ICBP (International Council for Bird Preservation), International Waterfowl Research Bureau & WWF. Gland : IUCN, 1989. xiv, 1181p. & maps. ISBN: 2-88032-984-1.

Smakhtin V, Revenga C, Döll P (2004) Taking into Account Environmental Water Requirements in Global-scale Water Resources Assessments

Sood A, Smakhtin V, Eriyagama N, et al (2017) Global Environmental Flow Information for the Sustainable Development Goals

So, N., Eng, T., Souen, N. and Hortle, K. (2005) Use of freshwater low value fish for aquaculture development in the Cambodia's Mekong basin, p. 25, Hanoi, Viet Nam.

Sun Visal & S. Mahood. 2011. *Monitoring of large waterbirds at Prek Toal, Tonle Sap Great Lake, 2011*. Wildlife Conservation Society, Cambodia Program, Phnom Penh

Tansey,K. J.M. Grégoire, D. Stroppiana, A. Sousa, J. Silva, J.M.C. Pereira, L. Boschetti, M. Maggi, P.A. Brivio, R. Fraser, S. Flasse, D. Ershov, E. Binaghi, D. Graetz & P. Peduzzi (2004) - Vegetation burning in the year 2000: Global burned area estimates from SPOT vegetation data. Journal of Geophysical Research, vol. 109, D14S03, doi:10.1029/2003JD003598.

Tharme, R.E., 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications, 19, 397–441.

Theilade, I. & R. de Kok (2015) – Editorial – the status of botanical exploration and plant conservation in Cambodia. Cambodian Journal of Natural History, 2015 (2): 117-120.

Thi, S., Y.T. Lee, L.Y.F Gaw, C. Grundy-Warr & N.J. Souter (2017) - The hollow drum: impacts of human use on the Tonle Sap flooded forest at Kampong Luong, Cambodia. Cambodian Journal of Natural History 2017 (2) 179–188.

Thorncraft, G. and Harris, J.H. (2000) Fish Passage and Fishways in New South Wales: A Status Report, Cooperative Research Centre for Freshwater Ecology, Canberra, ACT, Australia.

Tingay, R., M. Nicoll & Sun Visal 2006. Status and distribution of the Grey-headed Fish-eagle (*Ichthyophaga ichthyaetus*) in the Prek Toal core area of the Tonle Sap lake, Cambodia. *Journal of Raptor Research* 40: 277-283.

Tran, T. (2016) – Transboundary Mekong River Delta (Cambodia and Vietnam). In: C.M. Finlayson et al. (eds.), The Wetland Book, DOI 10.1007/978-94-007-6173-5_40-1; 12 pp.

Vadrevu, K.P. & C.O. Justice (2011) – Vegetation Fires in the Asian Region: Satellite Observational Needs and Priorities. Global Environmental Research ©2011 AIRIES. 15/2011: 65-76.

Valbo-Jorgensen, J., Coates, D. and Hortle, K.G. (2009) The Mekong: Biophysical Environment of an International River Basin. Campbell, I.C. (ed), p. 432, Elsevier Publishers, Amsterdam, the Netherlands.

Van Zalinge, R., T. Evans & Sun Visal. (2008) - *A Review of the Status and Distribution of Large Waterbirds in the Tonle Sap Biosphere Reserve*. WCS Cambodia Program.

van Zalinge, R., T. Evans & Sun Visal (2009) - The status and distribution of large waterbirds in the Tonle Sap Biosphere Reserve, 2009 update. Pp 20-56 in: *Biodiversity monitoring in the floodplain of the Tonle Sap in 2008-9*. Wildlife Conservation Society Cambodia Program, Phnom Penh.

van Zalinge, R., Tran Triet, T. Evans, Hong Chamnan, Seng Kim Hout & J. Barzen (2010) - *Census of non-breeding Sarus Cranes in Cambodia and Vietnam, 2010*. Wildlife Conservation Society Cambodia Program, Phnom Penh.
Vromant, N. and Chau, N.T.H. (2005) Overall effect of rice biomass and fish on the aquatic ecology of experimental rice plots. Agriculture, Ecosystems and Environment 111, 153–165.
Warren, T.J. (1999) Stung Chinit Water Resources Development Project. Summary Initial Environmental Examination with Respect to Fisheries. Final Report, December 1999, Asian Development Bank. Department of Hydrology, General Directorate for Irrigation, Meteorology and Hydrology, Ministry of Agriculture, Forestry and Fisheries, Cambodia.
Welcomme, R.L. and Vidthayanon, C. (2003) The impact of introductions and stocking of exotic species in the Mekong Basin and policies for their control. MRC Technical Paper 9, 1-38.
Woodsworth, G. (1995) – Disappearing Lakes – What is to be Done? A Case of the Tonle Sap, Cambodia. In: Proceedings of the Regional Dialogue on Biodiversity and Natural Resources Management in Mainland Southeast Asian Economies, Kunming, China, 21-24 February 1995. Natural Resources and Environment Program of the Thailand Development Research Institute, and Kunming Institute of Botany (Chinese Academy of Sciences), p:99-109.
WWF. (2019). *Greater Adjutant.* Available: http://www.wwf.org.kh/projects_and_reports2/endangered_species/birds/greater_adjutant/. Last accessed 20/07/2019.
WWT et al. (2013) - Boeung Prek Lapouv management plan, January 2014 – December 2018. Part 1: Description and Evaluation. Wildfowl and Wetlands Trust, Chamroen Chiet Khmer Organization, BirdLife International, Critical Ecosystem Partnership Fund, Min. of Environment, 56 pp.
Xiao, Q.Y. (1992) Role of fish in pest control in rice farming. ICLARM Conference Proceedings 24, 235-243.

Appendix A - Brief description of surveyed sites.

14 ecologically important lowland wetland areas located within the Tonle Sap and Mekong Delta River Basin Groups were identified on the basis of IBA listing and listing as Key Biodiversity Areas. Prek Toal IBA & Ramsar site was dropped as a significant amount of recent data exists and the remaining 13 sites were targeted for surveys (see list and general location map below). All sites were surveyed during the period 24 June-3 July 2019, except for Dei Roneat IBA. The latter was inaccessible from the landward side and as there was insufficient time to survey this from the Tone Sap side, it was subsequently dropped. Surveys were carried out by a joint MOWRAM and project staff team that included Sour Sdey IM, Visal HON and Sovathepheap KEO (MOWRAM PMU staff) and Bas van Balen, Wim Giesen and Dararath YEM (project staff); additional project staff accompanied the field team, including Soknea OUN (26-30 June) and Juliet Mills (24 & 26 June).

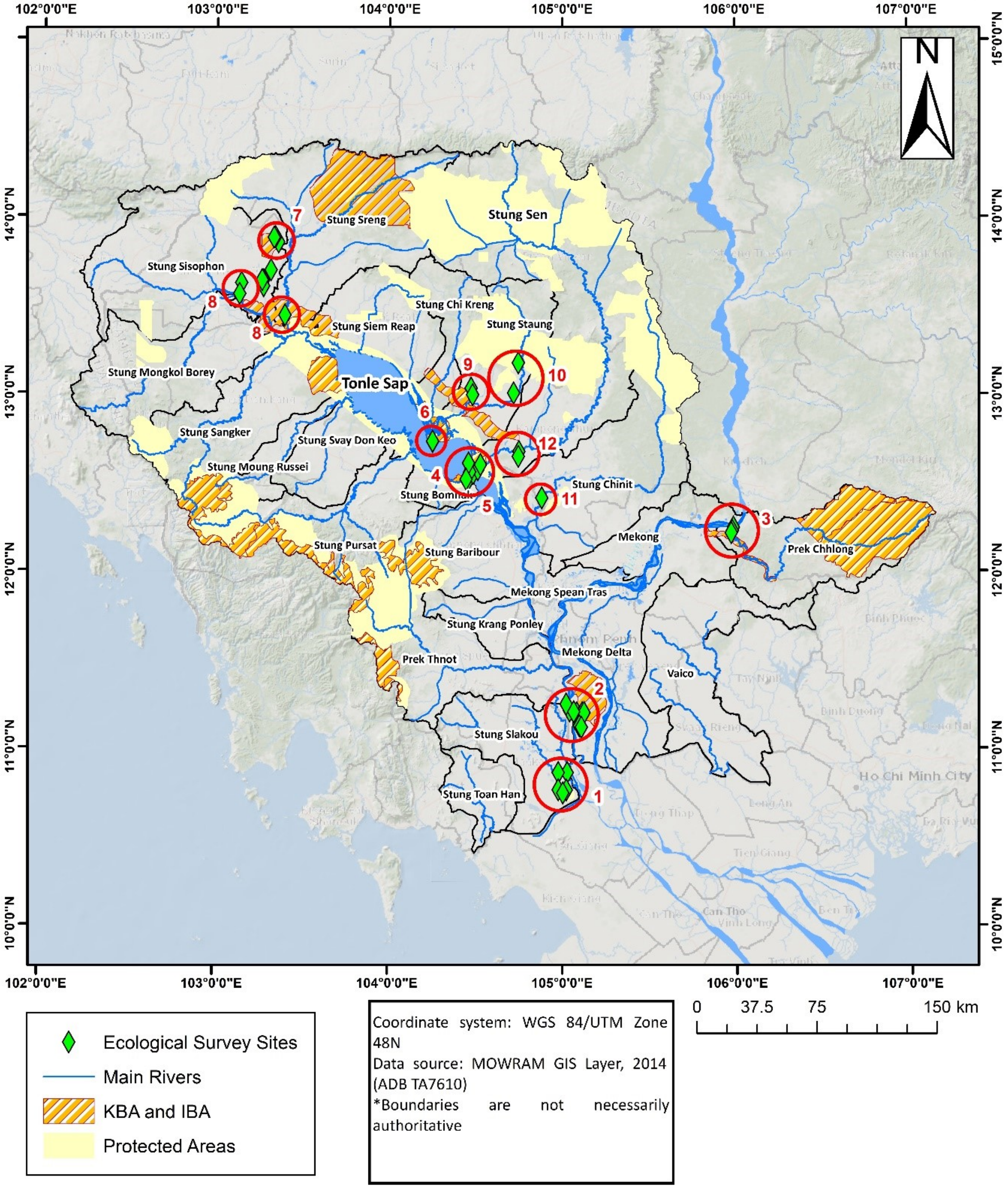
Ecological survey site locations and visited areas are indicated in Appendix A, and on the map below (next page) that also indicates protected areas, Key Biodiversity Areas (KBAs) and Important Bird Areas (IBAs). Descriptions of key findings are in summary descriptions provided below, in order of location:

1. Boeng Prek Lapouv (IBA39)
2. Bassac marshes (IBA38)
3. Prek Chhlong
4. Lower Stung Sen (IBA19)
5. Chhnok Tru (IBA18)
6. Boeng Chhmar (IBA15)
7. Ang Tropeang Thmor (IBA01)
8. Preah Net Preah / Kra Lanh / Pourk (IBA02)
9. Stung/Chi Kreng/Kampong Svay (IBA16)
10. Stung/ Prasat Balang (IBA17)
11. Veal Srongae (IBA20)
12. Stung Sen / Santuk / Baray (IBA21)

Note that these numbers correspond with the survey site cluster numbering in Appendix A.

Ecological Survey Site Locations in the Tonle Sap and Mekong Delta River Basins

FutureWater
Research and consultancy for a sustainable future of our water resources
Mekong Modelling Associates
ADB



1. **Boeng Prek Lapouv** (24 June 2019)

The Takeo crane reserve 'Boeng Prek Lapouv' is located along the border with Vietnam and is bordered by Canal 98. Officially, BPL consists of a 919 ha central Core zone surrounded by a 3-4 km wide buffer zone (7,386 ha) consisting of a Conservation zone, Multiple use zone and a Community zone. The area was surveyed by a team consisting of MOWRAM staff (3x) and project staff (JM, BvB, DY, WG); this joint team visited the MoE field office for BPL and three MoE staff joined in the field and in discussions.

According to the Boeng Prek Lapouv Management Plan (2014-2018), the area was largely forested and remained wet throughout much of the dry season. During 1975-79 small channels were excavated for drainage, the area was cleared and used for planting deep water rice. The first cranes were spotted only in 1986, after these changes had occurred. The EU irrigation project (PRASAC) from 1991-1998 provided for canal transport and more irrigation, and cultivation of rice in the dry season. As a result, the reserve becomes drier earlier and earlier in the dry season. During Important bird Area (IBA no. 39) surveys by BirdLife in 2001-2004 the area was identified as one of Cambodia 40 IBAs, and in 2007 the area was formally gazetted as a protected reserve.

In practice, however, intensively cultivated rice paddy fields are found all around right up to the canal that forms the outer perimeter of the Core zone, apparently handed out by MAFF before management was taken over by MOR. These are cultivated 2-3x per year and consist of fast-growing varieties that take only 75-85 days to mature. They are intensively sprayed with pesticides (given the number of bottles found around) and are preyed upon by rats (see many traps and plastic sheeting around the edges).

The reserve's hydrology has been altered by canal construction, both in the Pol Pot era and later by the EU-funded PRASAC project that resulted in the construction of Canal 98. Currently, the area in the south of the Canal 98 command area is not irrigated as the canal has silted up too much. The Core zone is slightly drained by Pol Pot era canals, but these are largely silted up. Desilting is to be carried out, along with concrete lining of sections of sandy soil where there is lots of infiltration. A section of a former river still remains as a 300m long, 5m wide, 2-2.5m deep body of water in the middle of the reserve that serves as a source of fish stock.

The reserve is affected by poaching/hunting, encroachment (on the northeast of the Core zone), pesticides and fertilizers from the adjacent rice paddies, noise and disturbance from ongoing mechanized farming practices, fires (in 2018 and 2019, not in 2016 and 2017) and drying out of the reserve from Feb-April. A dike of 1.5-2 m height has been constructed around a small section of 16 ha in the centre of the reserve, to preserve wet habitat needed by Sarus Cranes.

The reserve management is generally positive about the rehabilitation of Canal 98, as long as this provides more water in the drier months (Sarus cranes prefer soggy grasslands). However, the grasslands should not be too flooded, nor should the dry season be too short. Some burning may actually be required to keep the area open and not encroached by trees and shrubs. Active water management with inputs from MOE, local communities and MOWRAM is required to manage water resources of the area, as needs are not always compatible. At present there are no structures (e.g. sluices) at all along primary, secondary or tertiary canals so there is little active water management, and the latter will definitely be required. At the time of the survey water levels were lower than a week before (according to JM), and all along the canals, farmers were actively pumping water from the canals onto their rice fields. During the last wet season water levels at the MoE field station were

1.87 m above ground level <It is unclear which reference is being used on the gauge at the MoE field station>.

Potential acid sulphate soils possible occur at BPL, judging from jarosite colouration observed (see photo). If these are exposed during dike construction this could lead to acidification and aluminium toxicity issues. It is recommended that a simple soil survey be carried out to assess the magnitude of the problem (concentrations of iron sulphide [FeS], depth). If FeS concentrations are low or very local, the problem may be non-existent and ignored. However, if higher concentrations occur opportunities for flushing this with irrigation water need to be investigated, or dike construction reconsidered or adapted (e.g. shallower borrow pits).

Vegetation in the reserve Core zone consists primarily of seasonally inundated grasslands with scattered shrubs and small trees. According to the BPL management plan, the grassland vegetation includes *Chloris barbata, Cynodon dactylon, Echinochloa stagnina, Eleusine indica, Ischaemum* sp., *Leersia hexandra, Phragmites vallatoria* and *Saccharum spontaneum* grasses, along with sedges such as *Eleocharis dulcis* and herbs such as *Persicaria hydropiper, Merremia umbelata* and *Ipomoea nil.* The few tree and shrub species include the exotic *Mimosa pigra* and *Phyllanthus reticulata.*[1] They also recorded *Morinda citrifolia,* but this is an incorrect ID as the *Morinda* species commonly seen at the site is a small straggling herb with a much smaller, elongated fruit (identified as *Morinda persicifolia* or nhor/nhor tuk).

Our own observations along the dikes and areas directly around the BPL reserve Core Zone include a number of tree and shrub species such as *Acacia auriculiformis, Borassus flabellifer, Eucalyptus camaldulensis, Ficus* sp., *Mimosa pigra* and *Phyllanthus reticulatus.* Herbs and grasses include *Actinoscirpus grossus, Ceratopteris thalictroides, Echinochloa stagnina, Eichhornia crassipes, Fimbristylis miliacea, Grangea maderaspatana, Gymnopetalum chinense, Heliotropium indicum, Ipomoea aquatica, Ludwigia adscendans, Ludwigia hyssopifolia, Monochoria hastata, Morinda persicifolia, Passiflora foetida, Phragmites karka, Polygonum pulchrum* and *Saccharum spontaneum.*

The BPL management plan lists 110 bird species, while the local guards mentioned a number of 70+ species; the BirdLife IBA fact sheet gives the following IBA trigger species: Sarus Crane *Antigone (Grus) antigone*, Bengal Florican *Houbaropsis benghalensis*, Spot-billed Pelican *Pelecanus philippensis*, and Black-necked Starling *Sturnus nigricollis*. Our brief survey fell outside the breeding season of most of these species, and only a few Black-necked Starlings were seen. Altogether our survey yielded just 34 species, but certainly noteworthy were however a flock of 100+ of the globally near-threatened Painted Stork *Mycteria leucocephala* and a single male in breeding plumage of the Near-threatened Asian Golden Weaver *Ploceus hypoxanthus*. As described above the BPL core area is entirely surrounded by intensively managed rice fields, where 1000s of ducks were kept along the canals to feed on these in separate groups of hundreds each; the impact of this on the food availability for a number of native waterbirds is unclear.

[1] They also recorded *Morinda citrifolia,* but this is an incorrect ID as the *Morinda* species commonly seen at the site is a small straggling herb with a much smaller, elongated fruit, correctly named *Morinda persicifolia*.

Photo at Boeng Prek Lapouv, showing how rice fields continue up to the edge of the Core Zone (right).

Drone photo of Boeng Prek Lapouv, showing the permanent lake that lies in the Core zone; also visible are trail made by buffalo grazing in the area

Photo: possible jarosite exposed in clay along present dike

2. **Bassac marshes** (25 June 2019)

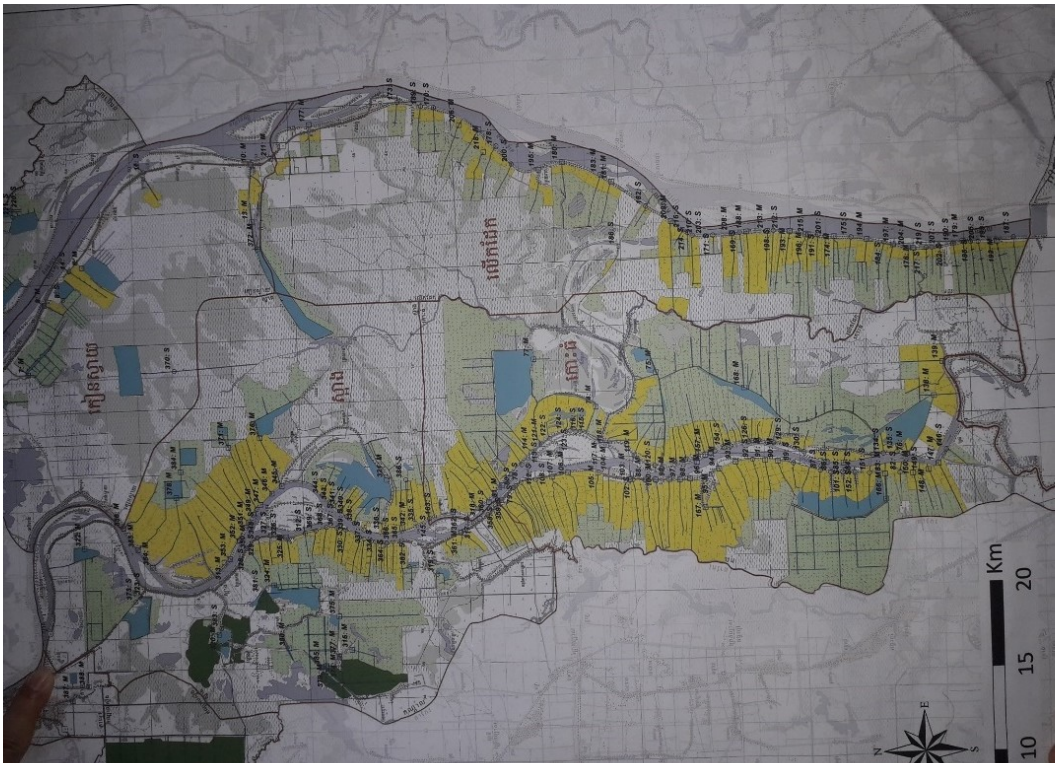
The Bassac marshes are described on the BirdLife website as 'an extensive IBA (IBA 38) consisting of wetlands between the Mekong and Bassac rivers'. The vegetation is described as being "dominated by seasonally inundated shrub and savanna swamp, which is surrounded by agricultural land. During the wet season, the IBA is inundated, and is characterised by large areas of deep, open water, with substantial areas of emergent, floating and submerged aquatic vegetation." Scott (1989) mentions that this area is flooded to a depth of 2.5-4.5m for five to seven months a year.

During the present survey the area was entered from the western side, driving along the road running along the east bank of the Bassac River. We found that while much of the periphery is converted to agriculture, much of the central part includes vast areas of grassland and scrubland that according to MOWRAM is flooded during the wetter months (usually from August to Feb-March). This vegetation is dominated by tall reedland dominated by wild sugarcane *Saccharum spontaneum* and common reed *Phragmites karka*, along with scattered trees and shrubs, especially *Barringtonia acutangula, Combretum trifoliatum, Croton caudatus, Glochidion obscurum, Hiptage triacantha, Sesbania javanica,* and the invasive exotic *Mimosa pigra*. Woody climbers such as *Uvaria* *rufa, Dalbergia cambodiana* and *Terminalia cambodiana* are common, while herbs include *Grangea maderaspatana.*

There are a number of 'baray' or shallow reservoirs that are used as a source of irrigation water in the drier months. Reportedly, these date from the Khmer Rouge period, and are dry during the present survey. Of these, no. 77 (see map) is to be rehabilitated by JICA funding, and no. 168 by funding from ADB. AFD funding has been used to rehabilitate 21 canals extending from the Bassac River into the marshes; we observed one that had already been upgraded – this was deepened, and a sluice gate constructed near the mouth at the Bassac.

To preserve the marshes, the deepening of the canals into the marsh and especially the adding of sluice gates to retard water, would have a beneficial effect in that the marshes will not dry out as quickly as happens now.

Map of Bassac marshes (MOWRAM)



The IBA supports large numbers of commoner waterbirds, as well as small numbers of Darter *Anhinga melanogaster*, Spot-billed Pelican *Pelecanus philippensis* and Asian Golden Weaver *Ploceus hypoxanthus*. In addition, the IBA regularly supports more than 1% of the Asian biogeographic population of Whiskered Tern (*Chlidonias hybridus*). Other significant assemblage of waterbird species are 2000 Pond Heron species, 600 Intermediate Egrets, 230 Pheasant-tailed Jacanas and 85 Black-winged Stilts. Many shorebird species also occur in the area such as Black-tailed Godwit, Marsh Sandpiper, Wood Sandpiper, Common Sandpiper, Common Greenshank, Asiatic Golden Plover, Little Ringed Plover, Kentish Plover etc. (BirdLife International 2019).

Our survey fell outside both the breeding season of most resident marsh birds mentioned above, and the wintering and migrating season of the shorebirds. Also, access was seriously hampered by low water which did not allow us to venture far inside the swamps. Consequently, the number of birds recorded was low (33 spp), but most were characteristic of open sparsely wooded swamps, such Oriental Pratincole *Glareola maldivarum* and Red-wattled Lapwing *Vanellus indicus*.

Photo: only some pools remain in the Bassac marshes from April-June

Photo: drone image of the surveyed site showing the mosaic of various grassland types (e.g. silvery-grey = Saccharum spontaneum patches) with scrub/shrubland and a string of houses along the canal/road in the distance.

3. Prek Chhlong (26 June 2019)

Consists of lower reaches of Prek Chhlong just before this river flows into the Mekong River at Chhlong township. It is listed as an area of biodiversity importance but has not been listed as an IBA, nor is it a protected area. According to the listing, it consists of gallery forest found along lower 40-50 km of the river. The upper catchment of the Prek Chhlong consists largely of a forested protected area.

The survey was carried out by boat from Chhlong, where a new bridge is under construction at the mouth of the river. Due to this, the Chhlong has been constricted so it is possible that water levels in the river are higher than they otherwise would have been. Due to the direct connection with the Mekong, though, it is unlikely that this lower part of the river falls dry. This was confirmed by the deputy head of PDRAM, who says that the river always flows, even in 2015 when levels were low it kept flowing; the lowest in memory was in the 1980s, but then it also flowed. The river is about 20-30(-35)m wide and the banks are steep and high, varying in height from 8-15m above the present (low) water levels. Waters are very muddy and silt-laden, appearing a 'milk coffee' colour compared to the darker waters of the Mekong.

The vegetation of this 'gallery forest' is dominated by clumps of 10-15m tall bamboo, which account for more than half of the woody vegetation. The rest consists of scrubland, mainly with low trees (5-10m) and shrubs, with many species common in secondary forest including *Mallotus* and *Macaranga.* There are occasional emergent larger trees of 15m height, including *Parkia* and *Ficus.* The undergrowth of the higher (and flatter) parts of the gallery scrub includes an *Amorphophallus* aroid (locally very common), the shrub *Leea indica,* grasses and the *Hibiscus*-like lady's fingers

Abelmoschus esculentus. The lower parts of the banks include typical riparian tree species such as *Barringtonia acutangula, Crateva nurvala, Phyllanthus reticulata* and *Lagerstroemia speciosa.* Climbers are common, including rattans *Calamus* sp., but also *Cardiospermum halicacabum, Cassytha filiformis, Cayratia trifoliata, Connarus* sp., *Gymnopetalum chinense* and *Piper* sp. (wild pepper). This zone further includes reed *Phragmites karka,* wild sugarcane *Saccharum spontaneum, Polygonum pulchrum* and the invasive exotic shrub *Mimosa pigra.* Close to the water's edge there are clumps of the willow-like rheophytic shrub *Homonoia riparia* that is adapted to withstand fast-flowing waters.

There are scattered houses along the upper banks, each with trails leading to the water's edge where often a small boat is moored. Pumps and piping for irrigation are also common along the river. As observed from the drone and a field visit, rice fields immediately border the gallery forest throughout. There are some interesting geomorphological features such as ox-bows with pools of less muddy waters and with a denser gallery forest.

Despite the timing (afternoon) and duration (only 3 hours) a total of 32 bird species was recorded along the river stretch, many belonging to species depending on primary and secondary forest. Most birds were of no conservation concern, but have their value as members of riparian bird communities that are under great pressure of the present development of river courses. In particular, the Pied Kingfisher *Ceryle rudis*, near-threatened in Cambodia, is rare and at risk in neighbouring countries, and the small population and a partial decline in Cambodia may warrant uplisting to nationally Threatened (Goes 2013).

Biodiversity value. Overall, this would seem to be reasonable to good, but not outstanding as true forest seems lacking. If tree-felling could be halted it is probable that a denser and true gallery forest would recover within 1-2 decades, though a high bamboo cover is likely to remain for some time to come. In terms of hydrology it is probably important to maintain a flood pulse as this deters farmers from cultivating the sloping banks that now have the gallery scrub.

Photo: vegetation along the banks of the Prek Chhlong river is dominated by bamboo

Photo: drone image of lower Prek Chhlong river showing the 'gallery forest' consisting of groves of bamboo with scattered trees

4. & 5. Lower Stung Sen & Chhnok Tru (27 June 2019)

The lower course of the Stung Sen river (IBA 19) has been nominated as a Ramsar wetland of international importance since about 2001, although it was not officially designed until late 2018 (according to the official plaque in the Ramsar site office). The Ramsar site consists largely of swamp forest and scrub on the lower west bank of the Stung Sen and runs inland up to include much of the left bank wetlands (see map). As observed from the river, there are still many taller trees but not a contiguous closed canopy expected in a forest, as there are clearings and patches of scrub. Housing and fishing huts occur, and beyond these patches cleared for cultivation, mainly of vegetables and maize.

According to locals, fires were widespread in the area and during the present survey smaller fires could be seen occurring along the banks of the Stung Sen at various points, albeit mainly (just) outside the reserve. There were major fires during 2015, which was an El Niño year, although according to Ramsar site staff the reserve was not that much affected.

Water levels are low, and much of the bank lies 3-5(-6)m above the present water level in the river, although flood marks indicate that water levels rise to at least 2m above the level of the banks, and according to locals anywhere from just above the bank to 3-3.5m above the bank. The river never falls dry although levels can be low, such as at present.

The forest is varied in number of species, although not many are in flower or fruit, making identification difficult. Species observed include *Barringtonia acutangula, Gmelina asiatica*, *Macaranga* sp., *Mallotus* sp., *Phyllanthus reticulatus* and bamboos. The exotic *Mimosa pigra* shrub is common, especially along the river and in past clearings. Banks are often lined with reed *Phragmites karka* and patches of floating waterhyacinth *Eichhornia crassipes.* Vines are also common, and rattans (*Calamus* sp.) are seen from along the river, along with *Cardiospermum halicacabum, Combretum trifoliatum, Connarus* sp., *Gymnopetalum chinense* and *Passiflora foetida.* Typical riparian species such as *Lagerstroemia speciosa* and *Crateva nurvala* are absent.

It was not possible to have sufficient access to either IBA, and numbers of species seen are consequently very low, 8 and 19 for Chhnuk Tru and Stung Sen respectively. Wetland specialists as globally (and nationally) Near-threatened Grey-headed Fish Eagle *Ichthyophaga ichthyaetus*, and Stork-billed Kingfisher *Pelargopsis capensis* were seen only once, but other waterbirds, such as storks, cormorants, and herons were not seen at all during the survey, though reported by staff at the Head Quarters of the Stung Sen Ramsar Site as locally breeding in the dry season. Riparian forest, where present, was very much disturbed, with no birds dependent on good forest observed.

The Chhnok Tru (aka Snoc Trou) site (IBA 18) is located to the southwest of the Stung Sen Ramsar site, closer to the open waters of the Tonle Sap. It is also much lower-lying and only just (20-30 cm) above present water level to a maximum of about 1m above present water level. Trees are absent, and vegetation is dominated by only a few species, including reeds *Phragmites karka,* the sedge *Actinoscirpus grossus,* the shrub *Sesbania javanica* (which can also form floating mats), floating waterhyacinth *Eichhornia crassipes* and submerged-rooted *Hydrilla verticillata.* Few birds were seen, but our boat operator showed a film of large groups of (hundreds of) egret in the area taken several months ago.

Photo: trees at Stung Sen Ramsar site are important for the Near-threatened grey-headed fish eagle

Map of Stung Sen Ramsar site

Photo: drone image of the lower Stung Sen river showing a limited area of flooded forest and ongoing burning and cultivation of the higher banks

6. Boeng Chhmar (28 June 2019)

Boeng Chhmar is a 39,000 ha reserve that has been designated as a Ramsar wetland of international importance, and straddles Siem Reap and Kompong Thom provinces. It consists of a mix of flooded forest and shallow lake wetlands. Access is an issue, as it is not easy to reach from either Siem Reap or Kompong Thom, and the most convenient way of accessing the area is from Pursat province and crossing the lake. At Krakor town (located just 30km before Pursat, coming from Chhnok Tru), one takes the road leading to Kompong Loeung village, located on the shore of Tonle Sap. From there it is about 20km by boat to the access point for Boeng Chhmar, at Peam Bang village (see drone image photo, below).

At the time of the survey water levels were still low, and although they had risen by about 30-40 cm since it's lowest point, the flooded forest was still dry throughout and the main river channel via which one can normally access the reserve was also very shallow and poorly accessible. After travelling for two hours little progress had been made due to the presence of large, dense mats of floating waterhyacinth and a large number of discarded nets snagging in the boat's propeller. In the end the survey team made it to about 2km from the border of the reserve as decided we would have to do the rest by drone instead and survey the shallow lake wetland at the furthest point, plus the flooded forest at Peam Bang instead as this is likely to be very similar to Boeng Chhmar.

The open wetland vegetation consists of free-floating species such as *Azolla pinnata* and waterhyacinth *Eichhornia crassipes* (see photo), with patches of waterlilies *Nymphaea nouchali* and submerged-rooted *Hydrilla vericillata.* Other common species are emergent *Sesbania javanica* shrubs (that sometimes float as well), with *Ipomoea aquatica, Melochia corchorifolia, Ludwigia hyssopifolia* and *Polygonum pulchrum,* plus grasses such as wild rice *Leersia hexandra, Echinochloa stagnina* and Asian reed *Phragmites karka,* and the floating herb *Neptunia natans.* The flooded forest at Peam Bang is dominated by a small number of woody species, especially *Diospyros* cf. *bejaudii* (tol), *Barringtonia acutangula* (*riang)* and the woody climber *Dalbergia entadioides* (kom preang). Other woody species include *Terminalia cambodiana, Phyllanthus reticulatus,* the sub-shrub *Morinda persicifolia*, plus two unidentified trees pim-prei and arw-kroper. Other climbers include *Cardiospermum halicacabum* and *Passiflora foetida.*

The globally threatened species Spot-billed Pelican *Pelecanus philippensis*, Lesser *Leptoptilos javanicus* and Greater Adjutant *Leptoptilos dubius* and Finfoot *Heliopais personata* as species have strongholds in the Boeung Chhmar marshes as well as concentrations of several other waterbird species (BirdLife International 2013), of which the Asian Openbill *Anastomus oscitans* is one. This stork species has been declining in Cambodia during the 1980s and 1990s and recovered since it received protection from human persecution. The present, brief survey showed good numbers of this stork (45+ birds), the globally Near-threatened Oriental Darter (15+ birds) and a number of other waterbirds, such as two species of cormorant, but its short duration explains the small overall number of species.

Eco-hydrology. The Boeng Chhmar lake becomes part of Tonle Sap lake when waters rise in the wet season, and according to locals by August the flooded forest should be flooded and the lakes linked.

Photo of wetland vegetation just south of Boeng Chhmar

Photo: drone image of Peam Bang village, with flooded forests

7. Ang Tropeang Thmor (1 July 2019)

Ang Tropeang Thmor (ATT) is an IBA (IBA 1) designated as the ATT Sarus Crane Conservation Area. Its total area is 12,659 ha and it consists of an artificial lake or shallow reservoir, located 70 km to the north-west of Tonle Sap Lake. Access is from Preah Net Preah, about 70km west of Siem Reap on Highway No. 6, and heading 16k north on the road to Srah Chik.

Hydrology. During the Angkorian period, from the 10th to the 13th century AD, a major causeway was constructed through the area, which led to increased water accumulation to the north, mainly of surface runoff. In 1976, an 11 km stretch of this causeway was converted into a dam and a 9 km dyke constructed perpendicular to it. However, the planned irrigation reservoir was never completed, and until recently only the south-eastern corner of the reservoir remains inundated during the dry season, although, at the height of the wet season most of the area is inundated. In March-April 2019 it was almost completely dry, and this has led to MOWRAM's concerns and the perception that an intervention may be required. From 2015-2018, ADB (loan 3125-CAM) and AusAID (grant 0281-CAM) financed the Tropaing-Thmor Irrigation System Construction out of MOWRAM's Flood Damage Emergency Reconstruction Project – additional funding. Under this, new sluice gates and spillways were constructed, and the dike and dam received new embankment lining. In 2015, Chinese funding was provided to partly construct an 8m wide concrete-lined canal taking water from the existing large canals leading from the three reservoirs (153, 158 and 258 million m^3, respectively). on the Stung Serey river. However, this Chinese canal appears unfinished as it peters out in the northern part of the reserve. Recently, MOWRAM has undertaken excavation of an extension, but it would prefer to re-do the whole canal, make this 12m wide and lead it right up to the reservoir area. During the dry season the reservoir holds 60 Mm^3 and plans are to raise this to 80 Mm^3; in the wet season it holds about 150-180 Mm^3.

The area largely consists of artificial habitats, including open waters/shallow lake, with submerged *Hydrilla verticillata* and submerged-floating *Nymphaea nouchali, Nymphoides indica* and *Nelumbo nucifera.* These species also occur in the channels, pools and ponds that dot the landscape, often arising due to borrow pits for dike and road construction. In addition, there are vast grasslands with many true grasses (*Echinochloa stagnina, Eragrostis uniloides*) but also various sedges (*Cyperus digitatus, C. imbricatus, Fimbristylis miliacea*), and large areas of rice fields. The description of the IBA states that the area has been 'extensively converted to wet rice agriculture, but this land has only been irregularly used for a number of years'. That no longer seems to be the case, and by far the largest part of the northern half has been converted to rice fields that achieve 2-3 crops per year. The IBA description further mentions that in 'the extreme north of the IBA, the habitat grades into open deciduous dipterocarp forest' – this no longer can be regarded as forest, as only a scattered sprinkling of trees remain (local names: kokah, koko, sedal and toyung), with a total cover less than 1%. There were signs of continued pollarding of trees, but also ring-barking and charcoal making. Botanically the most interesting are the shrub habitats that line canals, as these are rich in species and include *Holarrhena curtisii, Leea indica Memecylon* sp. and *Olax obtusa*.

According to the BirdLife website (http://datazone.birdlife.org/site/results?cty=36), the IBA is the most important non-breeding site for Sarus Crane *Antigone (Grus) antigone* in Cambodia and regularly supports a significant proportion of the global population of the eastern subspecies *A. a. sharpii*. In addition to Sarus Crane, the IBA regularly supports over 1% of the Asian biogeographic population of Lesser Whistling-duck *Dendrocygna javanica*, Comb Duck *Sarkidiornis melanotus*, Asian Openbill *Anastomus oscitans* and Black-necked Stork Ephippiorhynchus asiaticus. Furthermore, a large number of globally threatened and near-threatened species have been recorded at the IBA, including Bengal Florican *Houbaropsis bengalensis* (which probably breeds), White-shouldered Ibis *Pseudibis davisoni* and Greater Adjutant *Leptoptilos dubius*. Additionally, the globally threatened Pallas's Fish Eagle *Haliaeetus leucoryphus* has been recorded at the site as a vagrant.

During the survey 20 bird species were observed. We arrived at the south-eastern corner of the reservoir in the southern part of the IBA around midday; only very few waterbirds were seen (cormorants), and a few stilts along the margins; we followed the road along a canal. The whole area is marshy with low vegetation, and some sparsely distributed trees, grazed by water buffaloes. Several dozens of Asian Openbill stork were observed inside the area, but hundreds in the surrounding grasslands. An Asian Pied Kingfisher was also observed.

Photo: grasslands with scattered trees and rice fields at the northern end of the IBA wetland

Photo: drone image of the outlet of the reservoir, without any flow at the time of the survey

8. Preah Net Preah / Kra Lanh / Pourk (1 July 2019)

The IBA (#02, 69,570ha) wetland is located at the north-western part of the Tonle Sap floodplain and was entered at two locations: at the western end, coming from Preah Net(r) Preah, and the second point at Kralanh, in the middle of this elongated site. According to the BirdLife IBA website, the area is comprised of seasonally inundated grassland and scrub. This includes, in the south-east of the IBA, an area reportedly dominated by Wild Rice *Oryza rufipogon*, in mosaic with tall scrub and flooded forest.

The Preah Net Preah end of the wetland was found to be largely converted to rice fields with a few scattered trees remaining, although even those were still being cleared, judging from ring-barked trees and carts of timber leaving the area. Grazing is also common. There are still areas of short grassland that are suitable habitat for the highly endangered Bengal florican – these are characterized by a range of true grasses, including *Chloris barbata, Echinochloa crus-galli, Panicum scrobiculatum, Digitaria,* a number of sedges including *Fimbristylis miliacea* and *Cyperus procerus* and herbs such as *Ageratum conyzoides.* Trees and shrubs include *Antidesma ghaesembilla, Calotropis gigantea, Jatropha gossypiifolia* and *Muntingia calabura;* note that the latter two are introduced exotics. Pools and ponds include waterlilies *Nymphaea nouchali* and lotus *Nelumbo nucifera.*

The central Kralanh part of the wetland also is a varied landscape with rice fields and short grasslands, with tree and shrub-lined waterways and dotted with many irrigation ponds. The main river has stopped flowing and consists of a series of ponds (see drone image, below). Grazing – mainly of cattle – is more common than at the Preah Net Preah. Trees and shrubs include *Acacia auriculiformis, Antidesma ghaesembilla, Glochidion obscurum, Gmelina asiatica, Mallotus* sp., *Mimosa pigra* and *Morinda persicifolia,* regularly bearing climbers such as *Merremia hederacea* and *Passiflora foetida.* Herbaceous species include *Ageratum conyzoides, Crotalaria striata, Heliotropium* *indicum* and *Polygonum pulchrum,* while grasslands include the same grass species assemblage as at Preah Net Preah.

Photo: short grasslands and pools with waterlilies and lotus

Photo: drone image of the area south of Kralanh

Photo: grasslands with tree'd vegetation lining the waterway in the distance

According to the BirdLife website (http://datazone.birdlife.org/site/results?cty=36), the IBA is an important dry season breeding area for Bengal Florican *Houbaropsis bengalensis*, which occurs in areas of seasonally inundated grassland throughout. In addition, several other globally threatened and near-threatened species have been seasonally recorded at the IBA in small numbers, including Sarus Crane *Antigone (Grus) antigone*, Black-necked Stork *Ephippiorhynchus asiaticus* and Spot-billed Pelican *Pelecanus philippensis.*

During the survey of 1 July 2019 29 bird species were observed, with the general impression as IBA 16, extensive, swampy grasslands.

9. Stung/Chi Kreng/Kampong Svay (2 July 2019)

The 53,543ha IBA wetland (listed by BirdLife as IBA 16) is described on the IBA website as "one of the largest remnant tracts of contiguous semi-natural grassland within the Tonle Sap inundation zone. Note that the Stung Chi kreng Bengal Florican Conservation Area (BFCA) of 7,448 ha is included in this IBA. The vegetation of the IBA is characterised by a mosaic of tall and short grass swards, mixed with some patchy, dense scrub, limited deep water rice fields and small, scattered wetlands. Wet season rice is cultivated along the IBA's northern fringe adjacent to RN6." During the present survey it was confirmed that the area to the north of the IBA wetland has largely been converted to rice fields that are either rainfed, receding rice or are irrigated from on-farm water storage ponds. The IBA itself largely consists of mixed grasslands that are annually flooded up to a level of about 2m, along with patches of shrubs and small trees, and some small pools. There is lots of evidence of burning, with patches of burnt grass visible throughout, and a significant amount of cattle and water buffalo grazing (150 observed). There is no evidence of any irrigation / drainage works in the area, nor are any planned by MOWRAM as the area is officially listed as a protected zone.

The grassland is highly varied in species composition and includes various sedges (*Cyperus cephalotes, Fimbristylis acuminata, F. tomentosa*), grasses (*Eleocharis ochrostachys, Eragrostis unioloides, Panicum repens, Rottboellia exaltata*) and a mix of herbs (e.g. *Decaschistia parviflora*, *Grangea maderaspatana, Murdannia macrocarpa*). Shrubs and tree(-lets) include *Antidesma ghaesembilla, Borassus flabellifer, Glochidion obscurum, Gmelina asiatica, Holarrhena curtisii* and *Hiptage triacantha.* Climbers include rattans *Calamus palustris, Calamus salicifolius, Cassytha filiformis* and *Uvaria rufa.* The grassland is likely a fire climax, although shrubs and trees may also be suppressed by browsing livestock, and the climax is likely a woody vegetation. From that perspective, the ongoing grazing and moderate burning regime seems beneficial as it maintains this open grassland habitat. The presence of clumps of rattan in the grass-landscape are also an indication that woody vegetation is the climax in this area.

According to the BirdLife website (http://datazone.birdlife.org/site/results?cty=36), this seasonally inundated grassland supports the highest densities of breeding Bengal Floricans *Houbaropsis bengalensis* found in Cambodia to date, and the IBA supports a highly significant population of this species. The small pools are used as feeding areas by a number of large waterbirds dispersing from the Tonle Sap breeding colonies, including Painted Stork *Mycteria leucocephala* and Lesser Adjutant *Leptoptilos javanicus*. The IBA also supports a substantial wintering population of Manchurian Reed Warbler *Acrocephalus tangorum*, as well as small numbers of wintering Greater Spotted Eagle *Aquila clanga*. During the 2 July 2019 survey, 15 bird species were observed. We entered an extensive grassland from the main road, where we had a good view of the area; though not very bird-rich, a Bengal Florican was observed (one of 40 nesting pairs in the area this year, according to WCS), several pairs of pratincoles (breeding according to our WCS guide), numerous Zitting Cisticolas, and a few bushlarks.

Photo: mixed, short grassland, with patches of shrub are characteristic of this wetland

Photo: drone image of grassland with patches of scrub, and a large pool with buffalo in foreground

10. **Stung/Prasat Balang** (2 July 2019)

The centre of the IBA (#17) was surveyed: apparent is that a lot of conversion has occurred since the IBA assessments of 2009. Most of the area is now under agriculture, with rice fields and cashew plantations dominating, although some cattle and buffalo rearing also occurs. Remnant trees occur but clearing of forest has taken place on a massive scale, and almost half of the households along the main road leading into the IBA have stacks of timber outside, presumably for sale. Seasonally inundated grassland still occurs given the presence of livestock. To the north of the IBA forest patches still occur (and not only remnant trees), but also there the clearing for conversion to cashew plantation is rapidly occurring with many new plantations seen and clearing/levelling with bulldozer ongoing. Soils are sandy (often pure white sands) and very poor, and none of the cashews were seen in flower or fruit (seasonal here?); dead trees were also seen, so an assessment of viability would be welcome. No water infrastructure was observed in the area apart from on-farm ponds and small channels. To the south of the IBA, though, two concrete lined irrigation channels were observed running east to west. These forest remnants include many tree species, including *Borassus flabellifer, Grewia asiatica, Lagerstroemia calyculata, Myristica* sp., *Shorea siamensis* and *Sindora siamensis* and shrubs such as *Aralia* sp., *Ixora chinensis, Licuala spinosa, Melastoma* sp., *Memecylon* sp., *Phyllanthus taxodiifolius* and *Tabernaemontana divaricata,* and a range of climbers such as *Caesalpinia* sp., *Calamus salicifolius, Cassytha filiformis, Gymnopetalum scabrum, Smilax lanceifolia, Tetracera scandens* and *Uvaria rufa.*

Photo: patches of remnant forest interspersed with grassland; tree to the left is a dipterocarp

Photo: drone image taken near the centre of the IBA wetland, showing a park-like landscape with remnant trees, grasslands and fields

11. Veal Srongae (3 July 2019)

Veal Srongae is a 5,873ha wetland (listed as IBA 20) consisting of seasonally flooded grasslands surrounded by tall, dense scrub and swamp forest, with seasonal pools and lakes. Beyond this the area is dominated by rice fields, with some seasonally flooded scrub and patches of grassland used for grazing cattle and buffalo. At the time of the survey the area proper was inaccessible, as roads were extremely muddy, while at the same time water levels in canals and streams were too low for using boats. Nevertheless, vegetation/habitats and birds were surveyed in an adjacent area about 5 km from the north-eastern boundary of the IBA, and it is assumed that there will be strong similarities in habitat and species, albeit with differences in land use (-intensities). During the present survey the area is exposed and dry, but during the wet season it is entirely flooded, presumably by up to 2-3m of water, and in total for up to 5-6 months.

Large wooded areas (e.g. of more than 1-2 ha) were not seen, only smaller patches, usually strung out along canals and around pools. Larger trees include *Ardisia ghaesembilla* (don-kip-kraem) and *Mitragyna diversifolia,* and shrubs include *Abelmoschus moschatus, Clerodendrum infortunatum, Desmodium* sp., *Glochidion obscurum, Gmelina asiatica, Hymenocardia punctata, Macaranga* sp., *Mimosa pigra* and *Morinda persicifolia.* The trees and shrubs are often festooned with climbers that include *Cayratia trifoliata, Passiflora foetida, Smilax lanceifolia, Terminalia cambodiana* and *Tetracera scandens.* True short grasslands were not observed, only tall grassland dominated by *Saccharum spontaneum,* along with *Phragmites karka* and some occasional climbers and *Mimosa pigra.* Areas previously cultivated with rice were recolonized by short grassland species such as *Echinochloa crus-galli, Ludwigia hyssopifolia, Melochia corchorifolia* and *Polygonum pulchrum.*

According to the BirdLife website (http://datazone.birdlife.org/site/results?cty=36), the southern part of the IBA is situated within Tonle Sap Multiple Use Area, designated under the 1993 Royal Decree on Protected Areas, and Tonle Sap Biosphere Reserve. During the dry season, the IBA supports a breeding population of Bengal Florican *Houbaropsis bengalensis*. Also, during the dry season, the IBA is visited by a number of non-breeding large waterbirds, including Painted Stork *Mycteria leucocephala*, Asian Openbill *Anastomus oscitans*, Lesser Adjutant *Leptoptilos javanicus* and Greater Adjutant *L. dubius*. In addition, White-shouldered Ibis *Pseudibis davisoni* has been recorded at the IBA, although the precise status of this species is unclear. During the 3 July 2019 survey, 39 bird species were observed. Fair numbers of Yellow Bitterns were observed, possibly breeding.

Photo: short grassland on former rice fields, now grazed by cattle, with tall Saccharum*-dominated vegetation in background along with scattered trees*

Photo: drone image with grasslands, fields where rice has been harvested, and patches of scrubland

12. Stung Sen / Santuk / Baray

The Stung Sen/Santuk/Baray IBA (IBA # 21) is a 109,000ha wetland that runs approximately from south-west of Kampong Thom to south-west of Barang township along highway no. 6. The Baray-Chong Doung BFCA of 9,883ha is included in this IBA. According to the BirdLife IBA description, the wetland is "one of the largest remnant tracts of seasonally inundated grassland within the Tonle Sap floodplain, bordered by deep water rice on its eastern and northern fringes. This habitat is mixed with scattered, but often extensive, areas of dense scrub, lotus swamps, sedge beds, and, in the dry season, numerous small to medium-sized ponds." At the time of the survey the area proper was inaccessible due to poor condition of the roads (deep mud) and low water levels in the canals not permitting travel by boat. A survey was carried out at the closest point (8 km from the centre of the IBA), where most of the wetland has been converted to rice fields but where elongated patches of shrubs still occur, along with grassy patches in between. Shrub species include *Gmelina asiatica, Mimosa pigra, Phyllanthus* sp., *Sesbania javanica* and *Dalbergia* sp., along with several climbers including *Passiflora foetida* and a white *Convolvulaceae.* The patches of grasslands include sedges such as *Fimbristylis* and *Cyperus* spp., true grasses such as *Echinochloa crus-galli, Eragrostis unioloides* and *Miscanthus sinensis,* along with herbs such as *Ageratum conyzoides, Ludwigia hyssopifolia, Mimosa pudica* and *Polygonum pulchrum.*

Photo: the invasive exotic Mimosa pigra is common, especially along the canal and edges of ponds.

According to the BirdLife website (http://datazone.birdlife.org/site/results?cty=36), the whole IBA is inundated at the height of the wet season (August-October). Parts of the IBA lie within Tonle Sap Multiple Use Area, designated under the 1993 Royal Decree on Protected Areas, and Tonle Sap Biosphere Reserve. The IBA is a very important breeding site for Bengal Florican *Houbaropsis bengalensis* during the dry season (December to May). In the wet season (May to July), a number of non-breeding waterbirds visit the site, including adjutants *Leptoptilos* spp., Painted Stork *Mycteria leucocephala* and Asian Openbill *Anastomus oscitans*. In addition, the IBA supports a substantial wintering population of Manchurian Reed Warbler *Acrocephalus tangorum*, as well as small numbers of wintering Greater Spotted and Imperial Eagles *Aquila clanga* and *A. heliaca*. In addition, the largest flock of White-shouldered Ibis *Pseudibis davisoni* recorded in Cambodia in recent decades was observed here in 1999. The newly described Near-threatened Cambodian Tailorbird *Orthotomus chaktomuk* has been found here (Mahood et al. 2013).

During the 3 July 2019 survey, 20 bird species were observed. The survey involved walking along a trail along the canal running through wet rice fields in the northwest, low wet grass field in the southeast, fringed by shrubbery along most of the trail. Oriental pratincoles were common and are possibly breeding in the area; a few marsh birds such as 8 Cotton Pygmy-geese were observed.

Appendix B. Plant species recorded during surveys in Tonle Sap & Mekong Delta RBGs during 24 June – 3 July 2019

					Site 01	Site 02	Site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
	Species	**Family**	**Lifeform**	**Common name**	**Lapouv**	**Bassac marshes**	**Prek Chhlong**	**Lower Stung Sen**	**Snoc Trou**	**Boeng Chhmar**	**Ang Tropeang Thmor**	**Preah-net-Preah**	**Stung chi kreng**	**Stung Prasat Balang**	**Veal Srongae**	**Stung Sen**
1	*Abelmoschus esculentus*	Malvaceae	S	ochra/lady's fingers			+								+	
2	*Abelmoschus moschatus*	Malvaceae	S			+										
3	*Acacia auriculiformis*	Fabaceae	T	earleaf acacia	++							+				
4	*Actinoscirpus grossus*	Cyperaceae	H	sedge	+++				+++							
5	*Aganonerion polymorphum Pierre ex*	Apocynaceae	H	red flowered							+					
6	*Ageratum conyzoides*	Asteraceae	H				++					++		+		+
7	*Alternanthea sessilis*	Amaranthaceae	H									+				
8	*Amorphophallus* sp.	Araceae	H	aroid (corpse lily)			++									
9	*Antidesma ghaesembilla*	Phyllanthaceae	T	don-kip-kraem								++	+		++	
10	*Antidesma montanum*	Phyllanthaceae	T				+									
11	*Aporosa octandra*	Phyllanthaceae	T									+				
12	*Aralia* sp.	Araliaceae	S											+		
13	*Azolla pinnata*	Salviniaceae	H	mosquito fern						+++						
14	*Barringtonia acutangula*	Lecythidaceae	T	Raing (Reang)		++	++	+++		+++						
15	*Borassus flabellifer*	Arecaceae	T	borassus palm	++								+	++		
16	*Calamus palustris*	Arecaceae	L	rattan									+			
17	*Calamus salicifolius*	Arecaceae	L	rattan									++	+		
18	*Calotropis gigantea*	Apocynaceae	S									+				
19	*Cardiospermum halicacabum*	Sapindaceae	L		++	+++	+	++								
15	*Cassia javanica subsp. agnes (de Wit)*	Fabaceae	S											+		
20	*Cassytha filiformis*	Lauraceae	L				+							+		
21	*Cayratia trifoliata*	Vitaceae	L	wilde grape			+	+					+		++	
22	*Ceratopteris thalictroides*	Polypodaceae	H	water sprite	++											
23	*Chloris barbata*	Poaceae	H									+				
24	*Clerodendrum infortunatum*	Lamiaceae	S												+	
25	*Colocasia esculenta*	Araceae	H								++					
26	*Combretum trifoliatum*	Combretaceae	L			+		++								
27	*Commelia benghalensis*	Commelinaceae	H												+	
28	*Connarus* sp.	Connaraceae	L			++	++	++								
29	*Corchorus cf. aestuans L. Malvaceae*	Malvaceae	T				++	++								
30	*Costus* sp.	Costaceae	H											+		

	Species	Family	Lifeform	Common name	Site 01 Lapouv	Site 02 Bassac marshes	Site 03 Prek Chhlong	site 04 Lower Stung Sen	site 05 Snoc Trou	site 06 Boeng Chhmar	site 07 Ang Tropeang Thmor	site 08 Preah-net-Preah	site 09 Stung chi kreng	site 10 Stung Prasat Balang	site 11 Veal Srongae	site 12 Stung Sen
31	*Crateva nurvala*	Capparidaceae	T				++									
32	*Crotalaria striata*	Fabaceae	H	changkrang svar								+				
33	*Croton caudatus*	Euphorbiaceae	T			+										
34	*Cyperus cephalotes*	Cyperaceae	H										+			
35	*Cyperus digitatus* Roxb.	Cyperaceae	H		++	++					++					
36	*Cyperus imbricatus* Retz.	Cyperaceae	H		++						+					
37	*Cyperus procerus* Rottb.	Cyperaceae	H		+							+				
38	*Cyperus sphaecelatus*	Cyperaceae	H													+
39	*Dalbergia cambodiana*	Fabaceae	L			+										
40	*Dalbergia entadioides*	Fabaceae	L	kom preang				++		+++						+
41	*Dalbergia sp.?*	Fabaceae	L											+		
42	*Decaschistia parviflora*	Malvaceae	H	tolok									++			
43	*Desmodium cf. baccatum (Schindl.) S*	Fabaceae	H												+	
44	*Diospyros cambodiana (* cf *bejaudii)*	Ebenaceae	T	tol (Ptol)						+++						
45	*Eclipta alba*	Asteraceae	H		++	++									+	+
46	*Echinochlora crus-galli*	Poaceae	H									+			++	++
47	*Echinochloa stagnina*	Poaceae	H	hippo grass	+	+	+				++					
48	*Eichhornia crassipes*	Pontederiaceae	H	water hyacinth	+++		+	++	+++	+++						
49	*Eleocharis ochrostachys* Steud.	Cyperaceae	H										+			
50	*Eragrostis unioloides* (Retz.) Nees ex	Poaceae	H										+			+
51	*Eriochloa polystachya* H.B.K.	Poaceae	H	Carib grass		+					+	+				
52	*Eucalyptus camaldulensis*	Myrtaceae	T	river gum	+++											
53	*Ficus* sp. 1	Moraceae	T	fig	++											
54	*Ficus* sp. 2	Moraceae	T	fig			+									
55	*Fimbristylis acuminata* Vahl.	Cyperaceae	H										+			
56	*Fimbristylis dichotoma* (L.) Vahl	Cyperaceae	H													+
57	*Fimbristylis miliacea*	Cyperaceae	H		+++						++	+++				
58	*Fimbristylis tomentosa* Vahl.	Cyperaceae	H										+			
59	*Glochidion obscurum*	Phyllanthaceae	S			+						+	+		++	
60	*Gmelina asiatica*	Lamiaceae	S					+				++	++		+	

	Species	Family	Lifeform	Common name	Site 01 Lapouv	Site 02 Bassac marshes	Site 03 Prek Chhlong	site 04 Lower Stung Sen	site 05 Snoc Trou	site 06 Boeng Chhmar	site 07 Ang Tropeang Thmor	site 08 Preah-net-Preah	site 09 Stung chi kreng	site 10 Stung Prasat Balang	site 11 Veal Srongae	site 12 Stung Sen
61	*Gossypium herbaceum*	Malvaceae	S				+					++				
62	*Grangea maderaspatana*	Asteraceae	H		++	++							+			
63	*Grewia asiatica*	Malvaceae	S									+		+		
64	*Gymnopetalum chinense*	Cucurbitaceae	L		++		+	++			+					
65	*Gymnopetalum scabrum*	Cucurbitaceae	L								+			+		
66	*Helicteres hirsuta*	Malvaceae	S									+		+		
67	*Heliotropium indicum*	Boraginaceae	H		++		+	+				+				
68	*Hiptage triacantha* Pierre	Malpighiaceae	S	possible new species		+							+			
69	*Holarrhena curtisii*	Apocynaceae	S								++		+			
70	*Homonoia riparia*	Euphorbiaceae	S				++									
71	*Hydrilla verticillata*	Hydrocharitaceae	H						++	++						+
72	*Hymenocardia punctata*	Phyllanthaceae	T								++				+	
73	*Ipomoea aquatica*	Convolvulaceae	H	water spinach	++	++				+						
74	*Ixora chinensis*	Rubiaceae	S											+		
75	*Jatropha gossypiifolia*	Euphorbiaceae	S								++	+				
76	*Lagerstroemia calyculata*	Lythraceae	T											+		
77	*Leea indica*	Leeaceae	S				++				++					
78	*Leersia hexandra*	Poaceae	H	wild rice						++						
79	*Leptochloa chinensis* (L.) Nees	Poaceae	H									+				
80	*Licuala spinosa*	Arecaceae	S	Phaao										+		
81	*Ludwigia adscendans*	Onagraceae	H	water primrose	+	+										
82	*Ludwigia hyssopifolia*	Onagraceae	H	seedbox	+++	++				+					++	+
83	*Mallotus* sp.	Euphorbiaceae	T				+	+								
84	*Melastoma malabathricum L. subsp.*	Melastomataceae	S											+		
85	*Melastoma saigonense (Kuntze) Mer*	Melastomataceae	S											+		
86	*Melochia corchorifolia*	Malvaceae	H			++		+		+++					++	+
87	*Memeclyon edule Roxb. var. ovata C.*	Melastomataceae	S								++			++		
88	*Memeclyon edule Roxb. var. scutella*	Melastomataceae	S											+		
89	*Merremia hederacea*	Convolvulaceae	L									+				
90	*Mimosa pigra*	Fabaceae	S	Giant mimosa	+++		+++	+++				++			+++	+++

	Species	Family	Lifeform	Common name	Site 01 Lapouv	Site 02 Bassac marshes	Site 03 Prek Chhlong	site 04 Lower Stung Sen	site 05 Snoc Trou	site 06 Boeng Chhmar	site 07 Ang Tropeang Thmor	site 08 Preah-net-Preah	site 09 Stung chi kreng	site 10 Stung Prasat Balang	site 11 Veal Srongae	site 12 Stung Sen
91	*Mimosa pudica*	Fabaceae	H	Sensitive mimosa												++
92	*Miscanthus chinensis*	Poaceae	H													+
93	*Mitragyna diversifolia*	Rubiaceae	T	kratom											++	
94	*Monochoria hastata*	Pontederiaceae	H		+											
95	*Morinda persicifolia*	Rubiaceae	S	Nhor (Nhor tuk)	++	++		++		+++						
96	*Muntingia calabura*	Muntingiaceae	T									+				
97	*Murdannia macrocarpa*	Commelinaceae	H										++			
98	*Myristica* sp.	Myristicaceae	T											+		
99	*Nelumbo nucifera*	Nelumbonaceae	H								++	++				
100	*Neptunia natans*	Fabaceae (Mim.)	S							+						
101	*Nymphaea nouchali*	Nymphaeaceae	H	waterlilies						++		++				
102	*Nymphoides indica*	Menyanthaceae	H								++					
103	*Olax obtusa*	Olacaceae	S								+					
104	*Operculina petaloidea* (Choisy) Oost	Convolvulaceae	L													+
105	*Parkia sumatrana* Miq	Fabaceae	T				+									
106	*Passiflora foetida*	Passifloraceae	L	stinking passionfruit	++	+		++		+		++			++	+
107	*Panicum repens* L.	Poaceae	H	torpedo grass									+			
108	*Panicum scrobiculatum*	Poaceae	H									+				
109	*Phragmites karka*	Poaceae	H	asian wild reed	+++	++	+++	+++	+++	++						
110	*Phyllanthus reticulatus*	Phyllanthaceae	S		+		++	++		+						
111	*Phyllanthus taxodiifolius*	Phyllanthaceae	S								++			+		
112	*Phyllanthus* sp.	Phyllanthaceae	S													+
113	*Piper* sp.	Piperaceae	L	wild pepper			++									
114	*Polygonum pulchrum*	Polygonaceae	H		++	++	++			++		++			++	
115	*Polytrias amaura* (Buese) O.K.	Poaceae	H										+			
116	*P1300852/8*	Celastraceae	H	white flowered										+		
117	*Quassia harmandiana (Pierre) Nootel*	Simaroubaceae	T	plae kroh				+								
118	*Rhodomyrtus tomentosa* (Aiton) Has	Myrtaceae	S											+		
119	*Rottboellia exaltata*	Poaceae	H	Itchy grass		+							+			
120	*Saccharum spontaneum*	Poaceae	H	wild sugarcane	+++	+++	+++								+++	

	Species	Family	Lifeform	Common name	Site 01 **Lapouv**	Site 02 **Bassac marshes**	Site 03 **Prek Chhlong**	site 04 **Lower Stung Sen**	site 05 **Snoc Trou**	site 06 **Boeng Chhmar**	site 07 **Ang Tropeang Thmor**	site 08 **Preah-net-Preah**	site 09 **Stung chi kreng**	site 10 **Stung Prasat Balang**	site 11 **Veal Srongae**	site 12 **Stung Sen**
121	*Sesbania javanica*	Fabaceae	S			+			+++	+++						++
122	*Setaria pumila (Poir.) Roem. & Schult*	Poaceae	H									+				+
123	*Shorea siamensis*	Dipterocarpaceae	T											++		
124	*Sindora siamensis*	Fabaceae	T									+		++		
125	*Smilax lanceifolia*	Smilaceae	L											+	++	
126	*Tabernaemontana divaricata* (L.) R.B	Apocynaceae	T											+		
127	*Terminalia cambodiana*	Combretaceae	T	ta-ou		+				+					+	
128	*Tetracera scandens*	Dilleniaceae	L								++			+	++	
129	*Urena lobata*	Malvaceae	H												+	
130	*Uvaria rufa*	Annonaceae	L			+					+	+		+		
131	*Viburnum-like*	Adoxaceae	S											+		
132	*unidentified tree (2)*		T	pim-prei						+						
133	*unidentified tree (3)*		T	arw kroper						+						
134	*Bambusa* sp.		T				+++									
135	*white 'grape'(liana)*		L									+				
	Lifeforms: T= tree; S= shrub; L= liana; H= herb															

APPENDIX C-1 Bird species seen during the survey.

1, rare ; 2, occasional; 3, frequent; 4, common; 5, very common

			Lapouv	Bassac marshes	Prek Chhlong	Lower Stung Sen	Chhnok Tru	Boeung Chhmar	Ang Tropeang Thmor	Preah Net Preah	Stung Chi Kreng BFCA	Stung Prasat Balang	Veal Strongae	Stung Sen BFCA
Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Coturnix chinensis	Phasianidae	Blue-breasted Quail												2
Dendrocygna javanica	Anatidae	Lesser whistlingduck							2					
Nettapus coromandelianus	Anatidae	Cotton Pygmy-goose												3
Anas poecilorhyncha	Anatidae	Spot-billed Duck	3					2						
Dendrocopos macei	Picidae	Fulvous-breasted Woodpecker			2							2	2	
Picus vittatus	Picidae	Laced Woodpecker											2	

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Megalaima lineata	Megalaimidae	Lineated Barbet										2		
Coracias benghalensis	Coraciidae	Indian Roller		3		2						2		3
Eurystomus orientalis	Coraciidae	Dollarbird		2										2
Pelargopsis capensis	Alcedinidae	Stork-billed Kingfisher				2							3	
Halcyon smyrnensis	Alcedinidae	White-throated Kingfisher		2	4									
Todorhamphus chloris	Alcedinidae	Collared Kingfisher												
Ceryle rudis	Alcedinidae	Pied Kingfisher			2				2					
Merops orientalis	Meropidae	Green Bee-eater	4	3										
Merops philippinus	Meropidae	Blue-tailed Bee-eater					2			3			3	
Merops leschenaulti	Meropidae	Chestnut-headed Bee-eater			4	4								
Cacomantis merulinus	Cuculidae	Plaintive Cuckoo	3											3

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Surniculus lugubris	Cuculidae	Drongo Cuckoo						2						
Eudynamys scolopacea	Cuculidae	Asian Koel		2										
Centropus sinensis	Cuculidae	Greater Coucal	3	2	4	3		2		2		3	4	
Centropus bengalensis	Cuculidae	Lesser Coucal	3	3	3		3						3	
Collocalia fuciphaga	Apodidae	Edible-nest Swiftlet	3	3		4	4	2						
Cypsiurus balasiensis	Apodidae	Asian Palm Swift	4	3	3		4	3	3	3	3	3	4	4
Hemiprocne coronata	Hemiprocnidae	Crested Treeswift			2									
Columba livia	Columbidae	Rock Pigeon		2	3				3	3				
Spilopelia chinensis	Columbidae	Spotted Dove	3	3	4	3				3	2	3	4	4
Streptopelia tranquebarica	Columbidae	Red Collared Dove	3		3					3			3	3
Geopelia striata	Columbidae	Peaceful Dove	3	2	2	3				4		3		3
Treron vernans	Columbidae	Pink-necked Green Pigeon											3	

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Houbaropsis bengalensis	Otididae	Bengal Florican									3			
Amaurornis phoenicurus	Rallidae	White-breasted Waterhen											2	
Porpyrio porphyrio	Rallidae	Purple Swamphen							2	2				2
Himantopus himantopus	Recurvirostridae	Black-winged Stilt							3	2				
Vanellus indicus	Charadriidae	Red-wattled Lapwing	3	3					2					
Glareola maldivarum	Glareolidae	Oriental Pratincole	4	3					3	2	4			4
Elanus caeruleus	Accipitridae	Black-shouldered Kite	2	3	2					2			2	2
Ichthyophaga ichthyaetus	Accipitridae	Grey-headed Fish Eagle				2								
Tachybaptus ruficollis	Podicipedidae	Little Grebe		2										
Anhinga melanogaster	Anhingidae	Darter						3						
Phalacrocorax niger	Phalacrocoracidae	Little Cormorant		2				3	3				3	3

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Phalacrocorax fuscicollis	Phalacrocoracidae	Indian Cormorant	4					3	3					
Egretta garzetta	Ardeidae	Little Egret	3						3					
Ardea purpurea	Ardeidae	Purple Heron	3											
Casmerodius [Ardea] alba	Ardeidae	Great Egret						3	3					
Bubulcus ibis	Ardeidae	Cattle Egret		3					2					
Ixobrychus sinensis	Ardeidae	Yellow Bittern							2				4	
Ixobrychus cinnamomeus	Ardeidae	Cinnamon Bittern	3				2						2	
Dupetor flavicollis	Ardeidae	Black Bittern						2					2	
Mycteria leucocephala	Ciconiidae	Painted Stork	4											
Anastomus oscitans	Ciconiidae	Asian Openbill						4	3	4			3	
Leptoptilos javanicus	Ciconiidae	Lesser Adjutant											2	
Pitta moluccensis	Pittidae	Blue-winged Pitta			4								3	

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Gerygone sulphurea	Acanthizidae	Golden-bellied Gerygone	2	3				2						
Crypsirhina temia	Corvidae	Racket-tailed Treepie		3		3						3	3	
Corvus macrorhynchos	Corvidae	Large-billed Crow				3	3	3	4		2		3	3
Rhipidura javanica	Rhipiduridae	Pied Fantail	3	3	4								3	
Dicrurus hottentottus	Dicruridae	Spangled Drongo			2									
Dicrurus paradiseus	Dicruridae	Greater Racket-tailed Drongo			2							2		
Hypothymis azurea	Monarchidae	Black-naped Monarch											2	
Aegithina tiphia	Aegithinidae	Common Iora		3	4	2				3		2	3	
Cyornis tickelliae	Muscicapidae	Tickell's Blue Flycatcher			2			3					2	
Copsychus saularis	Turdidae	Oriental Magpie Robin		4	2	3	3						3	
Copsychus malabaricus	Turdidae	White-rumped Shama			2									
Saxicola caprata	Muscicapidae	Pied Bushchat	2	2							3			2

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Sturnus malabaricus	Sturnidae	Chestnut-tailed Starling		2									2	
Sturnus nigricollis	Sturnidae	Black-collared Starling	2							2	2			
Acridotheres tristis	Sturnidae	Common Myna	3	4	3	3		3		4	3	3	3	4
Acridotheres grandis	Sturnidae	White-vented Myna		5				3	3	3			4	
Gracula religiosa	Sturnidae	Hill Myna										2		
Hirundo rustica	Hirundinidae	Barn Swallow	3	3			2	2					2	
Pycnonotus flaviventris	Pycnonotidae	Black-crested Bulbul						3				3		
Pycnonotus aurigaster	Pycnonotidae	Sooty-headed Bulbul			2									
Pycnonotus finlaysoni	Pycnonotidae	Stripe-throated Bulbul										2		
Pycnonotus goiavier	Pycnonotidae	Yellow-vented Bulbul		3	3	3			3		2	3	4	
Pycnonotus blanfordi	Pycnonotidae	Streak-eared Bulbul		2		3					2	3	3	
Iole propinqua	Pycnonotidae	Grey-eyed Bulbul			3									

Cisticola juncidis	Cisticolidae	Zitting Cisticola	4								4		3	3
Cisticola exilis	Cisticolidae	Bright-headed Cisticola											3	
Prinia flaviventris	Cisticolidae	Yellow-bellied Prinia	3	4	2	2		3					5	
Prinia inornata	Cisticolidae	Plain Prinia	3	3	2			2			3		3	
Orthotomus sutorius	Cisticolidae	Common Tailorbird		3	3				2			3		3
Orthotomus atrogularis	Cisticolidae	Dark-necked Tailorbird			4	2		2				4		
Orthotomus chaktomuk	Cisticolidae	Cambodian Tailorbird			?									
Megalurus palustris	Locustellidae	Striated Grassbird	3	2							2			2
Garrulax leucolophus	Leiothrichidae	White-crested Laughingtrush										2		
Pellorneum ruficeps	Pellorneidae	Puff-throated Babbler										2		
Mixornis gularis	Timaliidae	Striped Tit Babbler			4			3				3		
Timalia pileata	Timaliidae	Chestnut-capped Babbler			1									

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Mirafra javanica	Alaudidae	Australasian Bushlark									2			
Mirafra marionae	Alaudidae	Indochinese Bushlark									3			
Dicaeum cruentatum	Dicaeidae	Scarlet-backed Flowerpecker				2			2			3		
Anthreptes malacensis	Nectariniidae	Brown-throated Sunbird			4							3		
Chalcoparia singalensis	Nectariniidae	Ruby-cheeked Sunbird										2		
Nectarinia jugularis	Nectariniidae	Olive-backed Sunbird	2										4	
Nectarinia sperata	Nectariniidae	Purple-throated Sunbird			2									
Passer domesticus	Passeridae	House Sparrow	4			3			3					
Passer flaveolus	Passeridae	Plain-backed Sparrow	3	3										
Passer montanus	Passeridae	Eurasian Tree Sparrow	4	4				3	3	3	3			

Species	Family	Common Name	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12
Anthus rufulus	Motacillidae	Paddyfield Pipit	2											
Ploceus philippinus	Ploceidae	Baya Weaver					3	4	3	3			3	3
Ploceus hypoxanthus	Ploceidae	Asian Golden Weaver	2											
Lonchura striata	Estrildidae	White-rumped Munia										2		2
Lonchura punctulata	Estrildidae	Scaly-breasted Munia		3						3			2	3
			33	37	33	19	9	23	22	19	16	25	39	20

Appendix C -2 Bird species recorded in the survey areas, 1994-2019.

1, rare ; 2, occasional; 3, frequent; 4, common; 5, very common

Cr, Critically Endangered; En, Endangered; Vu, Vulnerable; NT, Near-threatened; DD, Data-deficient. Where two annotations are given divided by a slash, the first refers to the species' global status, the second to its local (Cambodian) status (following Goes 2013)

		threatened status		migrant	BP Lapouv	Bassac marshes	Prek Chhlong	Lower Stung Sen	Chhnok Tru	Boeung Chhmar	Ang Trop. Thmor	Preah Net Preah	Stoung Chikreng	Stung Prasat Balang	Veal Strongae	Stung Sen /Baray BFCA	Dey Roneath	Prek Toal		Swamp Forest	Marshes	Shrubland	Grasslands	Riverine channels	Open countryside
		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Francolinus pintadeanus	Chinese Francolin												2									1	1		
Coturnix chinensis	Blue-breasted Quail	-/NT											4			2						1	1		1
Dendrocygna javanica	Lesser whistlingduck				1	2				1	5							2			1				
Sarkidiornis melanotus	Comb Duck	-/NT			2					1	4		1			2		3			1				
Nettapus coromandelianus	Cotton Pygmy-goose				1					1	4					3		1			1				
Anas penelope	Eurasian Wigeon			1							3										1				
Anas poecilorhyncha	Spot-billed Duck				3					2	3										1				
Anas clypeata	Northern Shoveler			1							2										1				
Anas acuta	Northern Pintail			1							3										1				
Anas querquedula	Garganey			1	1						4										1				
Anas crecca	Common Teal			1							2										1				
Aythya nyroca	Ferruginous Pochard	NT		1							2										1				
Aythya fuligula	Tufted duck			1							1										1				
Aythya marila	Greater Scaup			1							1										1				
Turnix sylvatica	Small Buttonquail	-/NT									3												1		
Turnix tanki	Yellow-legged Buttonquail	-/DD									1												1		

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Turnix suscitator	Barred Buttonquail				1																		1		1
Jynx torquilla	Eurasian Wryneck			1							1		1												1
Dendrocopos macei	Fulvous-breasted Woodpecker						2				3			2	2					1				1	
Micropternus brachyurus	Rufous Woodpecker																	2		1					
Picus vittatus	Laced Woodpecker									1					2			1		1				1	
Picus xanthopygaeus	Streak-throated Woodpecker										1									1					
Picus erythropygius	Black-headed Woodpecker										3									1					
Dinopium javanense	Common Flameback																	1							
Megalaima lineata	Lineated Barbet													2						1					
Megalaima haemacephala	Coppersmith Barbet																			1					1
Coracias benghalensis	Indian Roller					3		2						2		3									1
Eurystomus orientalis	Dollarbird			1	2	2					2					2									1
Alcedo atthis	Common Kingfisher			1	1					1	2							2		1				1	
Pelargopsis capensis	Stork-billed Kingfisher				1			2		1					3			1			1			1	
Halcyon smyrnensis	White-throated Kingfisher				1	2	4			1	2							1			1				
Halcyon pileata	Black-capped Kingfisher			1	1						2							1			1			1	1
Todorhamphus chloris	Collared Kingfisher				1													2							1
Ceryle rudis	Pied Kingfisher	-/NT			3		2			1	3							1			1			1	
Merops orientalis	Green Bee-eater				4	3																		1	1
Merops philippinus	Blue-tailed Bee-eater				1				2			3			3			1							1
Merops leschenaulti	Chestnut-headed Bee-eater						4	4												1				1	
Cacomantis merulinus	Plaintive Cuckoo				3						4					3		1		1					1

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Surniculus lugubris	Drongo Cuckoo									2										1					
Eudynamys scolopacea	Asian Koel					2					2							2		1					1
Phaenicophaeus tristis	Green-billed Malkoha									1								1		1					
Centropus sinensis	Greater Coucal				3	2	4	3		2		2		3	4			1				1			
Centropus bengalensis	Lesser Coucal				3	3	3		3	1	2				3			2				1	1		1
Psittacula finschii	Grey-headed Parakeet										1									1					
Psittacula alexandri	Red-breasted Parakeet																	1							
Collocalia fuciphaga	Edible-nest Swiftlet				3	3		4	4	2															1
Aerodramus germani	Germain's Swiftlet	-/DD									?														1
Cypsiurus balasiensis	Asian Palm Swift				4	3	3		4	3	3	3	3	3	4	4		1							1
Apus affinis	House Swift										2														1
Hirundapus giganteus	Brown Needletail																	1							
Hemiprocne coronata	Crested Treeswift						2													1					
Tyto alba	Common Barn Owl					2					3		1												1
Tyto longimembris	Eastern Grass Owl												2										1		1
Otus lettia	Collared Scops Owl					2												2		1					1
Otus bakkamoena	Collared Scops-owl																	1							
Ketupa ketupu	Buffy Fish Owl																	2		1	1				
Strix seloputo	Spotted wood Owl																	3		1					
Caprimulgus affinis	Savanna Nightjar										1		1										1		1
Caprimulgus macrurus	Large-tailed Nightjar																	1							
Columba livia	Rock Pigeon					2	3				3	3													1
Spilopelia chinensis	Spotted Dove				3	3	4	3		1		3	2	3	4	4		1				1		1	1

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Streptopelia tranquebarica	Red Collared Dove				3		3				2	3			3	3						1		1	1
Geopelia striata	Peaceful Dove				3	2	2	3			3	4		3		3						1		1	1
Treron vernans	Pink-necked Green Pigeon														3					1		1			
Houbaropsis bengalensis	Bengal Florican	Cr											3			1							1		1
Grus antigone	Sarus Crane	Vu			3						3		3			3		4		1	1				
Grus virgo	Demoiselle Crane			1									1										1		
Heliopais personata	Masked Finfoot	En/Cr								2								3		1	1				
Amaurornis phoenicurus	White-breasted Waterhen				1					1					2			1			1	1			1
Porzana pusilla	Baillon's Crake	-/DD		1														1			1				
Porzana fusca	Ruddy-breasted Crake				3						3							1			1				
Porzana cinerea	White-browed Crake										3										1				
Gallicrex cinerea	Watercock				1						3							1			1				
Porpyrio porphyrio	Purple Swamphen				1					1	4	2	4			2		4			1				
Gallinula chloropus	Common Moorhen				1					1	4							4			1				
Fulica atra	Common Coot					1				1	3										1				
Gallinago gallinago	Common Snipe			1	1																1				
Limnocryptes minimus	Jack Snipe			1							?										1				
Limosa limosa	Black-tailed Godwit	NT		1	3	2					3							3			1				
Limosa lapponica	Bar-tailed Godwit			1					1												1				
Tringa erythropus	Spotted Redshank			1							2							2			1				
Tringa totanus	Common Redshank			1	1						1							1			1				
Tringa stagnatilis	Marsh Sandpiper			1	2																1				
Tringa nebularia	Common Greenshank			1	3						3										1				

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Tringa ochropus	Green Sandpiper			1	1																1				
Tringa glareola	Wood Sandpiper			1	1																1				
Actitis hypoleucos	Common Sandpiper			1	1																			1	
Arenaria interpres	Ruddy Turnstone			1							1										1				
Calidris ruficollis	Red-necked Stint			1					2		2										1				
Calidris temminckii	Temminck's Stint			1							1										1				
Calidris subminuta	Long-toed Stint			1	1				1		1							1			1				
Calidris ferruginea	Curlew Sandpiper			1					?		1							?			1				
Philomachus pugnax	Ruff			1							3										1				
Phalaropus lobatus	Red-necked Phalarope			1	1													1			1			1	
Rostratula benghalensis	Greater Painted-snipe				2						3										1				
Hydrophasianus chirurgus	Pheasant-tailed Jacana			1	1	3				1	3							1			1				
Metopidius indicus	Bronze-winged Jacana				1					1	3							3			1				
Burhinus indicus	Indian Thick-knee	-/DD									2												1		1
Himantopus himantopus	Black-winged Stilt				1					1	3	2						1			1				
Pluvialis fulva	Pacific Golden Plover			1	1													1			1		1		
Pluvialis squatarola	Grey Plover																	1							
Charadrius dubius	Little Ringed Plover			1	2																1				
Charadrius mongolus	Lesser Sand Plover			1							2										1				
Charadrius leschenaulti	Greater Sand Plover			1							2										1				
Charadrius veredus	Oriental Plover			1							2		3			2							1		
Vanellus duvaucelii	River Lapwing	NT/En									1													1	
Vanellus cinereus	Grey-headed Lapwing			1	2						2										1				

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Vanellus indicus	Red-wattled Lapwing				3	3					2										1				
Glareola maldivarum	Oriental Pratincole				4	3					3	2	4			4		4					1		
Chroicocephalus brunnicephalus	Brown-headed Gull			1						1	1							1			1			1	
Chroicocephalus ridibundus	Black-headed Gull			1		1															1			1	
Gelochelidon nilotica	Gull-billed Tern			1														?						1	
Hydroprogna caspia	Caspian Tern			1	1													1						1	
Sterna aurantia	River Tern	NT/Cr							1															1	
Sterna hirundo	Common Tern									1															
Chlidonias hybrida	Whsikered Tern			1	1	4			4	1	3							1			1			1	
Chlidonias leucopterus	White-winged Ten			1	1						1							1			1			1	
Pandion haliaetus	Osprey			1	1					1								1		1	1		1	1	
Pernis ptilorhyncus	Oriental Honey-buzzard																	1		1					
Elanus caeruleus	Black-shouldered Kite				2	3	2					2			2	2						1	1		1
Milvus migrans	Black Kite	-/En									3										1				1
Milvus lineatus	Black-eared Kite			1							3							2			1				
Haliastur indus	Brahminy Kite									4	4							4			1			1	1
Haliaeetus leucoryphus	Pallas's Fish Eagle										1										1			1	
Ichthyophaga ichthyaetus	Grey-headed Fish Eagle	NT/NT				1		2		4	2							4			1			1	
Gyps bengalensis	White-rumped Vulture	Cr							1											1				1	
Aegypius calvus	Red-headed Vulture	Cr									1									1				1	
Circaetus gallicus	Short-toed Eagle			1									1							1			1		1
Spilornis cheela	Crested Serpent-eagle					1												1		1					
Circus aeruginosus	Western Marsh Harrier			1							2		1			1		1			1		1		

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Circus spilonotus	Eastern Marsh Harrier			1	1					1	2		3								1		1		
Circus melanoleucos	Pied Harrier			1	1																1		1		
Accipiter gularis	Japanese Sparrowhawk			1	1															1			1		1
Buteo burmanicus	Himalayan Buzzard			1							1									1					
Ictinaetus malayensis	Black Eagle										1									1					
Aquila clanga	Greater Spotted Eagle	Vu		1							1		1			1		1			1		1		1
Aquila pennata	Booted Eagle			1							1									1					1
Aquila heliaca	Eastern Imperial Eagle	Vu		1							2					1							1		
Polihierax insignis	White-rumped Pygmy Falcon	NT									1									1					
Falco naumanni	Lesser Kestrel			1							2												1		1
Falco tinnunculus	Common Kestrel			1							1														1
Falco peregrinus	Peregrine Falcon			1							1														1
Tachybaptus ruficollis	Little Grebe					4				1	4										1				
Anhinga melanogaster	Darter	NT/NT			1			3	3	3	3						4	4			1			1	
Phalacrocorax niger	Little Cormorant				1	2				4	3				3	3		4			1			1	
Phalacrocorax fuscicollis	Indian Cormorant				4					3	3							4			1			1	
Phalacrocorax carbo	Great Cormorant	-/NT			3	3				1	2							3			1			1	
Egretta garzetta	Little Egret				4					1	4					4		4			1			1	
Ardea cinerea	Grey Heron				4					4	4							4			1				
Ardea purpurea	Purple Heron				3	3				1	4							4			1		1	1	
Casmerodius [Ardea] alba	Great Egret				3					3	4							4			1		1	1	
Mesophoyx intermedia	Intermediate Egret				1	3				1	3					4		4			1			1	
Bubulcus ibis	Cattle Egret				1	3				1	2							1			1				1

Ardeola bacchus	Chinese Pond Heron			1	1	4				1	4							4			1				1
Ardeola speciosa	Javan Pond Heron				1					1								3			1				1
Butorides striatus	Little Heron			1	1					1								4			1			1	
Nycticorax nycticorax	Black-crowned Night Heron				1					1	4							4		1	1		1	1	
Ixobrychus sinensis	Yellow Bittern				1	3				1	4		4		4			4			1		1		
Ixobrychus cinnamomeus	Cinnamon Bittern				3				2	1					2			1			1		1		
Dupetor flavicollis	Black Bittern									2					2			1			1				
Botaurus stellaris	Great Bittern			1							1		1								1				
Plegadis falcinellus	Glossy Ibis	-/DD			3				2	2								3			1				
Threskiornis melanocephalus	Black-headed Ibis	NT/NT			3	2			3	3	4							3		1	1		1		1
Pseudibis davisoni	White-shouldered Ibis	Cr									1		1					1		1			1	1	
Platalea leucorodia	Eurasian Spoonbill										1							2			1				
Platalea minor	Black-faced Spoonbill	En		1	1																1				
Pelecanus onocrotalus	Great White Pelican										3							1			1				
Pelecanus philippensis	Spot-billed Pelican	NT/NT			3	3				4	3		2					4			1				
Mycteria cinerea	Milky Stork	Vu/CR							1	1	3							3			1				
Mycteria leucocephala	Painted Stork	NT/NT			4			2		3	4							4		1	1		1	1	
Anastomus oscitans	Asian Openbill				1					4	4	4			3		4	5		1	1		1	1	1
Ciconia episcopus	Woolly-necked Stork	-/NT									1		2					2		1			1		
Ephippiorhynchus asiaticus	Black-necked Stork	NT/Cr						2		2	3		1			2		2		1			1		
Leptoptilos javanicus	Lesser Adjutant	Vu/NT			2			3		3	3		2		2	2	4	4		1	1		1	1	1
Leptoptilos dubius	Greater Adjutant	En			3			3		3	3		1			1	1	3		1			1		
Pitta moluccensis	Blue-winged Pitta						4			1					3			1		1		1			
Cymbirhynchus macrorhynchos	Black-and-red Broadbill																	1		1				1	

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Gerygone sulphurea	Golden-bellied Gerygone				2	3				2										1					
Lanius cristatus	Brown Shrike			1	1				1		1							1				1			1
Lanius schach	Long-tailed Shrike			1							1									1					
Lanius tephronotus	Grey-backed Shrike			1							1											1			1
Pachycephala cinerea	Mangrove Whistler	-/DD																2		1					
Crypsirhina temia	Racket-tailed Treepie					3		3						3	3			1		1	1		1	1	1
Corvus macrorhynchos	Large-billed Crow							3	3	3	4		2		3	3		4		1	1	1	1	1	1
Pericrocotus divaricatus	Ashy Minivet																	1		1				1	
Hemipus picatus	Bar-winged Flycatcher-shrike								1											1				1	
Rhipidura javanica	Pied Fantail				3	3	4				2				3			1		1				1	
Dicrurus macrocercus	Black Drongo				1						3							2		1		1	1	1	1
Dicrurus hottentottus	Spangled Drongo						2													1				1	
Dicrurus paradiseus	Greater Racket-tailed Drongo						2							2						1				1	
Hypothymis azurea	Black-naped Monarch														2			1		1		1		1	1
Aegithina tiphia	Common Iora					3	4	2		1		3		2	3			1		1				1	
Muscicapa sibirica	Dark-sided Flycatcher			1							1									1					
Ficedula zanthopygia	Yellow-rumped Flycatcher			1														1		1					
Ficedula albicilla	Taiga Flycatcher			1														1		1				1	
Cyornis tickelliae	Tickell's Blue Flycatcher						2			3					2					1				1	
Luscinia svecica	Bluethroat			1	1						1							3				1	1		
Copsychus saularis	Oriental Magpie Robin				1	4	2	3	3	1					3			1		1	1	1	1	1	1
Copsychus malabaricus	White-rumped Shama						2													1					

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Saxicola maurus	Eastern Stonechat			1	1						3									1		1	1	1	
Saxicola caprata	Pied Bushchat				2	2							3			2		1		1			1	1	1
Saxicola ferreus	Grey Bushchat			1							1									1		1			
Sturnus malabaricus	Chestnut-tailed Starling					2					3				2					1				1	1
Sturnus sturninus	Purple-backed Starling			1							1									1		1			
Sturnus sinensis	White-shouldered Starling			1							3									1	1	1	1		1
Sturnus roseus	Rosy Starling			1							2														1
Gracupica contra	Asian Pied Starling				1					1	3										1		1		1
Sturnus nigricollis	Black-collared Starling				2							2	2								1		1	1	1
Acridotheres tristis	Common Myna				3	4	3	3		3	4	4	3	3	3	4		1		1	1		1	1	1
Acridotheres grandis	White-vented Myna				1	5				3	3	3			4			1		1	1		1	1	1
Gracula religiosa	Hill Myna													2						1				1	
Riparia riparia	Sand Martin			1	1				2							2		1		1	1		1	1	1
Hirundo rustica	Barn Swallow			1	3	3			2	2	5				2			1			1	1	1	1	1
Cecropis striolata	Striated Swallow										1													1	1
Delichon dasypus	Asian House Martin			1														1			1		1		1
Pycnonotus flaviventris	Black-crested Bulbul									3				3						1				1	
Pycnonotus aurigaster	Sooty-headed Bulbul						2														1			1	1
Pycnonotus finlaysoni	Stripe-throated Bulbul													2										1	
Pycnonotus goiavier	Yellow-vented Bulbul				1	3	3	3			3		2	3	4			1		1	1		1	1	1
Pycnonotus blanfordi	Streak-eared Bulbul				1	2		3		1	2		2	3	3			1		1		1		1	1
Iole propinqua	Grey-eyed Bulbul						3																	1	
Cisticola juncidis	Zitting Cisticola				4								4		3	3					1		1		1

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Cisticola exilis	Bright-headed Cisticola														3			1		1			1		
Prinia hodgsonii	Grey-breasted Prinia				1																	1	1		
Prinia flaviventris	Yellow-bellied Prinia				3	4	2	2		3					5			1		1	1	1	1	1	
Prinia inornata	Plain Prinia				3	3	2			2	2		3		3						1		1	1	1
Zosterops palpebrosus	Oriental White-eye				1															1		1			
Locustella lanceolata	Lanceolated Warbler			1							1										1		1		
Locustella certhiola	Rusty-rumped Warbler			1	1	2					2							1							
Acrocephalus bistrigiceps	Black-browed Reed Warbler			1	1						1							1			1		1	1	1
Acrocephalus tangorum	Manchurian Reed Warbler	Vu		1							?		3										1		
Acrocephalus concinens	Blunt-winged Warbler			1							1		1									1	1		
Acrocephalus orientalis	Oriental Reed Warbler			1	1						1									1	1	1	1	1	1
Orthotomus sutorius	Common Tailorbird					3	3				2			3		3								1	1
Orthotomus atrogularis	Dark-necked Tailorbird						4	2		2	1			4				1		1	1	1		1	
Orthotomus chaktomuk	Cambodian Tailorbird	NT/NT					?									3						1			1
Phylloscopus fuscatus	Dusky Warbler			1							1							1		1	1	1	1	1	
Phyllocopus inornatus	Yellow-browed Warbler			1														1		1				1	
Phylloscous borealis	Arctic Warbler			1														1		1				1	
Megalurus palustris	Striated Grassbird				3	2					1		2			2		1		1	1	1	1	1	
Garrulax leucolophus	White-crested Laughingtrush													2				1		1				1	
Pellorneum ruficeps	Puff-throated Babbler													2						1					
Mixornis gularis	Striped Tit Babbler						4			3				3				1		1		1		1	
Timalia pileata	Chestnut-capped Babbler						1															1	1		

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Mirafra javanica	Australasian Bushlark	-/NT									3		2										1		1
Mirafra marionae	Indochinese Bushlark												3									1	1		
Alauda gulgula	Oriental Skylark										3												1		1
Dicaeum cruentatum	Scarlet-backed Flowerpecker							2			2			3						1				1	1
Anthreptes malacensis	Brown-throated Sunbird						4							3						1	1			1	
Chalcoparia singalensis	Ruby-cheeked Sunbird													2				2		1				1	
Nectarinia sperata	Purple-throated Sunbird						2											3		1				1	
Nectarinia jugularis	Olive-backed Sunbird				2					1					4			3		1	1	1	1		1
Passer domesticus	House Sparrow				4			3			3														1
Passer flaveolus	Plain-backed Sparrow				3	3					3														1
Passer montanus	Eurasian Tree Sparrow				4	4				3	3	3	3					2							1
Motacilla alba	White Wagtail			1							1							2		1			1	1	1
Motacilla citreola	Citrine Wagtail			1									1										1		
Motacilla tschutschensis	Eastern Yellow Wagtail			1	1						1							1			1		1	1	
Anthus richardi	Richard's Pipit			1							3										1		1		1
Anthus rufulus	Paddyfield Pipit				2						2		2								1		1		1
Anthus cervinus	Red-throated Pipit			1							3		2										1	1	1
Ploceus manyar	Streaked Weaver	-/En			1						3		2								1	1	1		
Ploceus philippinus	Baya Weaver	-/NT			3	3			3	4	3	3			3	3		2		1			1	1	1
Ploceus hypoxanthus	Asian Golden Weaver	NT/En			4	4			2		3		2								1	1	1		
Amandava amandava	Red Avadavat	-/En									3		3										1		
Lonchura striata	White-rumped Munia													2		2					1	1	1	1	1
Lonchura punctulata	Scaly-breasted Munia					3					4	3			2	3		1		1	1	1	1	1	1

		Thr		m	site 01	site 02	site 03	site 04	site 05	site 06	site 07	site 08	site 09	site 10	site 11	site 12	site 13	site 14		SF	Ma	SL	GL	RC	OC
Lonchura atricapilla	Chestnut Munia	-/En			3								2								1		1	1	1
Emberiza fucata	Chestnut-eared Bunting	-/NT									1		3								1		1		
Emberiza aureola	Yellow-breasted Bunting	Vu/En		1	1						3		5			1					1		1		
				93	116	57	33	24	23	77	159	19	50	25	39	37	4	130		95	131	41	85	94	87
	Critically Endangered	4			-	-	-		1	-	2	-	2	-	-	1	-	-							
	Endangered	3			2	-	-	1	-	2	1	-	1	-	-	1	1	2							
	Vulnerable	7			3	-	-	1	1	2	6	-	5	-	1	5	1	4							
	Near-threatened	13			5	5	-	4	4	6	11	-	3	-	-	2	1	7							

APPENDIX C-3 Threatened and Near-threatened bird species in the survey areas.

Cr, Critically Endangered; En, Endangered; Vu, Vulnerable; NT, Near-threatened.

			IBA4 - Dey Roneath	Prek Chhlong	IBA3 - Prek Toal	IBA21 - Stung Sen	IBA 18 Chhnok Tru	IBA15 Boeung Chhmar	IBA01 - Ang T Thmor	IBA02 PNP/KL/Pourk	IBA16 St/Chik/K Svay	IBA17 - Stung P Balang	IBA20 - Veal Strongae	IBA21 - SS/Santuk/Baray	IBA39 - BP Lapouv	IBA 38 - Bassac marshes
Cr	*Houbaropsis [Eupodotis] bengalensis*	Bengal Florican									3			1		
Cr	*Gyps bengalensis*	White-rumped Vulture					1									
Cr	*Sarcogyps [Aegypius] calvus*	Red-headed Vulture							1							
Cr	*Pseudibis davisoni*	White-shouldered Ibis							1		1			3		
En	*Heliopais personata*	Masked Finfoot			3			2								
En	*Platalea minor*	Black-faced Spoonbill													1	
En	*Leptoptilos dubius*	Greater Adjutant	1		3	3		3	3		1			1	3	
Vu	*Grus antigone*	Sarus Crane			4				3		3			3	3	
Vu	*Aquila clanga*	Greater Spotted Eagle			1				1		1			1		
Vu	*Aquila heliaca*	Eastern Imperial Eagle							2					1		
Vu	*Mycteria cinerea*	Milky Stork			3		1	1	3							
Vu	*Leptoptilos javanicus*	Lesser Adjutant	4		4	3		3	3		2		2	2	2	
Vu	*Acrocephalus tangorum*	Manchurian Reed Warbler							?		3					
Vu	*Emberiza aureola*	Yellow-breasted Bunting							3		5			1	1	
			2	0	6	2	2	4	9	0	8	0	1	8	5	0

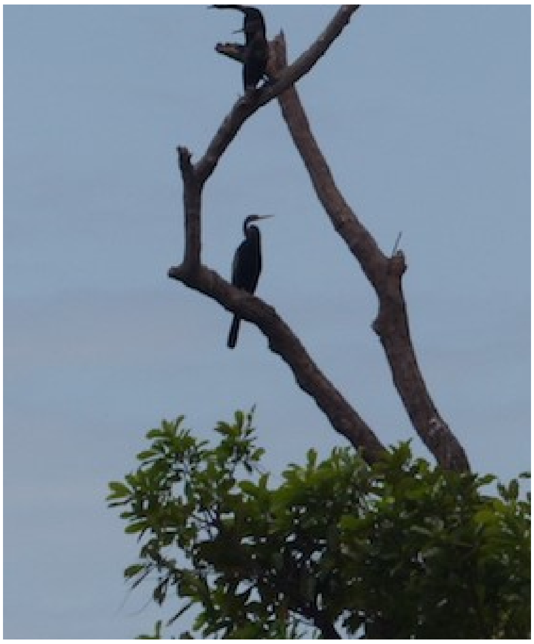
			IBA4 - Dey Roneath	Prek Chhlong	IBA3 - Prek Toal	IBA21 - Stung Sen	IBA 18 Chhnok Tru	IBA15 Boeung Chhmar	IBA01 - Ang T Thmor	IBA02 PNP/KL/Pourk	IBA16 St/Chik/K Svay	IBA17 - Stung P Balang	IBA20 - Veal Strongae	IBA21 - SS/Santuk/Baray	IBA39 - BP Lapouv	IBA 38 - Bassac marshes
NT	*Aythya nyroca*	Ferruginous Pochard							2							
NT	*Vanellus duvaucelii*	River Lapwing							1							
NT	*Limosa limosa*	Black-tailed Godwit			3				3						3	2
NT	*Sterna aurantia*	River Tern					1									
NT	*Ichthyophaga ichthyaetus*	Grey-headed Fish Eagle			4	2		4	2							1
NT	*Polihierax insignis*	White-rumped Pygmy Falcon							1							
NT	*Anhinga melanogaster*	Darter	4		4	3	3	3	3							
NT	*Threskiornis melanocephalus*	Black-headed Ibis			3		3	3	4						3	2
NT	*Pelecanus philippensis*	Spot-billed Pelican			4			4	3		2				3	3
NT	*Mycteria leucocephala*	Painted Stork			4	2		3	4						4	
NT	*Ephippiorhynchus asiaticus*	Black-necked Stork			2	2		2	3		1			2		
NT	*Orthotomus chaktomuk*	Cambodian Tailorbird												3		
NT	*Ploceus hypoxanthus*	Asian Golden Weaver					2		3		2				4	4
			1	0	7	4	4	6	11	0	3	0	0	2	5	5

Appendix D - Bird photo gallery (all photos by W Giesen)

1 & 2. Asian Openbills (or ចង្កៀលខ្យង), the most commonly stork, with large and smaller post-breeding flocks dispersed in marshlands and wet rice fields.
3. The Darters (or ស្នោញ) became nearly extirpated in the 1990s, but miraculously recovered since the protection of the Prek Toal waterbird colony.
4. Majority of Great Egrets (or កុកក្រោងធំ) seen are winter visitors, here a late group of birds in their non-breeding plumage (yellow bills, no plumes).
5. The Oriental Pratincole (or ទន្ទ្រីតធំ) is a common breeding visitor and passage migrant.
6. Indian Rollers (or ទៀវខៀវ) are strongly associated with palm trees
7. Outside their breeding season, the Bengal Florican (or សត្វខ្សឹប ឬត្រមាក់អណ្តើក) is notoriously difficult to detect.

1

2



3

4

5

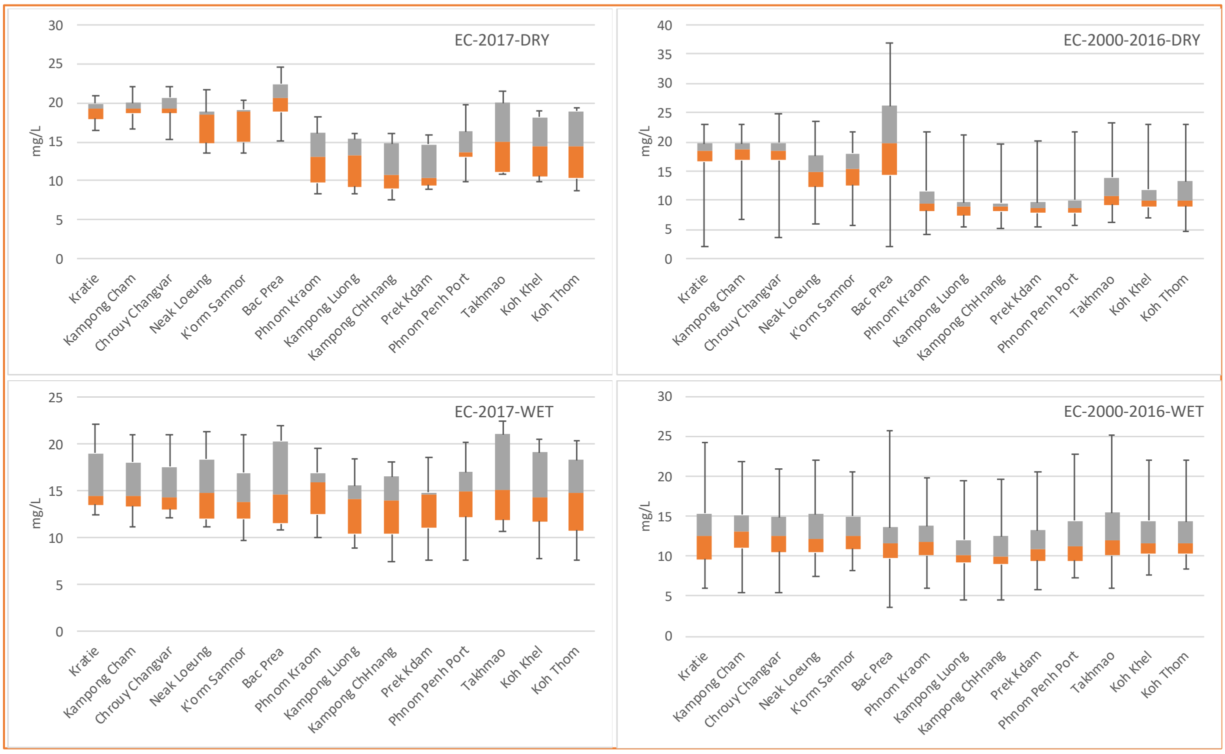
6

7

Appendix E

Electrical Conductivity (EC)

Conductivity is the measurement of the ability of water to conduct an electric current - the greater the content of dissolved ionic salts in the water, the more current the water can carry and the higher the conductivity. It provides a valuable baseline that has been used to identify any emerging effects of development on water quality in the Mekong River.



Source: MRC Database, 2000-2017

Figure 1: Spatial variation in Electrical Conductivity levels along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017 (left) and during the period of 2000-2016 (right)

Mekong, Tonle Sap, and Bassac Rivers are naturally low-salinity rivers with electrical conductivity values rarely exceeding 50 mS/m. Figure 1 illustrates spatial and temporal trends for electrical conductivity in the Mekong, Tonle Sap, and Bassac Rivers during the dry and wet season. The Mekong River can be generally characterised as a river with low conductivity values, with average historical values from 2000 to 2016 of about 13 mS/m in wet season to 17 mS/m in dry season. However, the average values in 2017 were slightly higher than the historical values, which ranged from 15 mS/m in wet season to 18 mS/m in dry season.

The average EC values of the historical data (2000-2016) in the Tonle sap river in the wet season (11.5 mS/m) were slightly higher than those in the dry season (10.7 mS/m). The average EC values in 2017 were high for both seasons (14.2 mS/m in the wet season, and 14 mS/m in the dry season) compared to the historical data (2000-2016).

For the Bassac River, the conductivity continued to be relatively low with the average values ranging from 11.6 mS/m in the dry season to 12.9 mS/m in the wet season for the historical data (2000-2016).

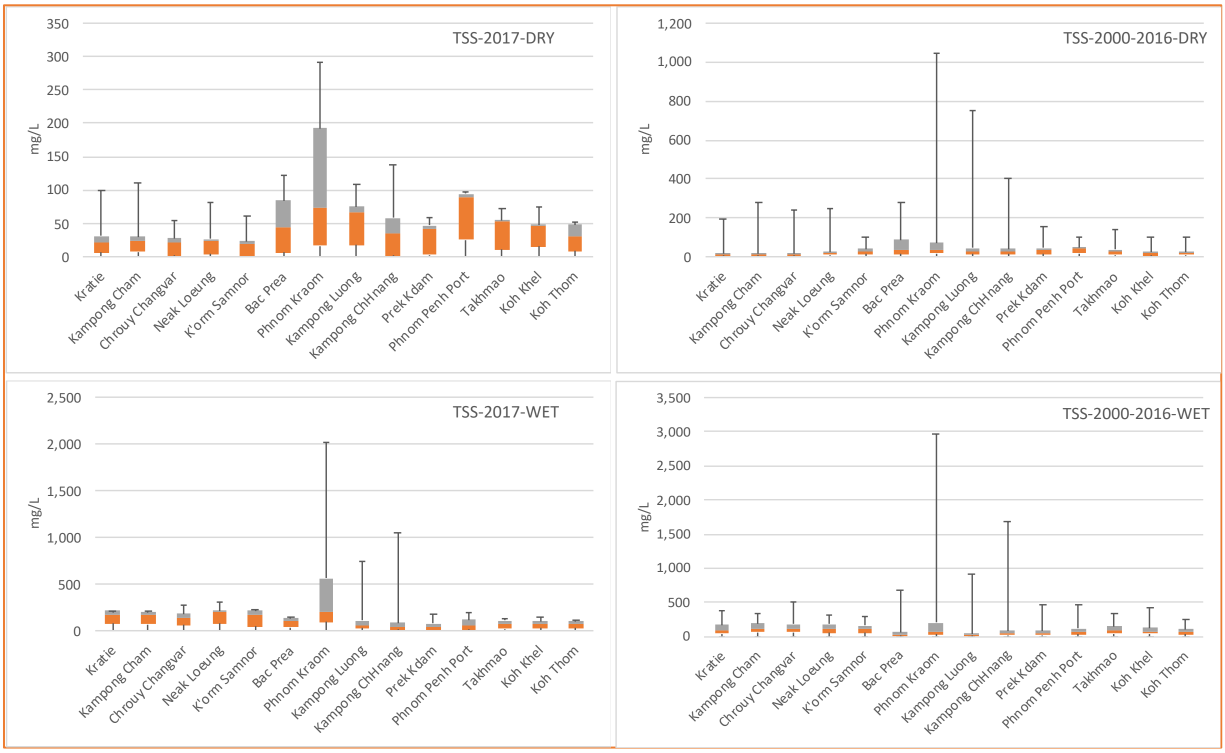
However, the values of 2017 (14.8 mS/m in the dry and 15.1 mS/m in the wet) were higher than those of historical data.

The maximum value of the EC in the three rivers (Mekong, Tonle Sap, and Bassac) was however recorded at Bac Prea station with a value of 36.8 mS/m in the Tonel Sap River on 22 February 2009 for the historical data (2000-2016).

Total Suspended Solid (TSS)

Total Suspended Solids (TSS) in the Mekong, Tonle Sap, and Bassac Rivers are influenced by both natural and anthropogenic activities in the Basin, including urban runoff, agricultural returns, industrial effluents, and natural and/or human induced.

The TSS concentrations observed along the Mekong River for the historical values (2000-2016) continued to be highly variable, with values ranging from 0.7 mg/L to 288 mg/L during the dry season and from 1.5 mg/L to 536 mg/L in the wet season. The average TSS value in wet season (120.5 mg/L) of the historical values (2000-2016) was considerably higher than that in the dry season (25.8 mg/L). the average TSS values in 2017 were however higher than those in the historical values (2000-2016), which were 35.8 mg/L in the dry season and 135 mg/L in the wet season.



Source: MRC Database, 2000-2017

Figure 2: Spatial variation in Total Suspended Solid levels along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017 (left) and during the period of 2000-2016 (right)

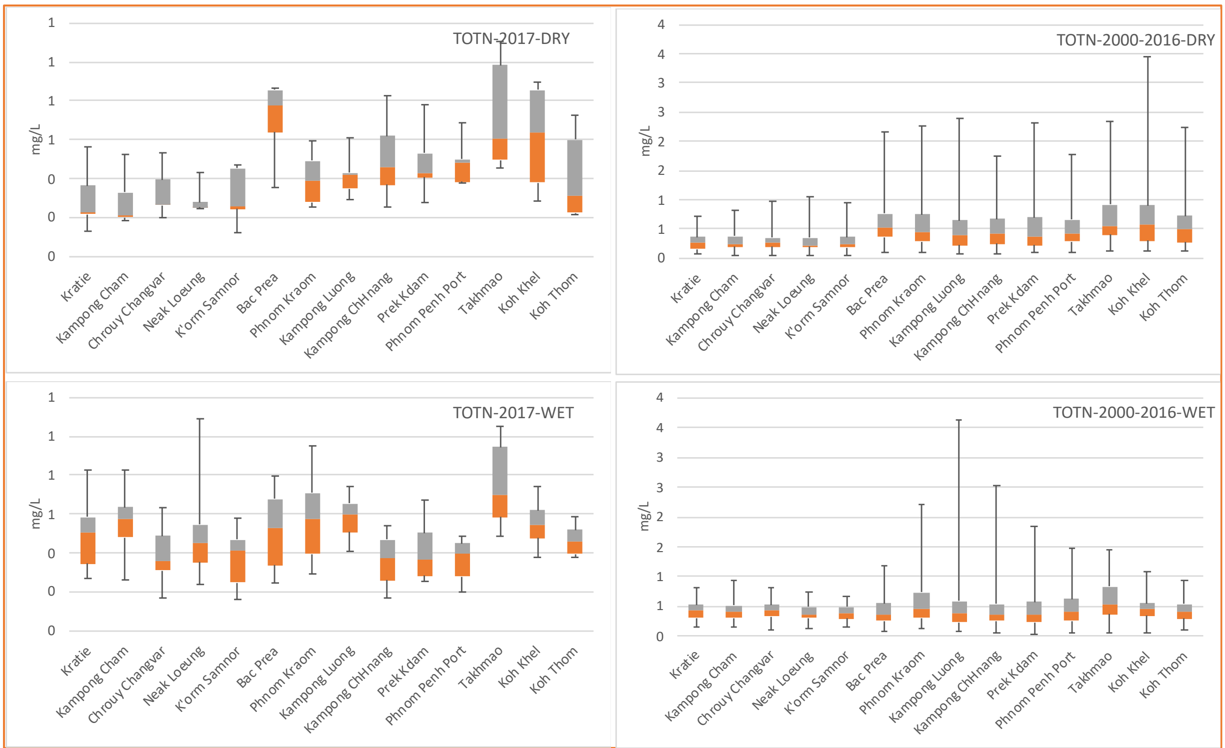
For stations around the Tonle Sap River and Lake, the average TSS concentrations for both seasons (dry and wet) in 2017 and in 2000-2016 were considerably higher than those along the Mekong River. The average values in 2017 increased twice compared to the averages in 2000-2016 for both seasons. The highest wet season concentration for TSS was recorded at 3,256 mg/L at Phnom Kraom (Tonle Sap River) on 23 May 2016. No available information (i.e. infrastructure construction or clearance of forest lands, etc.) why the TSS concentration was extremely high at this station. Yet, it might be a reason of a heavy rainfall or win taken place during that time (early wet season). Similarly, the maximum value in the dry season was also recorded at the same station on 24 March 2016 with a value of 1,190 mg/L.

Along the Bassac River, both seasons' TSS concentrations of the period of 2000-2016 were relatively low compared to those in Mekong and Tonle Sap Rivers. The wet season average value (86.7 mg/L) in 2017 was twice higher than the dry season (39.3 mg/L). Yet, the wet season average value of the historical data was considerably high compared to the average value in the dry season.

Nutrients

Nitrogen and phosphorus are nutrients that are essential for aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish and other aquatic organisms in the river. if too much nitrogen and phosphorus enter the river, the water can become polluted. Nutrient pollution has impacted on fish and other aquatic life in the river, resulting in serious environmental and human health issues, and impacting the economy.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.



Source: MRC Database, 2000-2017

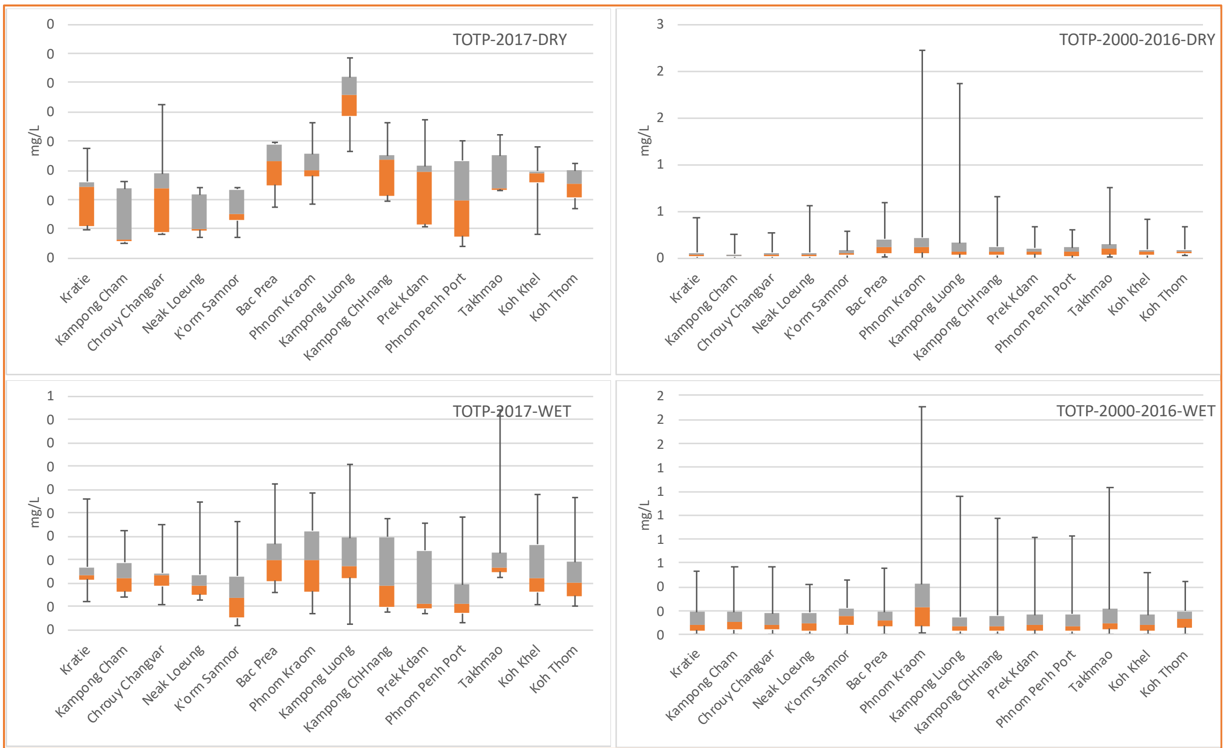
Figure 3: Spatial variation in Total Nitrogen along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017 (left) and during the period of 2000-2016 (right)

The spatial analysis demonstrates that the average ammonium concentrations of stations in the Bassac River in 2017 and 2000-2016 in dry season were higher than that of stations along the Mekong and Tonle Sap Rivers. The highest concentration of ammonium (1.13 mg/L) was measured at Takhmao station in November 2012. There was not clear information associated with the high concentration of the ammonium at this station.

The spatial analysis of water quality data shows that during the period of 2000-2016, the highest concentration of TOTN was recorded at Kampong Luong station (Tonle Sap River) in May (2015) with a value of 3.62 mg/L followed by a value of 3.45 mg/L at Koh Khel station (Bassac River) in February (2014).

Phosphorus

The total phosphorus concentrations were highly variable among stations in 2017. The average values (both seasons) in Tonle Sap and Bassac Rivers were higher than those in the Mekong River, which ranged from 0.13 mg/L to 0.16 mg/L. The maximum value of 0.47 mg/L was recorded at Takhmao station in August followed by a value of 0.35 mg/L at Kampong Luong in May.



Source: MRC Database, 2000-2017

Figure 4: Spatial variation in Total Phosphorus levels along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017 (left) and during the period of 2000-2016 (right)

The spatial analysis of water quality data shows that during the period of 2000-2016, the highest concentration of TOTP was recorded at Phnom Kraom station (Tonle Sap River) in April (2015) with a value of 2.2 mg/L. According to MRC (2019), the total phosphorus concentrations in the Mekong River increased slightly between 2000 and 2017. This might be due to a result of increased human activities, such as agricultural runoff and municipal wastewater discharge.

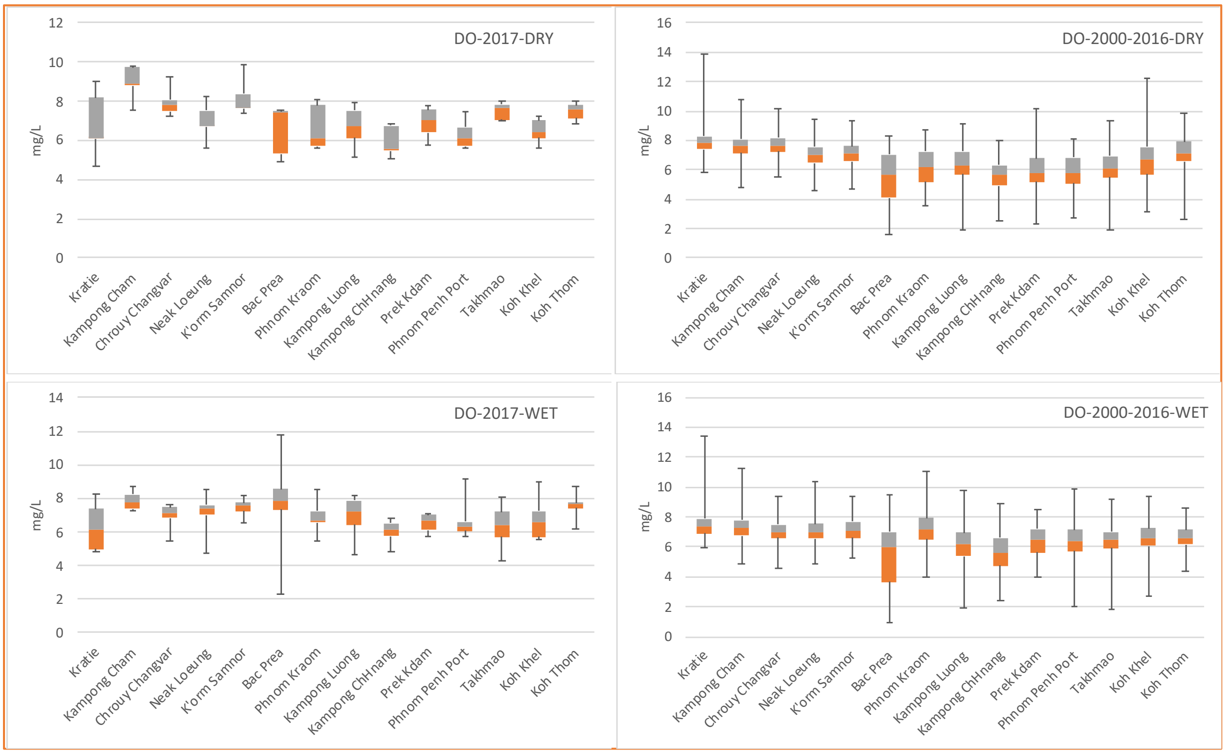
Dissolved oxygen (DO)

Dissolved Oxygen (DO) is essential for the survival of fish and other aquatic life and is an important indicator of pollution and/or eutrophication in rivers and streams. The solubility of oxygen in river waters depends mainly on the water temperature and salinity. Water in equilibrium with air is normally saturated with oxygen (i.e. at 100% Saturation). Several factors can cause deviations in DO from equilibrium conditions and there can be a time lag before the equilibrium is restored. Prolonged reduction in DO levels can lead to fish kill, and can affect other water quality indicators, including biochemical and aesthetic indicators, such as odour, clarity, and taste.

Recognising that dissolved oxygen is an integral component for determining the water quality of the rivers, lakes, and reservoirs, the Ministry of Environment has established a threshold value of between 2.0 mg/L and 7.5 mg/L for Public Water Areas (River, Lake, and Reservoir) for Biodiversity Conservation, which was stipulated under Sub-decree on Water Pollution Control (1999).

The DO values at stations along the Mekong Tonle Sap, and Bassac Rivers in both dry and wet seasons in 2017 were at the acceptable levels for biodiversity conservation in the rivers, which ranged from 11.09 mg/L to 11.80 mg/L in the wet season and from 4.68 mg/L to 9.83 mg/L in the dry season.

The DO values for the Tonle Sap River were considerably variable for most stations during the period of 2000-2016 compared to the values in 2017. Most DO values below the thresholds were recorded in Bac Prea station during the period of 2000-2016. The lowest value (0.98 mg/L) was recorded in Bac Prea station during the wet season (August 2009).



Source: MRC Database, 2000-2017

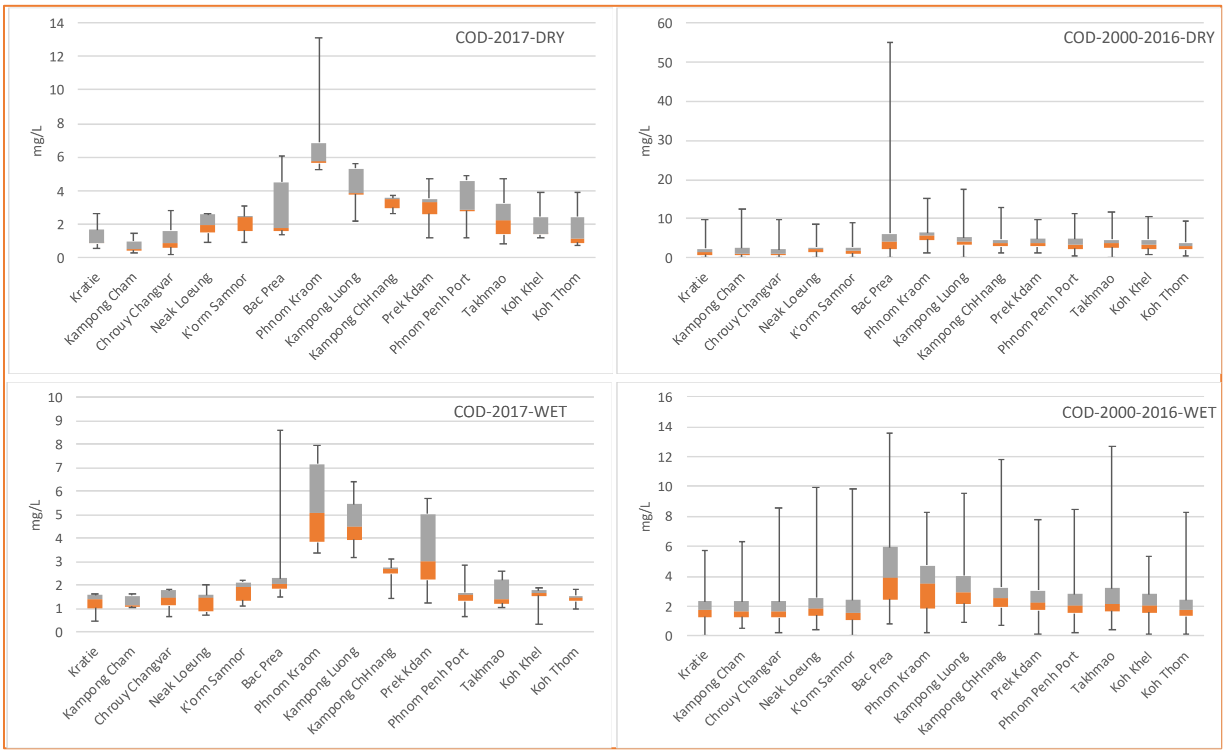
Figure 5: Spatial variation in Dissolved Oxygen levels along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017 (left) and during the period of 2000-2016 (right)

Chemical Oxygen Demand (COD)

According to World Health Organisation (1992), the chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate. The COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants. The COD is a useful, rapidly measured, variable for many industrial wastes and has been in use for several decades.

The MOE (1999) specified that the acceptable COD values for Public Water Areas (River, Lake, and Reservoir) for Biodiversity Conservation could be ranged between 1.0 mg/L and 8.0 mg/L (Sub-decree on Water Pollution Control, 1999).

The COD concentrations in both dry and wet season of the historical period (2000-2016) were higher than those of 2017. The maximum value was recorded at Neak Loeung station on 13 September 2001 (wet season) and at Kampong Cham station (12.65 mg/L) on 23 February 2005 (dry season). Similar with the Mekong River stations, the COD concentrations in both dry and wet season of the historical period (2000-2016) were slightly higher than those of 2017. High and increasing COD concentrations were observed for most stations for both dry and wet seasons. The maximum value of 55 mg/L was however recorded at Bac Prea station on 23 December 2009 (dry season). The highest COD values of the historical data in Bassac River were however recoreded at Takhmao station (12.72 mg/L) in the wet season (October 2001) and at Takhmao station (11.83 mg/L) in the dry season (Nomber 2001).



Source: MRC Database, 2000-2017

Figure 6: Spatial variation in Chemical Oxygen Demand levels along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017 (left) and during the period of 2000-2016 (right)

Biological Oxygen Demand (BOD)

The Biological Oxygen Demand (BOD) has not been testing by the MRC since the beginning of the water quality monitoring. It was started monitoring in 2017 at some stations such as Kampong Cham, Chroy Changvar, Neak Loeung, Phnom Penh Port, Takhmao, and Koh Thom. The BOD values in the monitored stations in both dry and wet seasons in 2017 was generally ‘good’ or ‘very good’ condition. The BOD values for all stations were within the MOE’s acceptable COD values (ranged from 1 mg/L to 10 mg/L) for Public Water Areas (River, Lake, and Reservoir) for Biodiversity Conservation. The highest BOD value of 2.0 mg/L was founded at Takhamo station in May 2017 (early wet season).

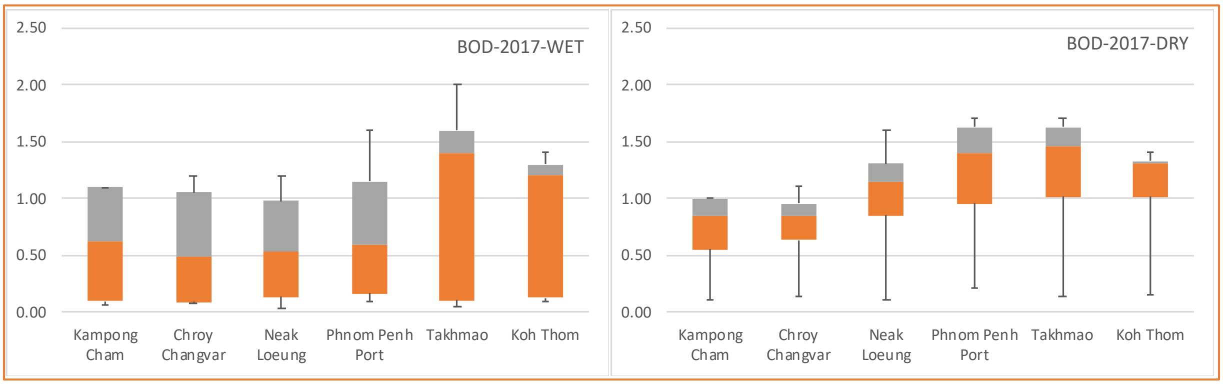


Figure 7: Spatial variation in Biological Oxygen Demand levels along the Mekong, Tonle Sap, and Bassac Rivers in the dry and wet season in 2017