Climate Change Vulnerability Assessment Stung Sen Ramsar Site, Cambodia

Vanessa Herranz Muñoz and Vutthy Vong

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

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

FISHING CAT
ECOLOGICAL ENTERPRISE

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ACRONYMS AND ABBREVIATIONS

BTCRS	Boeung Tonle Chhmar Ramsar Site
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CFi	Community Fisheries
CI	Conservation International
CPA	Community Protected Areas
DoAFF	Department of Agriculture, Forestry and Fishery
DoH	Department of Health
DoP	Department of Planning
DoT	Department of Tourism
DoYES	Department of Youth, Education and Sport
FACT	Fisheries Action Coalition Team
FCAs	Fish Conservation Areas
FiA	Fisheries Administration
GDNPA	General Directorate of Natural Protected Area
GHG	Green House Gas
IBBRI	Indo-Burma Ramsar Regional Initiative
IKI	International Climate Initiative
ICEM	International Center for Environmental Management
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LMB	Lower Mekong Basin
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoE	Ministry of Environment
NGO	Non-Governmental Organization
NL/BL	NatureLife Cambodia / BirdLife International
NTFPs	Non-Timber Forest Products
PDoAFF	Provincial Department of Agriculture, Forestry and Fisheries
PDoE	Provincial Department of Environment
SSRS	Stung Sen Ramsar Site
TSBR	Tonle Sap Biosphere Reserve
UNESCO	United Nation Education Scientific and Cultural Organization
VAs	Vulnerability Assessments
WA	Wildlife Alliance
WRRT	Wildlife Rapid Rescue Team of MAFF & WA

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EXECUTIVE SUMMARY

Stung Sen is the fifth and newest Ramsar Site designated in Cambodia (2018), and one of the three core areas of the Tonle Sap Biosphere Reserve (TSBR), since it was established in 2001. Stung Sen Ramsar Site (SSRS) covers an area of 9,293 hectares of flooded forests, shrublands and grasslands adjacent to the Tonle Sap Lake and the Stung Sen River in Kampong Thom province.

The Tonle Sap flooded habitats store inordinate amounts of carbon in their water-logged environment with slow decomposition rates. The Tonle Sap floodplain reserves have been identified among the most vital global “irrecoverable carbon” storage sites, which are vulnerable to release from human activity, and if lost could not be restored by 2050, when the world needs to achieve net-zero emissions to avoid the most catastrophic consequences of climate change (Goldstein *et al.,* 2020).

Climate in SSRS is dominated by tropical monsoons which bring about two marked seasons, a wet season of high precipitation from December to May, and a dry season with reduced rainfall and high temperatures from June to November. The hydrology of the site is determined by rainfall, the flow of the Stung Sen River and the annual flood pulse which fills the Tonle Sap Lake and its floodplain, inundating SSRS completely during the wet season. In the dry season, water remains only in scattered pools, streams and the flooded forests contiguous with the Tonle Sap Lake. SSRS harbors four types of wetland habitats: open water near the lake and in the dry season pools and waterways, flooded forests, flooded shrublands and flooded grasslands.

SSRS provides vital habitats for a variety of key species, including resident black fish and eels, seasonal grey fish and migrant white fish and megafish such as Critically Endangered giant barb (*Catlocarpio siamensis*). SSRS is a noteworthy site for large water birds such as lesser adjutant (*Leptoptilos javanicus*), spot-billed pelican (*Pelecanus philippensis*) and Asian openbill (*Anastomus oscitans*), as well as for grey-headed fish-eagle (*Icthyophaga ichthyaetus*). SSRS also provides essential refuge for one of the rarest otter species in the world, the Endangered hairy-nosed otter (*Lutra sumatrana*); one primate whose global stronghold is Cambodia, the Endangered Indochinese silvered langur (*Trachypithecus germaini*); and possibly one cat species which has become very rare in the region, the Vulnerable fishing cat (*Prionailurus viverrinus*). Economically important water snakes and highly threatened turtles such as Critically Endangered yellow-headed temple turtles (*Heosemys annandalii*) find crucial breeding grounds in SSRS as well.

Five villages and one sub-village are situated nearby SSRS, close to the Tonle Sap Lake and along the mainstream of the Stung Sen River. In total 1,164 households with a population of 5,252 people live right next to SSRS. The main income source in the area are fisheries, in addition to some seasonal vegetable farming and small-scale aquaculture. Besides fish, water snakes and molluscs (*Pila* spp) complement the fisheries income. Local households also generate income through fish processing and other fisheries related activities such as fixing nets, which are mainly carried out by women. The important roles played by women in fisheries however, have not been paid enough attention to by the sector (FiA, 2015). Around 70% of the population of one of the villages are migrants of Vietnamese origin who are at a disadvantage when it comes to accessing community decision-making, services and opportunities due to language barriers. During interviews they also reported to be less knowledgeable about fishing techniques, such as constructing different types of fish traps, than Khmer fishers.

SSRS wetlands and key species are threatened by a variety of human activities: agricultural encroachment advances on the northern portion; electro-fishing, use of bag nets and other illegal fishing activities occur throughout the site; forest fires are often provoked to clear for agriculture or to find scattered water buffaloes; invasive species such as *Mimosa pigra*, water hyacinth (*Eichhornia crassipes*) and golden apple snails (*Pomacea* spp.) are damaging flooded habitats; and poaching threatens mammal, bird and reptile species. In addition, water storage operations on the mainstream of the Mekong River have caused substantially lower-than-normal flood pulse volumes and durations during 2019, 2020 and 2021 (MRC, 2022) threatening the dynamics of the entire ecosystem.

Climate change projections for 2050 based on moderate emissions scenarios, estimated that maximum temperatures in dry season will increase to 35ºC and total average annual rainfall may increase from 1,249 mm/year to 1,381 mm per year, increasing both in wet and dry seasons. Rainfall will become more variable and irregular throughout the year, and extreme weather events such as storms and strong winds will increase in number and intensity.

Current paths however, indicate that the high-emission scenarios or “business as usual” might be more appropriate to estimate climate change impacts on the short term. According to these, by 2030, maximum temperatures in the dry season in SSRS may rise to 34ºC, and rainfall projections are becoming even more uncertain, with some models predicting up to 12% increase and others, up to 7% decrease.

The open water and flooded forest and grassland habitats in SSRS are highly vulnerable to the impacts of climate change. Higher temperatures, increased droughts and irregular rainfall will affect the extent of flooded habitats during the wet season; in the dry season they will affect open water depth and quality, and intensify the severity of forest fires. Strong winds in late dry season, mixing in poor quality water in shallow pools will increase the risk of mass fish death events. Only flooded shrubland habitats are more resilient to climate change impacts, but these may promote further advance of invasive shrub *Mimosa pigra*.

The combination of the climate change effects (already being felt in SSRS), and water infrastructure operations severely restricting the flow of the Mekong River and resulting in low water volumes and short duration of reversal of the flood pulse to the Tonle Sap wetlands, as experienced in the last three years, could spell ecological disaster for these critical habitats.

Among key species, eels, black fish and grey fish can withstand drier environments and take advantage of their ability to move overland to find refuge, making them more resilient to the impacts of climate change. White fish and flagship megafish giant barb (*Catlocarpio siamensis*) need higher quality water conditions and are more dependent on the extent of flooded habitats available, rendering them highly vulnerable to climate change. Wetland birds already suffering population declines such as the Near Threatened spot-billed pelicans (*Pelecanus philippensis*), and grey-headed fish-eagles (*Icthyophaga ichthyaetus*) are highly vulnerable to the loss and degradation of wetland habitats projected under climate change. Hairy-nosed otters (*Lutra sumatrana*) and Indochinese silvered langurs (*Trachypithecus germaini*) are globally Endangered and highly vulnerable to the impact of climate change on SSRS habitats. Fishing cats (*Prionailurus viverrinus*), if they still inhabit or re-colonize SSRS, would have more adaptive capacity and resilience to climate change. Turtles, such as Critically Endangered yellow-headed temple turtle (*Heosemys annandalii*) are dependent on temperature for sex determination which means climate change may skew sex ratios; additionally losing dry season pool breeding habitats makes them highly vulnerable.

Local communities have experienced drought, high temperatures, storms and strong winds in recent years, but the most significant effects of climate change are related to the reduction of the fish catch, which directly impacts livelihoods. In the last three years, due to the combination of climate change and water infrastructure operations, the fish catch has declined dramatically in SSRS and local community incomes are deeply affected, with more people taking up loans and temporary jobs in cities to survive. Increasing temperatures and water pollution from agricultural runoff upstream of the Stung Sen River have increased the incidence of disease and mass death of fish in household aquaculture, leading to further income losses.

Climate change adaptation planning in SSRS hinges on conserving and actively restoring flooded habitats and species, and local communities are keenly aware of this need. These activities also include finding effective strategies to remove invasive species and mitigate the impact of forest fires. The development of alternative sources of income, such as more and better managed aquaculture and other livestock production, are also important to local communities in order to reduce dependence and pressure on wetland resources. Other sources of alternative income may lay in the development of the eco-tourism potential of the area and income generation from water hyacinth. Strengthening the capacity and resources available to community-based approaches, such as Community Fisheries (CFi) and Community Protected Areas (CPA) for fisheries and conservation management, and increasing investment through carbon schemes and other sources for decisive, active restoration actions, will be the best way forward to combat the impacts of climate change in SSRS.

សេចក្តីសង្ខេប

ស្ទឹងសែនត្រូវបានកំណត់ជាតំបន់ថ្មីបំផុតស្ថិតក្នុងតំបន់រ៉ាមសារទី៥ នៅក្នុងប្រទេសកម្ពុជា និងជាតំបន់ស្នូលមួយក្នុងចំណោមតំបន់ស្នូលទាំងបី នៃតំបន់បម្រុងជីវៈមណ្ឌលបឹងទន្លេសាប (TSBR) ដែលត្រូវបានបង្កើតឡើងក្នុងឆ្នាំ ២០០១។ តំបន់រ៉ាមសារស្ទឹងសែនបានគ្របដណ្តប់លើផ្ទៃដីចំនួន ៩,២៩៣ ហិចតា នៃព្រៃលិចទឹក តំបន់ព្រៃទាបៗ និងតំបន់វាលស្មៅភ្ជាប់រវាងបឹងទន្លេសាបនិងស្ទឹងសែនដែលស្ថិតក្នុងខេត្តកំពង់ធំ។ តំបន់ទីជម្រកព្រៃលិចទឹកក្នុងបឹងទន្លេសាបស្តុកទុកបរិមាណកាបូនច្រើនដែរនៅក្នុងបរិស្ថានលិចទឹកជាមួយ និងអត្រាការរលាយយឺត។ តំបន់លិចទឹកក្នុងបឹងទន្លេសាបត្រូវបានគេកំណត់អត្តសញ្ញាណថាជាតំបន់ដែលមានសារៈសំខាន់បំផុតជាសកលដែលជាកន្លែងផ្ទុកទុក "កាបូនដែលមិនអាចទាញយកមកវិញបាន" ហើយវាងាយរងគ្រោះដោយសារសកម្មភាពមនុស្ស ប្រសិនបើបាត់បង់គឺមិនអាចស្តារឡើងវិញបាននោះទេនៅក្នុងឆ្នាំ ២០៥០ នៅពេលដែលពិភពលោកត្រូវតែសម្រេចឲ្យបាននូវភាពកម្រិត សូន្យនៃការបំភាយឧស្ម័នដើម្បីជៀសវាងពីផលវិបាកមហន្តរាយនៃការប្រែប្រួលអាកាសធាតុ។

អាកាសធាតុក្នុងតំបន់រ៉ាមសារស្ទឹងសែនគឺគ្របដណ្តប់ដោយខ្យល់មូសុងត្រូពិចដែលមានពីររដូវ គឺរដូវវស្សាដោយមានភ្លៀងធ្លាក់ខ្លាំងគិចចាប់ពី ខែធ្នូ រហូតដល់ខែឧសភា ហើយរដូវប្រាំងមានសីតុណ្ហភាពក្តៅខ្លាំងចាប់ពី ខែមិថុនា ដល់ខែ វិច្ឆិកា។ ជារាសាស្ត្ររបស់តំបន់រ៉ាមសារស្ទឹងសែនត្រូវបានកំណត់ដោយទឹកភ្លៀងការហូររបស់ទន្លេស្ទឹងសែន និងទឹកជំនន់ប្រចាំឆ្នាំដែលហូរទៅចាក់បំពេញបឹងទន្លេសាប និងតំបន់លិចទឹកស្ថិតជុំវិញបឹងទន្លេសាបដែលតំបន់រ៉ាមសារស្ទឹងសែនគ្របដណ្តប់ដោយទឹកទាំងស្រុងនៅក្នុងរដូវវស្សា។ ក្នុងរដូវប្រាំង ទឹកមានតែនៅក្នុងតាមប្រលាយ អូរ ត្រពាំង និងព្រៃលិចទឹកដែលជាប់គ្នាជាមួយបឹងទន្លេសាបប៉ុណ្ណោះ។ ក្នុងតំបន់រ៉ាមសារស្ទឹងសែនមានផ្ទុកតំបន់ទីជម្រកចំនួនបួនប្រភេទខុសគ្នាៗដូចជា៖ ១.តំបន់ទីជម្រកបើកចំហដែលស្ថិតនៅក្បែរបឹងទន្លេសាបដែលជាអាងទឹកដ៏ធំនៅក្នុងរដូវប្រាំ ២.តំបន់ព្រៃលិចទឹក ៣.តំបន់ព្រៃទាបលិចទឹក ៤.តំបន់វាលស្មៅលិចទឹក។

តំបន់រ៉ាមសារស្ទឹងសែនបានផ្តល់នូវទីជម្រកដ៏សំខាន់សម្រាប់ប្រភេទសត្វសំខាន់ៗជា ច្រើនប្រភេទរួមទាំងប្រភេទត្រីខ្មៅ អន្ទង់ និង តាមរដូវ ដូចជា ប្រភេទត្រីប្រផេះ ត្រីស និងរួមទាំងត្រីចំណាកស្រុកដូចជាត្រីដែលជិតផុតពូជ *Catlocarpio siamensis* ។ តំបន់រ៉ាមសារស្ទឹងសែនក៏ផ្តល់ទីជម្រកយ៉ាងសំខាន់ផងដែរសម្រាប់ប្រភេទសត្វស្លាបទឹកធំៗដូចជា Lesser Adjutant (*Leptoptilos javanicus*), Spot-billed Pelican (*Pelecanus philippensis*) និង Asian Openbill (*Anastomus oscitans*) ហើយក៏ដូចជាសត្វត្មាតក្បាលប្រផេះ(*Icthyophaga ichthyaetus*) ផងដែរ។ បន្ថែមពីនោះទៀត តំបន់រ៉ាមសារស្ទឹងសែនផ្តល់ជាទីជម្រកយ៉ាងសំខាន់បំផុតសម្រាប់ប្រភេទសត្វកម្រលើពិភពលោកសម្រាប់ជ្រកកោនដូចជាប្រភេទសត្វភេរវាមច្រមុះ ដែលដឹងថាជិតផុតពូជ (*Lutra sumatrana*), ប្រភេទសត្វស្វាដែលជិតផុតពូជ Silvered Langur (*Trachypithecus germaini*) និងប្រហែលជាកន្លែងទីជម្រកសម្រាប់ប្រភេទខ្លាត្រី (*Prionailurus viverrinus*) ដែលជាប្រភេទសត្វកំពុងកម្របំផុត និងងាយរងគ្រោះបំផុតនៅក្នុងតំបន់។ ប្រភេទសត្វពស់ទឹកដែលមានសារៈសំខាន់សម្រាប់សេដ្ឋកិច្ច និងប្រភេទអណ្តើកដែលបានចាក់ទុកថារងការគំរាមកំហែងខ្លាំងដូចជាអណ្តើកក្បាលលឿង (*Heosemys annandalii*) ត្រូវបានរកឃើញថានៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនគឺជាកន្លែងបន្តពូជយ៉ាងសំខាន់បំផុតរបស់ពួកវា។

មានភូមិចំនួនប្រាំ និងភូមិរងមួយស្ថិតនៅជិតតំបន់រ៉ាមសារស្ទឹងសែនក្បែរបឹងទន្លេសាប និងតាមបណ្តាយទន្លេស្ទឹងសែនដែលមានចំនួនគ្រួសារសរុប ១,១៦៤ និងប្រជាជនសរុប ៥,២៥២នាក់។ ប្រភពចំណូលសំខាន់របស់ប្រជាជនដែលរស់ក្នុងតំបន់នោះគឺការនេសាទ និងប្រកបមុខរបរបន្ទាប់ បន្សំមួយចំនួនទៀតមានដូចជា ការដាំបន្លែខ្លះៗ ធ្វើកសិកម្មកំឡុងពេលរដូវប្រាំង និងវារីវប្បកម្មបែបខ្នាតតូច។ ក្រៅពីការនេសាទត្រី នេសាទសត្វពស់ទឹក និងមានការប្រមូលខ្យងសម្រាប់បំពេញបន្ថែមប្រាក់ចំណូលក្នុងគ្រួសារ ប្រជាពលរដ្ឋក៏បង្កើនប្រាក់ចំណូលបន្ថែមទៀតតាមរយៈការកែច្នៃត្រី ការជួសជុលសំណាញ់ដែលភាគច្រើនគឺជាស្ត្រីជាអ្នកធ្វើ។ ប៉ុន្តែទោះជាយ៉ាណា តួនាទីសំខាន់នៃការចូលរួមរបស់ស្ត្រីក្នុងវិស័យជលផលគឺនៅតែមិនទាន់មានភាពយកចិត្តទុកដាក់គ្រប់គ្រាន់នៅឡើយទេ។ ប្រជាជនមានប្រមាណ ៧០% ស្ថិតក្នុងភូមិមួយត្រូវបានដឹងថាជាជនចំណាកស្រុកដែលមានដើមកំណើតមកពីប្រទេសវៀតណាមហើយដែលមានភាពលំបាកនៅពេលចូលរួមប្រជុំនិយាយអំពីការសម្រេចចិត្តក្នុងសហគមន៍ សេវាកម្ម និងឱកាសបញ្ចេញមតិដោយសារភាពពិបាកក្នុងការប្រើប្រាស់ភាសា ព្រមទាំងពួកគេមានបច្ចេកទេសនេសាទាបជាងប្រជាជនជាដើមកំណើតខ្មែរ។

តំបន់រ៉ាមសារស្ទឹងសែន និងប្រភេទសំខាន់ៗក្នុងតំបន់ត្រូវបានកំពុងគំរាមកំហែងដោយសារសកម្មភាពរបស់មនុស្សផ្សេងៗគ្នាដូចជា៖ ការទន្ទ្រានដីធ្វើកសិកម្ម ការទន្ទ្រានកាន់កាប់ដីនៅភាគខាងជើង ការនេសាទដោយប្រើឧបករណ៍អគ្គិសនីឆក់ ការប្រើប្រាស់សំណាញ់ពទ្ធ័ និងការប្រើប្រាស់ឧបករណ៍ខុសច្បាប់ជាច្រើនផ្សេងៗទៀត។ នៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនក៏មានកត្តាគំរាមកំហែងផ្សេងទៀតដូចជា ភ្លើងឆេះព្រៃបានកើតឡើងញឹកញាប់ ការរាតត្បាតប្រភេទចង្រៃបន្លាអុយយ៉ាស ប្រភេទខ្យងផ្លែប៉ោមមាស និងកំប្លោកដែលបានកំពុងគំរាមកំហែងទីជម្រកព្រៃលិចទឹក ការបរបាញ់ថនិកសត្វ បក្សី និងសត្វល្មូន។ លើសពីនេះទៅទៀត ការស្តុកទឹកច្រើនហួសនៅតាមដងទន្លេមេគង្គបានបណ្តាលឲ្យមានទឹកជំនន់ទាបជាធម្មតានៅក្នុងកំឡុងឆ្នាំ ២០១៩, ២០២០ និង ២០២១ ដែលបានគំរាមកំហែងដល់សក្តានុពលនៃប្រពន្ធ័អេកូឡូស៊ីនៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនទាំងមូល។

ការព្យាករណ៍ស្តីពីការប្រែប្រួលអាកាសធាតុសម្រាប់ឆ្នាំ ២០៥០ ដោយផ្អែកលើសេណារីយ៉ូនៃការបំភាយកម្រិតមធ្យមរបស់ឧស្ម័ន បានប៉ាន់ស្មានថាកម្រិតអតិបរិមារបស់សីតុណ្ហភាពនៅក្នុងរដូវប្រាំងនឹងកើនឡើងដល់ ៣៥អង្សា ហើយបរិមាណទឹកភ្លៀងប្រចាំឆ្នាំជាមធ្យមអាចកើតឡើងពី ១.២៤៩ មីលីម៉ែត្រក្នុងមួយឆ្នាំដល់ ១.៣៨១ មីលីម៉ែត្រក្នុងមួយឆ្នាំ ដែលកើនទាំងនៅក្នុងរដូវវស្សា និងរដូវប្រាំង។ ភ្លៀងធ្លាក់នឹងមានភាពប្រែប្រួលមិនទៀងទាត់ពេញមួយឆ្នាំ ហើយមានព្រឹត្តិការណ៍អាកាសធាតុធ្ងន់ធ្ងរកើតឡើងដូចជា ៖ ខ្យល់ព្យុះ ខ្យល់បោកបក់ខ្លាំង នឹងកើតឡើងជាញឹកញាប់។ ទោះជាយ៉ាងណាក៏ដោយ មានការសិក្សាបច្ចុប្បន្នបានបង្ហាញថាសេណារីយ៉ូដែលបញ្ចេញឧស្ម័នខ្ពស់គឺសមស្របក្នុងការប៉ាន់ប្រមាណផលប៉ះពាល់នៃការប្រែប្រួលអាកាសធាតុក្នុងរយៈពេលខ្លី។ យោងតាមរយៈការសិក្សាទាំងនេះ នៅក្នុងឆ្នាំ ២០៣០ អតិបរមាសីតុណ្ហភាពនៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនក្នុងរដូវប្រាំងអាចកើនឡើងដល់ ៣៤ អង្សា ហើយការព្យាករណ៍ទឹកភ្លៀង គឺស្ថិតក្នុងសភាពមិនទាន់ច្បាស់លាស់ដែលមានម៉ូឌែលខ្លះបានផ្តល់ការប៉ាន់ស្មានថាកើនឡើងដល់ ១២% និងថយចុះរហូតដល់ ៧%។

តំបន់ទីជម្រកបើកចំហទឹក តំបន់ទីជម្រកព្រៃលិចទឹក និងតំបន់ទីជម្រកវាលស្មៅ ដែលស្ថិតនៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនត្រូវ បានដឹងថាមានសភាពងាយរងគ្រោះយ៉ាងខ្លាំងដែលបណ្តាលមកពីការប្រែប្រួលអាកាសធាតុ។ សីតុណ្ហភាពកាន់តែខ្ពស់ ភាពរាំងស្ងួតកើនឡើង និងមានទឹកភ្លៀងធ្លាក់មិនទៀងទាត់ ដែលជាមូលហេតុចំបងប៉ះពាល់ដល់គុណភាពតំបន់ទីជម្រកបើកចំហទឹក និងបង្កឲ្យមានភ្លើងឆេះព្រៃ។ កំឡុងពេលចុងរដូវប្រាំងមានខ្យល់បោកបក់ខ្លាំង រួមផ្សំជាមួយទឹកគ្មានគុណភាពដែលជាមូលហេតុធ្វើឲ្យមានហានិភ័យនៃព្រឹត្តិការណ៍ងាប់ត្រីដ៏ច្រើននៅតាមត្រពាំង។ មានតែតំបន់ទីជម្រកព្រៃទាបលិចទឹកប៉ុណ្ណោះដែលធន់ទៅ នឹងបម្រែបម្រួលអាកាសធាតុ ប៉ុន្តែវាជាទីជម្រកដែលមានការជំរុញឲ្យមានការដុះរីករាលដាលនៃដើមបន្លាអុយយ៉ាស។ ការរួមបញ្ចូលគ្នានៃផលប៉ះពាល់នៃការប្រែប្រួលអាកាសធាតុដែលកំពុងកើតមាននៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែន និងការកសាងហេដ្ឋារចនាសម្ព័ន្ធក៏ដូចជាប្រព័ន្ធធារាសាស្ត្រ គឺបានប៉ះពាល់ដល់ការរារាំងទឹកហូរនៃទន្លេមេគង្គ ដែលជាលទ្ធផលធ្វើឲ្យមានបរិមាណទឹកទាប និងរយៈពេលខ្លីនៃការហូរទៅកាន់តំបន់ដីសើមទន្លេសាបដូចដែលបានជួបប្រទះក្នុងរយៈពេលបីឆ្នាំចុងក្រោយនេះ។ តាមរយៈសកម្មភាពខាងលើនេះ គឺជាមូលហេតុគ្រោះមហន្តរាយដែល អាចបំផ្លាញទីជម្រកប្រពន្ធ័អេកូឡូស៊ីដ៏សំខាន់ទាំងនេះ។ ក្នុងចំណោមប្រភេទសត្វស្លាសំខាន់ៗ ប្រភេទសត្វអន្ទង់ ប្រភេទត្រីពណ៌ខ្មៅ និងត្រីពណ៌ប្រផេះ គឺពួកវាមានសមត្ថភាពទប់ទល់នឹងបរិស្ថានរាំស្ងួត និងមានសមត្ថភាពអាចធ្វើការផ្លាស់ទីដើម្បីរកកន្លែងទីជម្រកសុវត្ថិភាពជ្រកកោន ដែលជាលទ្ធផលធ្វើឲ្យសត្វប្រភេទទាំងនេះមានភាពធន់ទៅនឹងផលប៉ះពាល់ការប្រែប្រួលអាកាសធាតុ។ ប្រភេទត្រីពណ៌ស និងប្រភេទត្រីកាបធំ (*Catlocarpio siamensis*) ត្រូវការទីជម្រកដែលមានទឹកមានគុណភាពល្អខ្ពស់ និងតំបន់លាតសន្ធឹងទឹកច្រើន ដែលជាហេតុធ្វើឲ្យត្រីប្រភេទទាំងនេះងាយរងគ្រោះខ្លាំងទៅនឹងការប្រែប្រួលធអាកាសធាតុ។ ប្រភេទសត្វស្លាបនៅតំបន់ដីសើមត្រូវបានដឹងហើយថាមានការថយចុះចំនួនប៉ូពុយឡាស្យុយដូចជាប្រភេទ *Pelecanus philippensis* និងប្រភេទ *Icthyophaga ichthyaetus* ដែលគឺជាប្រភេទសត្វស្លាបដែលងាយរងគ្រោះខ្លាំងដែលបង្កដោយការបាត់បង់ និងការវិចវិលនៃទីជម្រកដីសើមដែលត្រូវបានព្យាករណ៍នៅក្រោមការប្រែប្រួលអាកាសធាតុ។ ប្រភេទសត្វភេពោមច្រមុះ (*Lutra sumatrana*) និងប្រភេទសត្វស្វា (*Trachypithecus germaini*) គឺជាប្រភេទសត្វរងការគំរាមកំហែងទូទាំងសកលលោកនិងងាយរងគ្រោះខ្លាំងទៅនឹងការប្រែប្រួលអាសធាតុដែលស្ថិតនៅក្នុងទីជម្រកតំបន់រ៉ាមសារស្ទឹងសែន។ ប្រភេទសត្វខ្លាត្រី (*Prionailurus viverrinus*) ប្រសិនបើមានឬធ្វើការដោះប្រលែងឡើងវិញទៅក្នុងទីជម្រកនៃតំបន់រ៉ាមសារស្ទឹងសែនគឺមាននឹងមានសមត្ថភាពសម្របខ្លួនបានច្រើន និងមានសមត្ថភាពធន់នឹងការប្រែប្រួលអាកាសធាតុបាន។ ប្រភេទសត្វអណ្តើកក្បាលលឿង (*Heosemys annandalii*) ដែលជិតផុតពូជគឺអាស្រ័យលើសីតុណ្ហភាពសម្រាប់ការកំណត់ភេទដែលមានន័យថាការប្រែប្រួលអាកាសធាតុអាចធ្វើឲ្យខូចសមាមាត្រនៃការកំណត់ភេទ ជាពិសេសអណ្តើកប្រភេទនេះងាយរងគ្រោះយ៉ាងខ្លាំងនៅពេលមានការបាត់បង់ត្រពាំងដែលជាកន្លែងទីជម្រកសម្រាប់បន្តពូជក្នុងកំឡុងពេលរដូវប្រាំង។

សហគមន៍នៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនបានជួបប្រទះនឹងគ្រោះរាំងស្ងួត សីតុណ្ហភាពក្តៅខ្លាំង ខ្យល់ព្យុះ និងខ្យល់បក់ខ្លាំង ប៉ុន្តែផលប៉ះពាល់ដ៏សំខាន់បំផុតនៃការប្រែប្រួលអាកាសធាតុ គឺបណ្តាលឲ្យមានការថយចុះបរិមាណទិន្នផលនេសាទត្រី ដែលបានប៉ះពាល់ដោយផ្ទាល់ដល់ជីវភាពរបស់ប្រជាជនរស់នៅក្នុងសហគមន៍។ នៅក្នុងរយៈពេលបីឆ្នាំចុងក្រោយនេះ ដោយសារតែការរួមបញ្ចូលគ្នានៃការប្រែប្រួលអាកាសធាតុ និងការកសាងប្រពន្ធ័ធារាសាស្ត្រ និងការធ្លាក់ចុះទិន្នផលនេសាទត្រីនៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនបានប៉ះពាល់យ៉ាងខ្លាំងដល់ការរកប្រាក់ចំណូលរបស់ប្រជាពលរដ្ឋក្នុងសហគមន៍ ដែលមានប្រជាពលរដ្ឋភាគច្រើនបានធ្វើការកម្ចីប្រាក់ និងការរកការងារបណ្តោះអាសន្ននៅទីក្រុង។ ការកើនឡើងសីតុណ្ហភាព និងការបំពុលទឹកចេញពីការធ្វើកសិកម្មនៅតាមដងស្ទឹងសែនបណ្តាលឲ្យមានកើនឡើងនូវអត្រាកើតជម្ងឺ និងការស្លាប់ត្រីដ៏លើសលុបនៅតាមផ្ទះចិញ្ចឹមត្រីដែលជាហេតុនាំឲ្យគ្រួសារបាត់ប្រាក់ចំណូលបន្ថែម។

ផែនការបន្សាំខ្លួនទៅនឹងការប្រែប្រួលអាកាសធាតុនៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែនបានផ្តោតលើការអភិរក្ស និងការស្តារឡើងវិញយ៉ាងសកម្មប្រភេទនូវទីជម្រកព្រៃលិចទឹក ប្រភេទសត្វ និងការដាស់តឿនការយល់ដឹងរបស់សហគមន៍មូលដ្ឋានអំពីតម្រូវការទាំងនេះ។ សកម្មភាពទាំងនេះក៏រួមបញ្ចូលនូវការស្វែងរកយុទ្ធសាស្ត្រដ៏មានប្រសិទ្ធភាពដើម្បីលុបបំបាត់ប្រភេទចង្រៃ និងការកាត់បន្ថយផលប៉ះពាល់នៃភ្លើងឆេះព្រៃ។ ការអភិវឌ្ឍន៍ប្រភពរកប្រាក់ចំណូលបន្ថែមមានដូចជាការគ្រប់គ្រងវារីវប្បកម្មឲ្យកាន់តែល្អប្រសើរជាងមុន និងបសុសត្វផ្សេងៗទៀតរួមទាំងផលិតកម្មចំពោះសហគមន៍មូលដ្ឋានផងដែរក្នុងការរួមចំណែកក្នុងដំណើរការកាត់បន្ថយលើការពឹងផ្អែកទាំងស្រុងលើធនធាននៅក្នុងតំបន់ដីសើម។ ប្រភពចំណូលផ្សេងៗទៀតមានដូច ជាការអភិវឌ្ឍន៍សក្តានុពលវិស័យទេសចរណ៍ធម្មជាតិក្នុងតំបន់ និងការបង្កើនប្រាក់ចំណូលបន្ថែមពីការកែច្នៃវត្ថុអនុស្សាវរីយ៍សម្រាប់លក់ដែលកែច្នៃចេញពីកំប្លោក។ ការពង្រឹងសមត្ថភាពធនធានដែលមានស្រាប់ និងសមត្ថភាពទាំងសហគមន៍តំបន់ការពារក្នុងការគ្រប់គ្រងជលផល សហគមន៍តំបន់ការពារការអភិរក្ស រួមទាំងការបង្កើនការវិនិយោគកាបូន និងប្រភពផ្សេងទៀតសម្រាប់សកម្មភាពស្តារឡើងវិញដែលជាមធ្យាបាយដ៏មានប្រសិទ្ធភាពក្នុងការប្រយុទ្ធប្រឆាំងនឹងផលប៉ះពាល់នៃការប្រែប្រួលអាកាសធាតុនៅក្នុងតំបន់រ៉ាមសារស្ទឹងសែន។

1. GENERAL INFORMATION

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

Wetland areas, which refers to marshes, rivers, mangrove, coral reefs, and other coastal and inland habitats, play many important roles within ecosystems. Wetlands provide clean water, water flow regulation, carbon storage and perform as natural buffer against erosion, floods, landslides as well as storms and other extreme weather events. The Lower Mekong Basin (LMB) spans over a total area of 606,000 km^2, and covers four countries, Cambodia, Lao PDR, Thailand and Viet Nam, with more than 60 million inhabitants. The Lower Mekong Basin region harbors rich natural resources, particularly forests, rivers, and wetlands which support the livelihoods of millions of people who directly depend on natural resources. However, wetland area is decreasing and losing ecosystem functions due to human activities including population pressure, infrastructure development, agricultural intensification, deforestation, overexploitation and mismanagement. Climate change is set to intensify impacts on habitats, species and livelihoods.

“Mekong WET: Building Resilience of Wetlands in the Lower Mekong Region”[1] (2017-2022) aims to build climate resilience by harnessing the benefits of wetlands in Cambodia, Lao PDR, Thailand, and Viet Nam. The project is funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). Mekong WET will help the four countries to address their commitments to the Ramsar Convention, an international treaty for the conservation and sustainable use of wetlands, and to achieve the Aichi Biodiversity Targets. Through its focus on wetland ecosystems, the project also supports governments in implementing National Biodiversity Strategies and Action Plans (NSBSAPs) under the Convention of Biological Diversity and pursuing their commitments on climate change adaptation and mitigation under the United Nations Framework on Climate Change.

Vulnerability Assessments (VAs) were conducted in ten Ramsar sites/wetland sites in the four LMB countries as the first step of a participatory adaptation planning process. The approach combined scientific assessments with participatory appraisals and dialogues with communities living at the sites and the authorities in charge of site management. For Cambodia, four sites were selected: Koh Kapik Ramsar Site in Koh Kong Province (KKRS), Boeung Prek Lapouv Protected Landscape situated in Takeo Province (BPL), Boeung Tonle Chhmar Ramsar Site (BTCRS) located in Kampong Thom Province and Stung Sen Ramsar Site, also located in Kampong Thom Province. This report presents the results of the vulnerability assessment for Stung Sen Ramsar Site (SSRS).

1.2 Objectives and setup of the study

The main objectives of the assessment were:

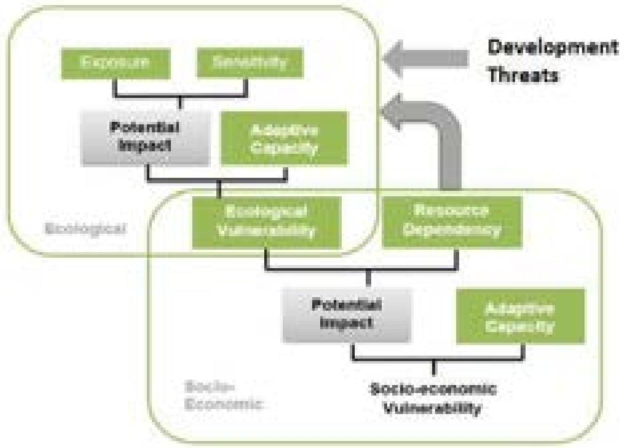
- To determine the vulnerability of ecosystems and livelihoods to the impacts of climate change.
- To identify options to address vulnerabilities and improve the resilience of wetlands and livelihoods to the impacts of climate change.

The assessment was carried out through two components: A description of the current situation and available knowledge of the wetland, and an assessment of climate change vulnerability of wetland habitats, species and livelihoods using the tools and methodologies developed by IUCN (IUCN, 2017) using a socio-ecological framework (Box 1). Livelihood vulnerability was assessment using the Village VA tool through a consultative process with key informants and local community members. The Habitat and Species VA tools were completed in consultation with experts as well as through primary research conducted by the SSRS VA team including a camera-trap survey, a questionnaire on presence and threats to mammal species in SSRS, and evaluation of habitats using remote sensing and ground-truthing. Finally, draft VA recommendations were validated through workshops run by members of a local Community Protected Area (CPA) group.

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

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

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



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

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

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

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

2. SITUATIONAL ANALYSIS

2. SITUATIONAL ANALYSIS

2.1 Description of the wetland

2.1.1 Location and site description

The Stung Sen Ramsar Site wetland is located along the southeastern shores of the Tonle Sap Lake and provides a unique natural habitat for a great variety of waterfowl, mammals and fishes. Stung Sen Ramsar Site covers an area of 9,293 hectares and it was recognized as the fifth Ramsar Site in Cambodia in 2018. SSRS lies within the Tonle Sap Biosphere Reserve (TSBR), which was successfully nominated as a UNESCO Biosphere Reserve in 1997 and established by Royal Decree of the Government of Cambodia in 2001. Three core areas are designated as Ramsar sites within TSBR: Prek Toal, Boeng Tonle Chhmar and Stung Sen (Figure 1). The Tonle Sap lake's unique dynamics are driven by an annual mono-modal flood pulse. When the monsoon peaks around November, the floodplain expands to an average maximum 12,000 km^2. This wetland ecosystem is highly productive, a vital nursery for many fish species and habitat for a variety of globally threatened species. The Stung Sen river is the biggest tributary to the Tonle Sap lake in the Mekong Basin of Cambodia. The water level of the Stung Sen river reaches at least 6 m during dry season and increases to 13 m during monsoon season (Nagumo *et al.,* 2013; 2015).

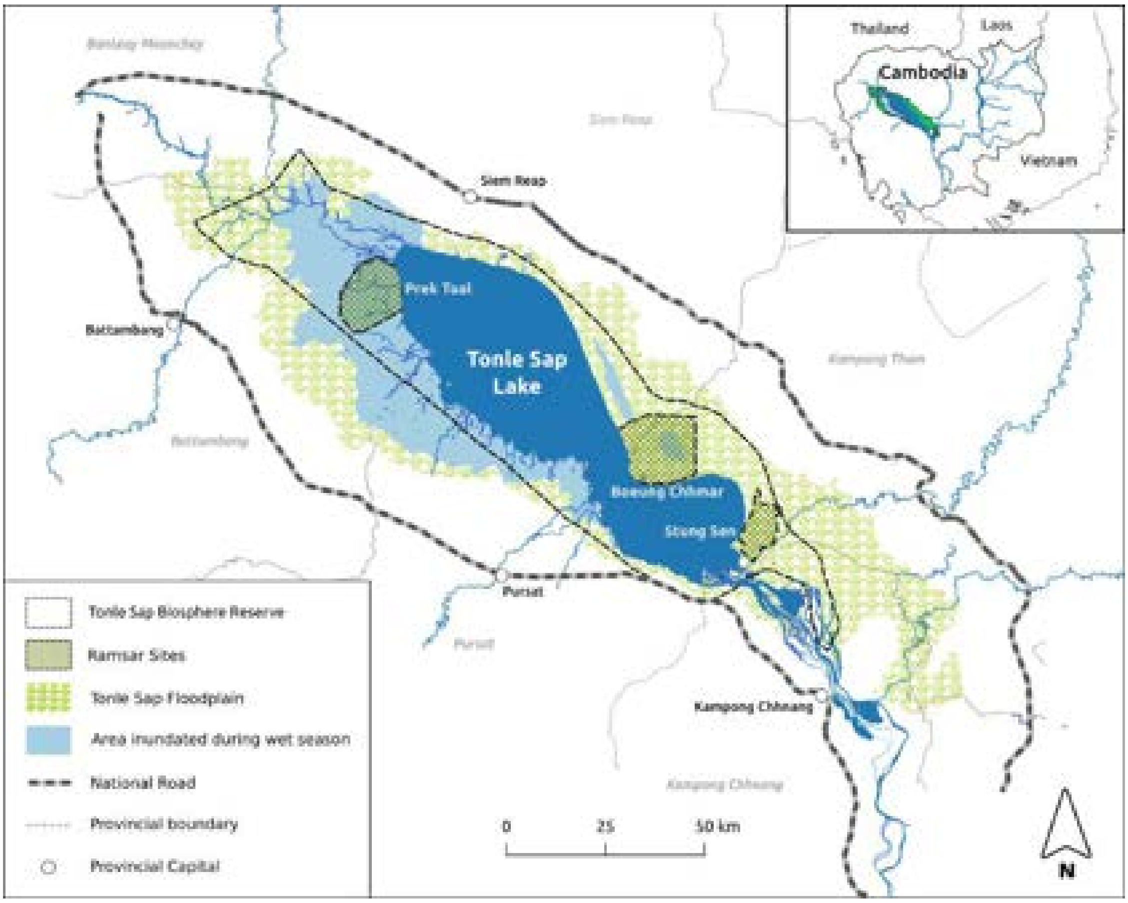


Figure 1. Tonle Sap Lake and floodplain, boundaries of TSBR and location of the three Ramsar sites.

The Tonle Sap flooded habitats store inordinate amounts of carbon in their water-logged environment with slow decomposition rates. The Tonle Sap floodplain reserves have been identified among the most vital global "irrecoverable carbon" storage sites (Figure 2), which are vulnerable to release from human activity, and if lost could not be restored by 2050, when the world needs to achieve net-zero emissions to avoid the most catastrophic consequences of climate change (Goldstein *et al.,* 2020). It is therefore of paramount importance at the global level to ensure the Tonle Sap flooded habitats are well conserved and maintain their capacity to store carbon.

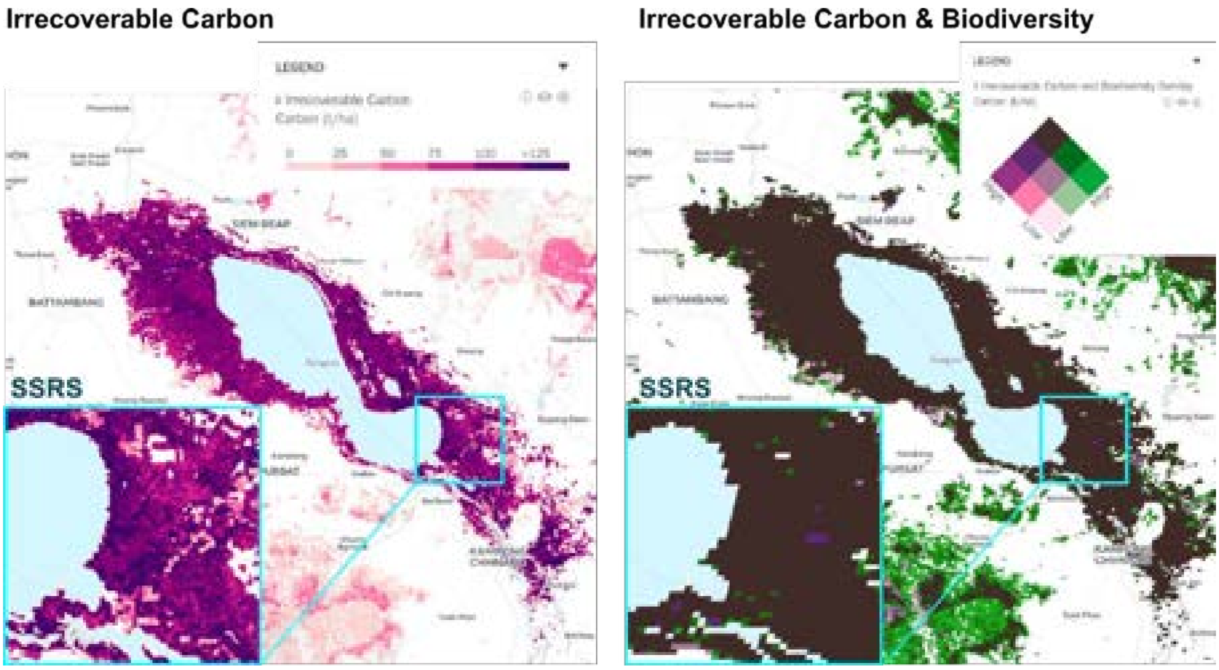


Figure 2. Irrecoverable carbon and overlay with Biodiversity on the Tonle Sap floodplain and SSRS (source: Resilience Atlas, Conservation International, 2022),

The Stung Sen wetland is very important for biodiversity conservation, and local livelihoods are highly dependent on harvesting aquatic resources (Chan and Mihara, 2018). High levels of biodiversity including many globally threatened species have been reported to be present Stung Sen Ramsar Site. According to the Stung Sen Core Area Tonle Sap Biosphere Reserve Management Plan 2008 – 2012 (MoE, 2007), TSBR supports up to 20 species of mammals, 200 species of birds, more than 107 species of fish, more than 30 species of reptiles, at least 5 species of amphibians, and more than 300 invertebrate species, many of which are expected to inhabit SSRS. The map of SSRS developed for the Ramsar site designation (Figure 3), shows the distribution of habitat types within the site.

Figure 3: Map of Stung Sen Ramsar Site (source: Ramsar). Below: Flooded forest and flooded grassland in SSRS.

[1] https://www.resilienceatlas.org/

2.1.2 Current and historic climate

Stung Sen Ramsar Site has a similar climate to other parts of Cambodia that are dominated by the tropical monsoon with wet and dry seasons. The wet season typically spans from May to October with southwest monsoon rains, and the dry season runs from November to April with northeast monsoon flows that bring both drier and cooler air. In Kampong Thom town, situated around 40 km from the center of SSRS, the monthly mean maximum temperature between 2002 and 2010 peaked in March/April at 35ºC, and was lowest from September to December at around 31ºC (Meynell *et al.*, 2019) (Figure 4).

The atmospheric temperature (AT) of the Tonle Sap Lake has increased significantly in the last two decades, with an average increase of 0.37ºC per decade between 2001 and 2018. Increasing atmospheric temperature is the main factor influencing warmer temperature of the Tonle Sap Lake surface water. Annual average atmospheric temperature of the Tonle Sap Lake increased from 27.30ºC to 28.56 ºC, with the lowest temperature recorded in 2008 (27.17ºC) and the highest atmospheric temperature recorded in 2016 (28.74ºC). Monthly atmospheric temperature increases from January to April and drops slowly from May, with the highest temperatures registered in April and and the lowest in January (Pan & Yang, 2021). Analyses of increase in atmospheric temperature in the Tonle Sap Lake by season indicate that the warming rate is highest (0.03ºC/year) between March and May (Pan & Yang, 2021). During dry season, temperature increases averaged 0.03ºC/year between 1988-2018 and number of warm days increased consistently, highly influenced by local climate trends driven by deforestation and agricultural development in the lake's watershed (Daly *et al.*, 2022). Temperature increases and rainfall deficits due to climate change, *El Nino* events and the impact of water storage on the flow of the Mekong are reported to have caused the intense drought experienced in the Lower Mekong Basin (LMB) in recent years (MRC, 2022 and references therein) (Figure 4A).

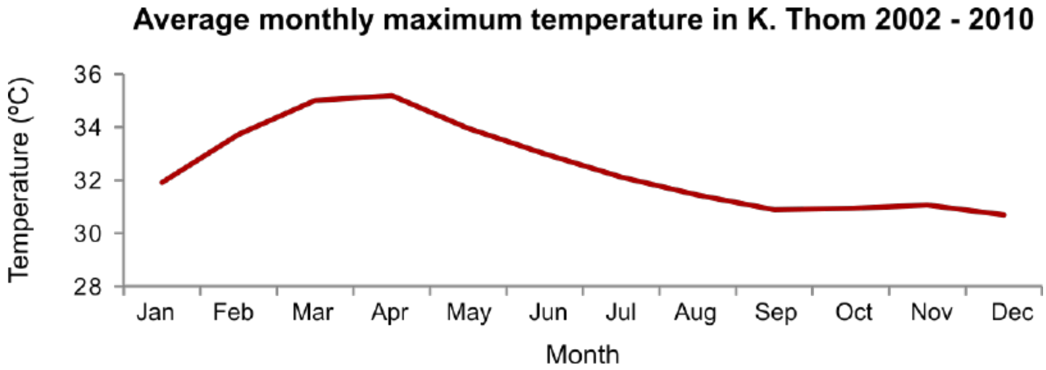


Figure 4. Monthly average temperature in Kampong Thom between 2000 and 2010 (source: Department of Water Resources and Metorology, Kampong Thom. Adapted from Meynell *et al.*, 2019).

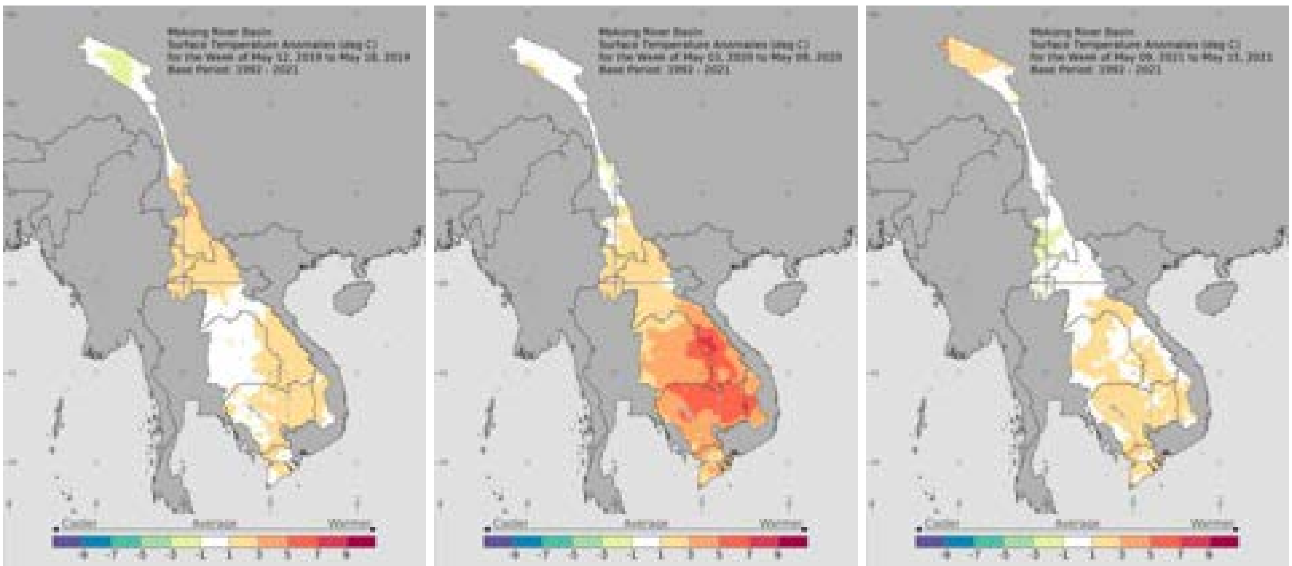


Figure 4A. Temperature anomalies in the LMB in May 2019, 2020 and 2021 (Mekong Dam Monitor. Stimson Center, 2022. https://www.stimson.org/project/mekong-dam-monitor/)

Several weather stations in Kampong Thom province have recorded rainfall data since 1920, showing an annual average rainfall of 1,481 mm, ranging between 1,300 and 1,900 mm, with a peak of 300 mm in September, and with December, January and February as the driest months (Meynell *et al.*, 2014, 2019) (Figure 5). The Climate Change Vulnerability Assessments of nearby wetland Boueng Tonle Chhmar (Meynell *et al.*, 2014) note that villagers reported rainfall had become erratic with wet seasons starting later and rainfall being heavier but lasting for shorter periods. In recent years, onset of wet season has become unpredictable with late dry seasons between 2014 and 2016 and early rains in 2017 and 2018. Local villagers in SSRS also reported experiencing irregular rainfall and drought between 2018 and 2021 (Figure 5A.)

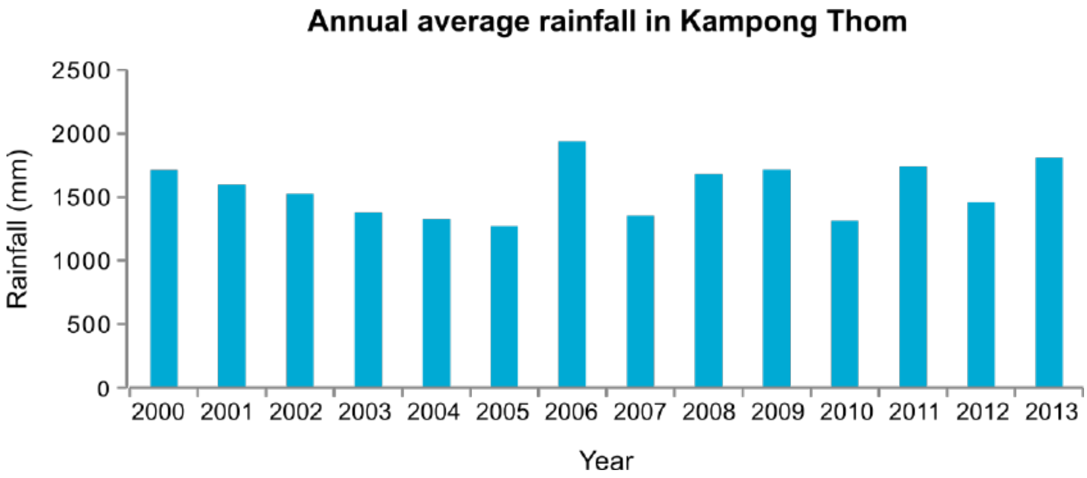


Figure 5. Annual average rainfall in Kampong Thom between 2000 and 2013 (source: Department of Water Resources and Metorology, Kampong Thom. Adapted from Meynell *et al.*, 2019).

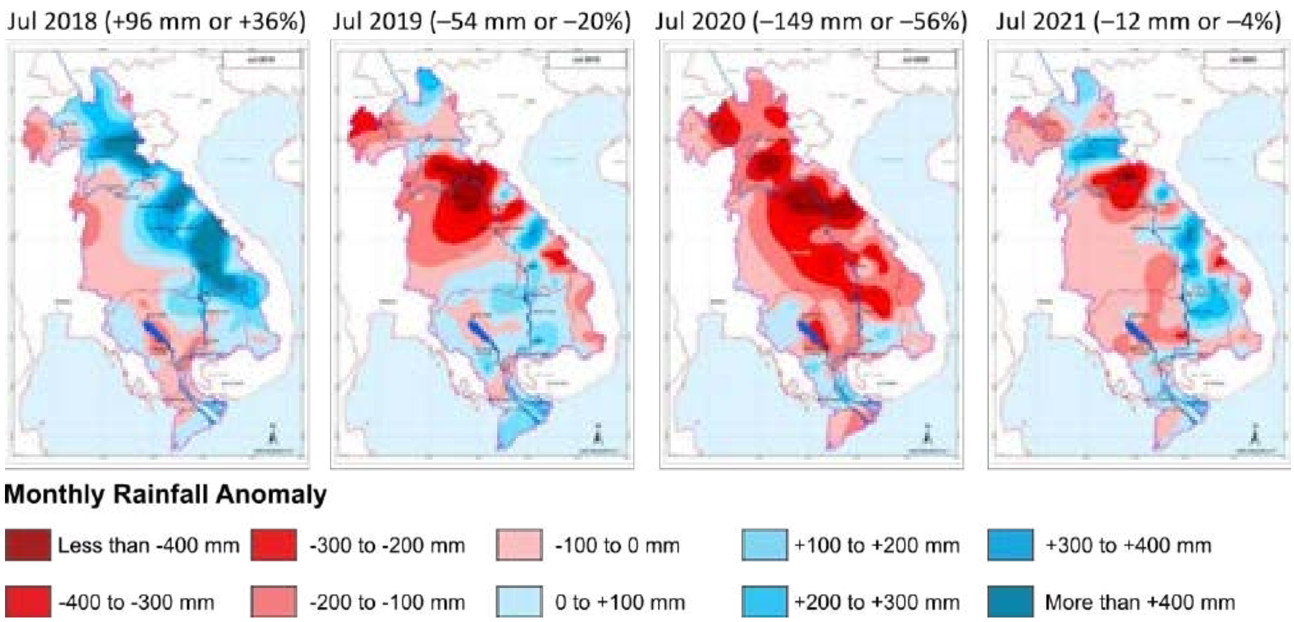


Figure 5A. Monthly rainfall anomaly in the LMB in July 2018, 2019, 2020 and 2021. Amount of rainfall in mm and ratio in % (source: MRC, 2022).

2.1.3 Hydrological characteristics

Stung Sen Ramsar Site is part of the Tonle Sap floodplain system and is strongly influenced by the water exchange between the Mekong River, the Stung Sen River and Tonle Sap Lake. The Tonle Sap Lake's water flows into the Mekong River through the Tonle Sap River during dry season, and water flows back to the Tonle Sap Lake during flood season (June to October) causing the floodplian surface area to swell from 2600 km^2 to 12000 km^2 (Oeurng *et al.*, 2019, Arias *et al.*, 2012). The Tonle Sap Lake's water level changes in different seasons, with an average depth of less than 2 m during dry season and up to 10 m during flood season. The surface area of the lake expands to cover an area more than 3 times larger than its area in dry season (Sabo *et al.*, 2017). The Stung Sen wetland in flood season is covered by water flowing from the Mekong mainstream contributing 57% (which is 52% from the Tonle Sap River and 5% received from overland flooding), 13% comes from precipitation, and 30% from tributaries of the Tonle Sap Lake, particularly the Stung Sen River which is the biggest tributary to the lake (Chan & Mihara, 2018; Oeurng *et al.*, 2019; Theara *et al.*, 2020). Water in the Stung Sen River comes mainly from the Stung Sen Basin and flows via Kampong Thom Province to the Tonle Sap Lake over a total length of 508 km (Nagumo *et al.*,2013). The Stung Sen wetland area is largely dry during the low water season, with water remaining only in scattered pools and watercourses, and completely flooded during the high-water season with only the tops of emergent trees remaining above water.

Over the last three years (2019, 2020 and 2021), the flow of the Mekong mainstream has decreased to levels not seen in more than 60 years. The flood pulse to the Tonle Sap Lake was delayed by nearly two months, carrying a considerably lower volume than the average between 2008 and 2017, and the high flow period lasted around four months (July to October) instead of five (June to October) (Figure 6. MRC, 2022). In August 2021, water levels in SSRS were significantly lower and less than 50% of the wetland was flooded. According to several scientific reports, the low and delayed flows of the Mekong River are caused by an unprecedented drought, climate change, an *El Niño* event and the impacts of water storage in large reservoirs in the Upper Mekong Basin (UMB) (MRC, 2022 and references therein).

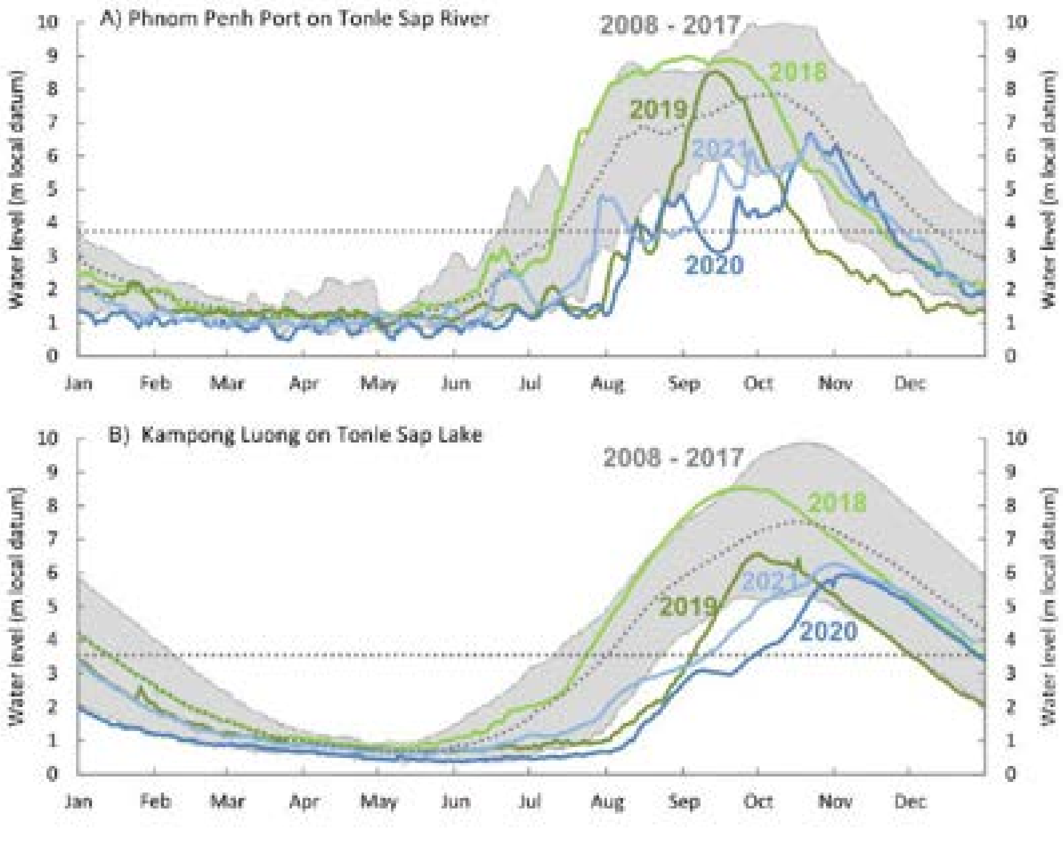


Figure 6. A) Characteristics of water level of the Tonle Sap Lake at the Phnom Penh Port, and B) at Kampong Loung on the Tonle Sap Lake (source: MRC, 2022, year legend added by the authors).

2.1.4 Wetland habitats

The wetland habitats of Stung Sen Ramsar Site are strongly influenced by the exchange of water between the Mekong River, the Stung Sen River and the Tonle Sap Lake, and particularly by the changes in water levels and the duration of the inundation period. Arias *et al*. (2012) showed that habitats and vegetation communities in the Tonle Sap floodplain were influenced by two main factors: human use of the ecosystem and the flood pulse. These factors lead to changing gradients of soil characteristics, and limiting areas cleared for agriculture subsequently impact the wetland, altering vegetation structure and plant species composition. Habitats within the Tonle Sap floodplain have been classified into six types underpinned by the hydrological flood extension and duration: open water area, gallery or flooded forest, seasonally flooded habitats (grasslands and shrublands), transitional habitats (agricultural land including abandoned fields), and rainfed habitats (wet season rice fields and village crops) (Arias *et al*., 2012). SSRS habitats comprise flooded forest, which covers areas flooded for up to 9 months of the year, seasonally flooded habitats, inundated for 1-5 months and transitional habitats which are also flooded for 1-5 months (Rundel, 1999, Bonheur, 2001). Open water areas are present near the Tonle Sap lake shores, and in the form of scattered permanent ponds and water courses (Figure 7).

The gallery forest or flooded forest is found along the right bank of the Stung Sen River and extends to the north and west. Gallery forest communities are generally flooded by 4-6 m of water for up to 8-9 months each year. Two tree species*,* *Barringtonia acutangula* and *Diospyros cambodiana* primarily dominate the flooded forest with accompanying woody lianas such as *Cambretum trifoliatum*, *Breynia rhamnoides*, *Acacia thailandica* and *Teracera sarmentosa (*Rundel, 2009). All of these plant species reduce their leaves when plants are submerged as the lake deepens and new leaves are produced rapidly when water recedes. The plants grow to produce flowers later, over several months with a peak in July and August (Rundel 2009). Woody plant species, *B*. *acutangula* and *C*. *trifoliatum* remain evergreen for 6-8 months each year (Campbell *et al*., 2006).

Figure 7: Floodplain of the Tonle Sap in Kampong Thom during October / November and May / June. Adapted from Balzer, 2002. Below: Open water habitat in SSRS near the Tonle Sap lake shore.

Seasonally flooded habitats (grasslands and shrublands) are generally found in soil that is not saturated with water during the dry season. These areas generally dominated by short tree or shrub woody species and form a semi-continuous canopy of deciduous species no more than 2-4 m in height (Rundel, 2009). The most common shrubland species are *Barringtonia acutangula*, *Barringtonia micrantha*, *Elaeocarpus griffithii*, *Elaeocarpus madropetalus*, *Hydnocarpus anthelminthicus*, and *Malotus anisopodum* (Rundel, 2009). Several common shrubland species can reach tree size in flooded forest habitats. Seasonal habitats also comprise of grasslands dominated by aquatic and floating plants, and shallow shoreline vegetation that supports dense mats of herbaceous plants 1-3 m tall or floating. The shallow shoreline is dominated by several king grasses or sedges including *Alocasia esculenta*, *Commelina salicifolia* (Commelinaceae), *Ipomoea aquatica* (Convolvulaceae), *Ipomoea chyseoides*, *Ludwigia adscendens* (Onagraceae), *Merremia hederacea* (Convolvulaceae) and *Polygonum barbatum* (Polygonaceae) (Campbell *et al*., 2006). The transitional habitats are flooded for 1-5 months and are dominated by abandoned agricultural land including former receding rice/floating rice.

Flooded forest with *Barringtonia acutangula*

Flooded grassland with *Polygonum barbatum*

Flooded shrubland

2.1.5 Key species

Fish

Stung Sen Ramsar Site supports a vital spawning ground for many fish species, including Critically Endangered Jullien golden carp (*Probarbus jullieni*), Critically Endangered giant carp (*Catlocarpio siamensis*), Critically Endangered Mekong giant catfish (*Pangasianodon gigas*) and Vulnerable small scale mud carp (*Cirrhinus microlepis*) (Davidson 2006 and references therein). The flood pulse ecosystem in Tonle Sap is considered to support a high average species richness from 40 up to 200 species depending on water depth, season and surface coverage. Fish diversity in Tonle Sap Lake is correlated to environmental conditions such as temperature, dissolved oxygen and neutral pH around 7 (MRC, 2021). Areas with a higher degree of inundation, combined with greater water depths provide significant habitats with suitable environmental conditions for both resident and migrating fish and drives greater fish species richness and diversity (Ngor *et al*., 2018). Fish species in Tonle Sap River and Lake are categorized into three groups based on their ecological attributes: black fish, grey fish and white fish.

- **Black fish:** Black fish species prefer mostly floodplain vegetation habitats and are adapted to high acidity and depleted oxygen waters, but count on the ability to move overland seeking fresh water bodies. Black fish species (floodplain residents) such as *Trichopodus trichopterus, Macrognathus siamensis, Oxyeleotris marmorata, Anabas testudineus, Clarias microcephalus*, C. *meladerma*, *C. batrachus*, as well as Channidae (Snakeheads) and Bagridae (some *Mystus* spp) are the dominant species known to permanently inhabit the Tonle Sap floodplain (Ngor *et al*., 2018). Black fish spend most of their life in lakes and swamps in floodplains adjacent to rivers and move to flooded areas during the flood season without longitudinal migrations upstream.
- **Grey fish:** Grey fish or floodplain spawning species have ecologically intermediate traits between the white and black fishes and are known to undertake short-distance lateral migrations between local tributaries and return to either the local river or stream channels during the dry season (MRC,2010). Floodplain spawners are known to grow fast to small adult sizes and some grey fish species such as *Henicorhynchus siamensis*, *Thynnichthys thynnoides* and *Dangila spilopleura,* play an important role as food for local consumption and are harvested in large quantities for traditional processing into fish sauce and *prahoc* (a popular local fermented fish paste). The floodplain spawner fish species found to be dominant in the Tonle Sap Lake include *Mystus mysticetus, Mystus singaringan, Labeo chrysophekadion, Labiobarbus lineatus, Osteochilus vittatus, Pristolepis fasciata, Parambassis wolffii, Yasuhikotakia modesta* (Ngor *et al*., 2018).
- **White fish:** White fish species perform longitudinal migrations between the Mekong mainstream and the Tonle Sap floodplain as well as their major tributaries. During the early wet season when water levels increase, white fish species move into the Tonle Sap Lake in order to grow and reproduce, and they return to the Tonle Sap and Mekong rivers when water starts to recede. White fish species include many fish species in the family Cyprinidae (*Cirrhinus microlepis*, *Hampala macrolepidota*, *Barbodes altus*, *Leptobarbus hoeveni*, *Osteochilus melanopleura*, *Morulius chrysophekadion*) and Notopteridae (*Notopterus chitala*) (Ngor *et al*., 2018).

Eels: Eels are nocturnal, carnivorous, facultative air-breather fish that are economically important for fisheries in Stung Sen. Three species of eel can be found in the Tonle Sap ecosystem: one true eel species, marbled eel (*Anguilla marmorata*), as well as two species of swamp eel, spiny eel (*Mastacembelus armatus*) and Asian swamp eel (*Monopterus albus*). Eel habitats include ponds, streams, canals, rice fields with both clear and turbid waters (Meynell *et al*., 2019).

Birds

The Tonle Sap floodplain provides essential habitats for many bird species, and is particularly important for waterbird species, harboring globally significant breeding colonies. Over 200 bird species, including around 25 species listed in the Threatened or Near Threatened categories on the IUCN Red List have been recorded in TSBR (Davidson, 2006; MoE, 2007; Meynell *et al.*, 2019). SSRS seems to be visited by water birds mainly in the non-breeding season (Van Zalinge *et al.*, 2012), and harbors important populations of Vulnerable lesser adjutant (*Leptoptilos javanicus*), Near Threatened spot-billed pelican (*Pelecanus philippensis*) and oriental darter (*Anhinga melanogaster*), as well as Asian openbill (*Anastomus oscitans*), cormorants and egrets (Table 1). The Stung Sen wetland is also an important site for Near Threatened grey-headed fish-eagle (*Icthyophaga ichthyaetus*) (NL/BL personal communication).

Table 1: Water bird species of conservation concern in TSBR and SSRS (Sources: MoE, 2007; Van Zalinge *et al.*, 2012)

Species	IUCN status	TSBR Significance	Presence in SSRS (2009-2010)
Greater adjutant (*Leptoptilos dubius*)	**Endangered**	Second largest colony in the world (>10% of global population)	Recorded during flood season August-October
Lesser adjutant (*Leptoptilos javanicus*)	**Vulnerable**	Largest colony in the world (20% of global population)	Group size ranges from 1-4, recorded during non-breeding season, reach peak in October
Painted stork (*Mycteria leucocelphala*)	**Near Threatened**	Largest colony in Southeast Asia (20% of global population)	Found only 2 groups of 7 and 10
Spot-billed pelican (*Pelecanus philippensis*)	**Near Threatened**	Largest colony in the world (20% of global population)	Total of 246 records, with most sightings between August and October. Present all months except April and May.
Oriental darter (*Anhinga melanogaster*)	**Near Threatened**	Largest colony in Southeast Asia (>10% of global population)	Present all months, with a total of 281 records, and a high count of 40 birds in February and a few groups around 27 birds in August.
Asian openbill (*Anastomus oscitans*)	**Least Concern**	Population has more than 1% of Asian biogeographic population	A total of 342 were recorded, 317 during non-breeding season and 25 found during breeding season


Grey-headed fish-eagle (*Icthyophaga ichthyaetus*) with striped snakehead (*Channa striata*) in TSBR
Photo: Conservation International

Asian openbill (*Anastomus oscitans*)

Reptiles

The Tonle Sap Lake floodplain is considered as the single most essential wetland for reptile conservation in Southeast Asia and harbors up to 23 reptile species (Meynell *et al.,* 2019). Globally threatened species found in TSBR include Critically Endangered Siamese crocodile (*Crocodylus siamensis*) (not likely to persist in SSRS), Vulnerable Burmese python (*Python bivittatus*) and six species of freshwater turtle, particularly Critically Endangered yellow-headed temple turtle (*Heosemys annandalii*). Boeung Chhmar Ramsar site and Stung Sen Ramsar site hold important breeding areas for water snakes and turtles (Meynell *et al.*, 2019).

Water snakes are considered a highly valuable resource in TSBR because they are used as feed for crocodile farming as well as for human consumption, particularly in northern areas of the lake. Crocodile farming is not as common in southern areas of the lake but water snakes are harvested as part of fishing activities around SSRS. Water snakes are collected in June on the shoreline of the Tonle Sap Lake, at their usual habitats including ponds, pools, streams, channels and rice fields (Seak *et al*., 2012).

Turtles in the Tonle Sap floodplain are harvested mainly for traditional medicine purposes, domestic food consumption and export to Viet Nam and China. There are six turtle species reported in the Tonle Sap Lake which are globally threatened: Critically Endangered yellow-headed temple turtle (*Hieremys annandalii*) and giant Asian pond turtle (*Heosemys grandis*), Endangered Southeast Asian box turtle (*Cuora amboinensis*) and black marsh turtle (*Siebenrockiella crassicollis*), Vulnerable Asiatic softshell turtle (*Amyda cartilaginea*), and Near Threatened Mekong snail-eating turtle (*Malayemys subtrijuga*) (Meynell *et al*., 2019). Turtles, specially the Asian box turtle (*Cuora amboinensis*) and Mekong snail-eating turtle (*Malayemys subtrijuga*) are captured using "*lorp tul*", a cylindrical bamboo trap that is 1.25 x 0.8 m, which is set in shrublands from January to March.

Longhead water snake (*Enhydris longicauda*)

Mammals

In the past, when the Tonle Sap floodplain was connected to surrounding forest blocks, the wetlands were most likely a seasonally important habitat for large mammal species such as Asian elephants (*Elephas maximus*), wild water buffalo (*Bubalus arnee*), Eld's deer (*Cervus eldi*) and hog deer (*Axis porcinus*); Irrawaddy dolphin (*Orcaella brevirostris*), was also present in the lake. All these species have been extirpated from the lake and floodplain in the last 20 to 40 years (Davidson, 2006; Campbell *et al*., 2006 and references therein). By 1997, the potential tiger (*Panthera tigris*) population in Kampong Thom province was already estimated to be one of the lowest in the country (Nowell *et al*.,1999).

Due to the complexities of navigating flooded areas, resident mammal species diversity of the Tonle Sap floodplain is not particularly high (Cambpell *et al*., 2006). Three primate species have been recorded: Endangered Bengal slow loris (*Nycticebus bengalensis*), Endangered Indochinese silvered langur (*Trachypithecus germaini*) and Vulnerable long-tailed macaque (*Macaca fascicularis*). Two otter species, Vulnerable smooth-coated otter (*Lutrogale perspicillata*) and Endangered hairy-nosed otter (*Lutra sumatrana*) are confirmed to be present in Preak Toal and Boeung Chhmar Ramsar sites (Willcox *et al*., 2016; Heng *et al*., 2016) and also persist in Stung Sen. Otters used to be heavily hunted for their skins and for the international wildlife trade throughout TSBR but this threat has slowed down in recent years (Gomez and Bouhuys, 2018).

With regards to other carnivores, the Endangered large-spotted civet (*Viverra megaspila*) was recorded in southwestern areas of the Tonle Sap floodplain between 2010 and 2012 (Conservation International *personal communication*). Golden jackal (*Canis aureus*) were formerly common in the Stung Sen outer floodplain, but the population declined due to hunting (Goes *et al*., 2001). Leopard cat (*Prionailurus bengalensis*) was recorded near the Phat Sanday Fisheries Office at the mouth of the Stung Sen river (Cambpell *et al*., 2006). Small Asian mongoose (*Herpestes javanicus*) is suggested to be widespread (Davidson, 2006).

Vulnerable fishing cats (*Prionailurus viverrinus*) were observed being held in captivity in the Tonle Sap floodplain between 1999 and 2002 by D. Ware and F. Goes (in Duckworth *et al*., 2005), and have long been assumed to inhabit TSBR, including SSRS (MoE, 2007). However, no reliable evidence had been obtained until recently. In 2018, a dead fishing cat was seized by the Wildlife Rapid Rescue Unit (WRRT of MAFF & WA) during a raid of bushmeat stalls along National Road 5 near the Tonle Sap wetlands. The 17 kg male fishing cat was most likely killed locally, which suggests that a remnant population still persists around the Tonle Sap lake (V. Herranz Muñoz *article in preparation*).

Local community members in SSRS reported that opportunistic poaching of mammals and birds occurs often, and bushmeat is consumed locally or sold. Poachers from outside the communities target primates and turtles for national and international illegal wildlife trade.

Invertebrates

Molluscs are among the most diverse groups of invertebrates in freshwater ecosystems, and account for the second largest fishery after fishes in Tonle Sap Lake and River system. Recent surveys of the Tonle Sap basin found 31 species of molluscs including 15 bivalves (five families) and 16 gastropods (eight families) including three new species records for Cambodia (*Scaphula minuta*, *Novaculina siamensis*, *Wattebledia siamensis*) (Ng *et al*., 2020). Bivalves such as Asian clam *Corbicula* spp. are abundant in the Tonle Sap Lake during the dry season and gastropod species (such as invasive apple snails *Pila* spp.) are found in great abundance during both rainy and early dry seasons (Ngor *et al*., 2018). The mollusc species *Pila scutata* is the most commonly harvested snail in TSBR and this species is found in great abundance when the water level and precipitation increase. Invasive apple snails *Pomacea* spp spread throughout the Tonle Sap in the 1990s, and their increasing populations destroy rice crops, damage inundated habitats and compete with native *Pila* spp (Figure 8)(Ng *et al*., 2020). Their distictive bright pink eggs were widespread in flooded shrubland in SSRS. Mollusc biodiversity and habitat patterns in the Tonle Sap Lake are influenced by climate change, chemical-physical conditions, agricultural intensification pollution, and changes in sediment types and water flow (Ng *et al*., 2020; Sor *et al*., 2020).

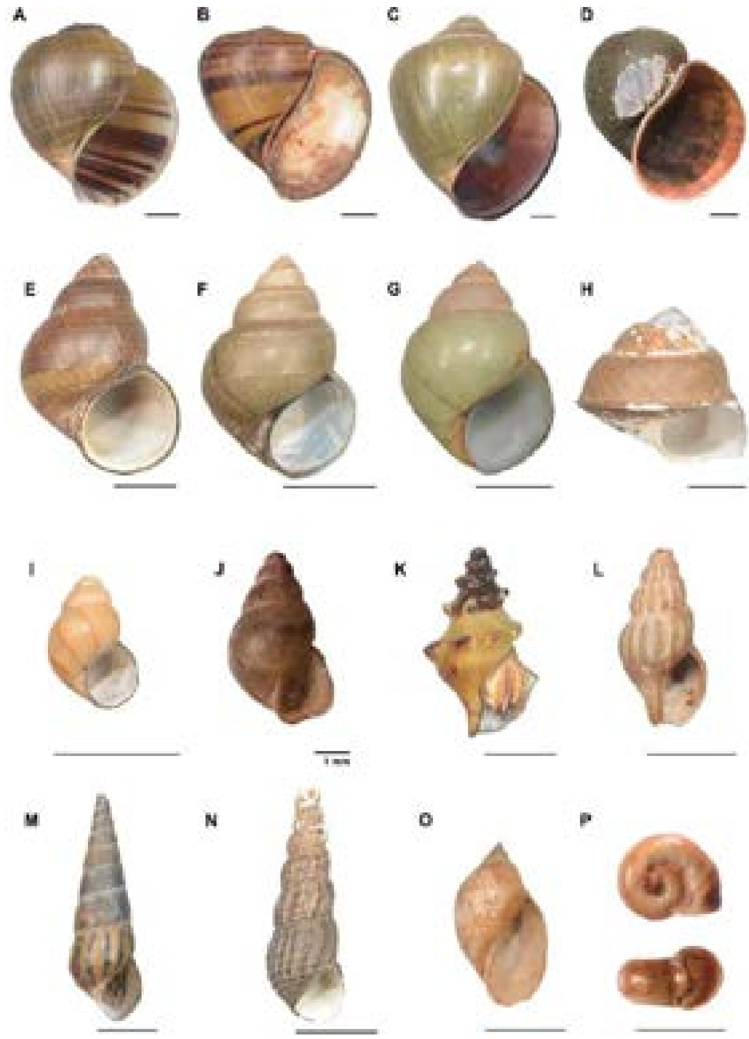


Figure 8. Freshwater gastropods of the Tonle Sap basin, Cambodia A *Pila gracilis,* B *Pila pesmei,* C *Pila virescens,* D *Pomacea maculata,* E *Filopaludina martensi cambodjensis,* F *Idiopoma umbilicata,* G *Mekongia rattei,* H *Trochotaia trochoides,* I *Bithynia siamensis goniomphalus* J *Wattebledia siamensis,* K *Anentome cambojiensis,* L *Anentome helena,* M *Sulcospira housei,* N *Melanoides tuberculata,* O *Indoplanorbis exustus* and P *Radix rubiginosa*. Scale bars: 10 mm, unless stated otherwise. Photographs by TH Ng (source: Ng *et al.*, 2020).

Pomacea spp eggs in SSRS

Crustacea

In the Tonle Sap Lake and its adjacent waters, 60 species of freshwater Cladocera (Crustacea, Branchiopoda) are reported and four species among this sixty Cladocera species*, Bunops cf*. *tuberculatus*, *Leydigia australis*, *Chydorus cf*. *dentifer,* and *Ceriodaphnia laticaudata*, are newly recorded from Southeast Asia (Tanaka and Ohtaka, 2010). Rice-field crab *Somanniathelphusa lacuvita* species was described by Ng (1995) in the Tonle Sap Lake. Crab genus *Somaniathelphusa* are rice pests and local people collect them from June to December for consumption in times of food scarcity. The local shrimp *Macrobrachium lanchesteri* is abundant between September and December in lowland rice-field habitats. Shrimp species *Macrobrachium hungi* was also recorded and its habitat is strictly freshwater in Tonle Sap Lake (Van Xuan, 2012).

2.1.6 Land use

Large areas within Stung Sen Ramsar Site are covered by water during flood season. Some open water areas are managed as community fisheries (CFi) and protected as Fish Conservation Areas (FCA). During the low water season, scattered pools and watercourses remain throughout Stung Sen Ramsar Site. Clearing for agriculture, both in the past and recently, has impacted more than a third of SSRS, particularly near the northern boundary.

Comparing the SSRS land cover map (Figure 9) generated by Karra, Kontgis, *et al.* (2020) and the satellite image from July 2021 (the driest month that year) and field observations, large flooded forest patches were lost on southern areas but tree stands are recovering on some central and northern areas. South of SSRS, within the Lower Stung Sen IBA, a significant area of flooded forest also remains. The high proportion of shrubland identified on the land cover map actually corresponds to both native shrubland and a highly pervasive invasion by *Mimosa pigra*, particularly on the northern half of SSRS, where recently cleared/converted areas show as a small patch of cropland and flooded vegetation; also, along the mainstream of the Stung Sen river where *M. Pigra* advances after clearing of slightly elevated areas of gallery/riverine forest.

A large proportion of the areas identified as flooded vegetation corresponds to massive floating carpets of invasive water hyacinth (*Eichhornia crassipes*). In a more natural state, these areas would have a smaller proportion of native floating plants and open water in the wet season, and more salient dry season ponds with native floating vegetation and patches of grassland and shrubland in the dry season.

On the land cover map, there are only a few small patches of grassland remaining on the west near the lake shore, which the satellite image shows they are actually recent clearings, however larger patches of grassland remain in the central portion of SSRS.

2.1.7 Drivers of change

Several factors influence the structure of the wetland and drive alterations to wetland habitats in SSRS:

- Clearing of natural habitats, including the use of fire is still prevalent at SSRS, particularly on the northern boundary.
- The flood pulse is the main underlying ecological driver of habitat alterations and vegetation community structure, including changes to plant species composition. The reduction of maximum flood extensions will impact natural habitats by changing the conditions under which important habitats such as flooded forest and flooded shrubland can persist, and by increasing the grassland areas that local communities may use to expand agriculture. Changes to habitat surface could cause shifts in sedimentation and nutrient cycling that supports primary fish production and livelihoods (Arias *et al*., 2012; 2019).
- The development of water infrastructure along the Mekong river is already producing serious alterations to the Tonle Sap flood pulse. Flood extent and duration in 2019, 2020 and 2021 were considerably lower than the average and this is likely to have negatively impacted fish catch in the region (MRC, 2022).
- The impacts of climate change are already being felt in TSBR. The upward trend of atmospheric temperature is resulting in an upward trend in surface water temperature which impacts natural habitats in TSBR (Pan & Yang, 2020). Over the last five years, both BTCRS and SSRS have experienced mass fish die-outs in dry season ponds when water temperatures and lack of dissolved oxygen exceeded biological thresholds. Climate change, in addition to global weather phenomena such as *El Niño,* are intensifying drought periods. Precipitation patterns are also showing important alterations in recent years (MRC, 2022).
- Invasive species, specially *Mimosa pigra*, water hyacinth (*Eichhornia crassipes*) and golden apple snails (*Pomacea* spp) are damaging all habitat types throughout SSRS.

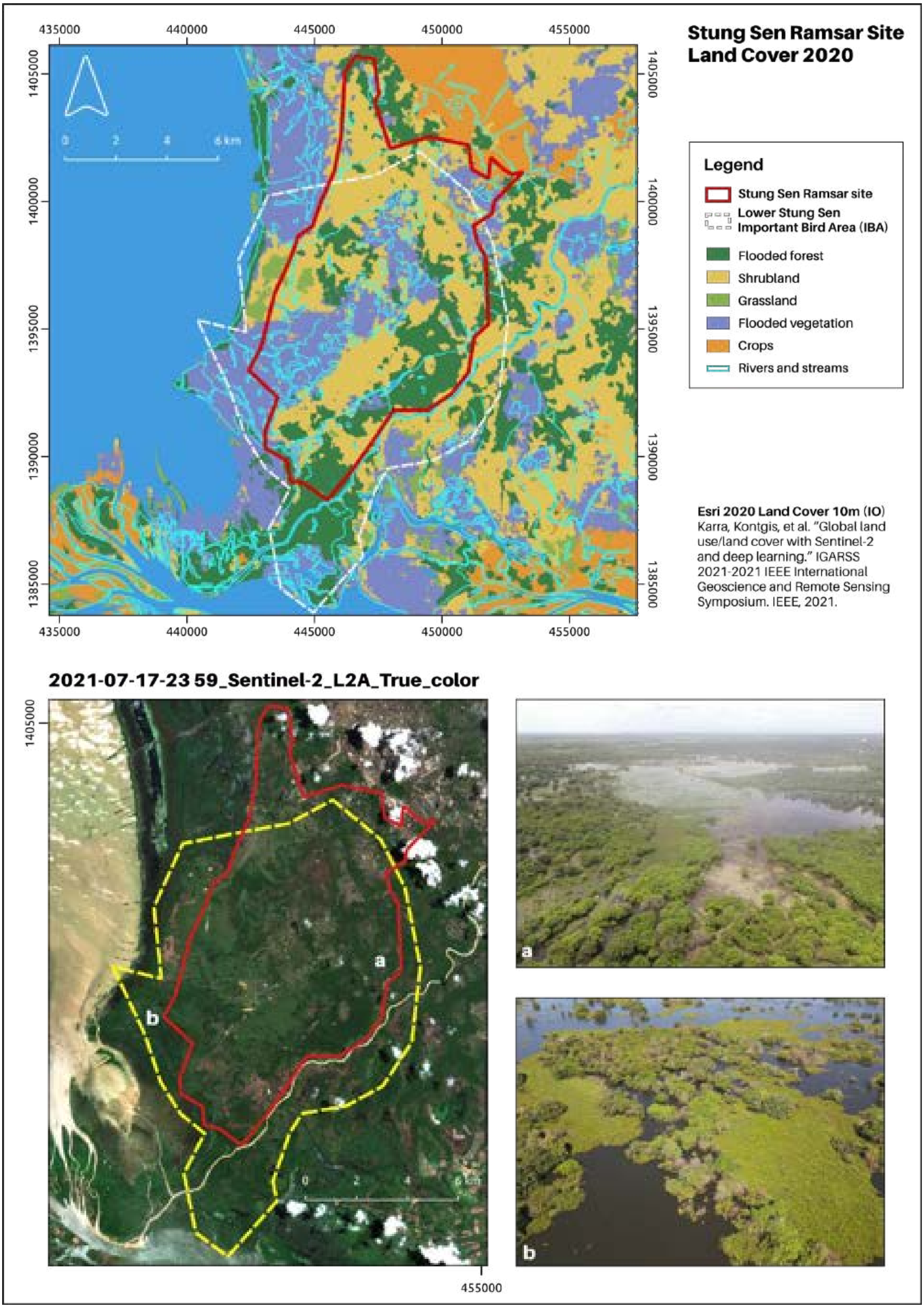


Figure 9. Land cover map (source: Karra, Kontgis *et al.,* 2021), water courses and boundaries of SSRS and LSS IBA/KBA. **Below:** Sentinel 2 L2A satellite image of SSRS in July 2021. **9a.** Flooded forest recovering around abandoned ricefields near the eastern border. **9b.** Water hyacinth mats near the Tonle Sap Lake.

Soil visible on the ground due to the extremely low water level in the center of SSRS in August 2021

2.1.8 Conservation and Zoning

Within Stung Sen Ramsar Site, a Community Protected Area (CPA) was created in Toul Neang Sav Plov village (Phat Sanday commune). NL/BL are currently conducting activities in collaboration with Toul Neang Sav Plov CPA such as strengthening CPA management and effectiveness. NL/BL are also establishing one additional CPA and building capacity in Phat Sanday commune and building both capacity and expertise for site management to support livelihoods and habitat conservation in Stung Sen Ramsar Site.

Fisheries in the area are managed through Community Fisheries (CFi) which fall under the jurisdiction of MAFF and are coordinated by the Fisheries Administration (FiA). SSRS also overlaps with Lower Stung Sen Key Biodiversity Area (KBA) and Important Bird Area (IBA). Fish Conservation Areas (FCAs) or fish sanctuaries have been established within the IBA and in nearby open waters of the Tonle Sap lake (Figure 10).

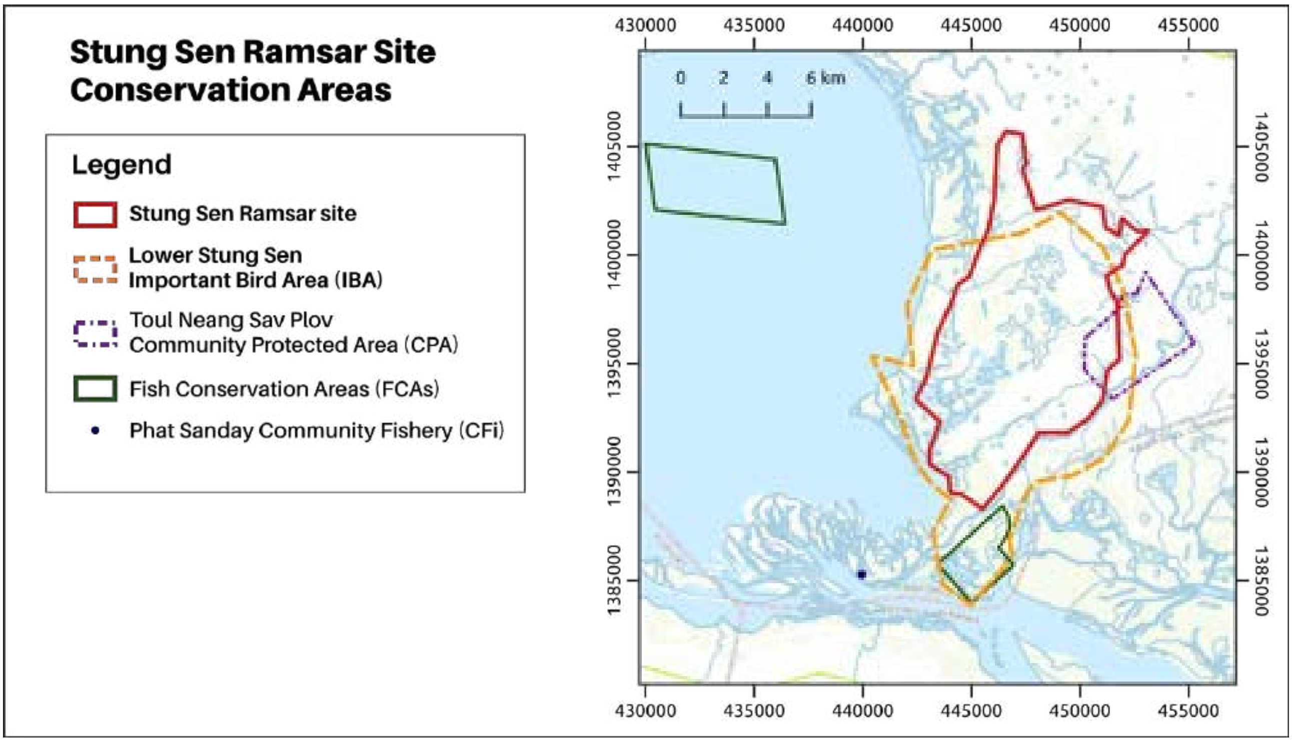


Figure 10. Conservation areas in the area of influence of SSRS.

2.2.1 Communities and population

Stung Sen Basin is the largest sub-catchment among 11 sub-basins around the Tonle Sap Lake. These basins cover an area of 14,138 Km^2 that contains 487 villages with a total population of 359,084 in 2003 (Theara *et al*., 2020; ADB, 2006). Stung Sen Ramsar Site is located along the south-eastern edge of the Tonle Sap Lake in Kampong Svay district, Kampong Thom Province. Stung Sen Ramsar Site has five villages and one sub-village nearby: Phat Sanday (159 households), Kampong Chamlang (206 households), Neang Sao (180 households), Koh Tapov (220 households), Toul Neang Sao and Psaot sub-village (total 209 households). In total 1,164 households with a population of 5,252 people live adjacent to SSRS, and their major income source are fisheries and seasonal vegetable farming (Chan & Mihara, 2018).

Phat Sanday is located about 30 minutes across the Tonle Sap traveling by boat from Chhok Trou village and all villages of this commune are located along a number of river tributaries of the Tonle Sap Lake. Households in Phat Sanday are mostly floating all year round but Phat Sanday has small areas of land during low water season. Neang Sao and Toul Neang Sao villages have a number of houses on land along the Stung Sen River but most houses are floating and some move seasonally along the river and the lake shore. Most villagers are ethnic Khmer except in Koh Tapov village where there are a large number of Vietnamese households (70%).

2.2.2 Key livelihood activities

The livelihoods of local communities around Stung Sen Ramsar Site are strongly dependent on natural resources inside and outside the core areas of SSRS. The main occupation of local people is fishing and they also practice additional fish related economic activities, such as small-scale aquaculture, fish processing and fish trading, while a minority is involved in grocery selling and crop farming (Baromey, 2008). The majority of people in the area are small scale fishermen with limited or no agricultural land. Villagers in floating homes are reliant on fishing all year round for both consumption and household income, even though the latter is problematic during the rainy season due to the use of small-scale fishing gear being illegal to protect spawning fish. Fishers also collect clams by dragging nets from motorized boats which is a completely different activity from only catching fish in the past (Johnston *et al.*, 2013). Most fishermen travel far from their village, between 5 to 30 km to fishing sites and they sell the fish immediately except for the amounts they keep for their own consumption. Some households are involved in additional activities such as fish processing including making *prahoc*, collecting fuel-wood for household use, producing dried fish and raising fish, pigs or chickens for income generation. A limited number of families from Koh Tapov and Toul Neang Sao villages along the Stung Sen River engage in farming during the dry season. Poor families have limited access to well managed fishery resources and they may spend 2-3 hours per day to catch around 5-10 kg of fish. The population in Stung Sen Ramsar Site increases due to influx of seasonal migrant fishers from nearby regions.

2.2.3 Use of wetland resources

The resident population near Stung Sen Ramsar Site is mainly dependent on fishing and uses a variety of (legal and illegal) fishing gears to catch fish to obtain income and for household consumption within and around SSRS. Other uses of wetland resources include:

- Small numbers of people migrate during wet and dry seasons from Stoung district and also catch fish, collect honey and practice farming along the outer (upland) edges.
- Local people collect fuelwood for dried fish production, as well as wild vegetables for consumption. Snails from the SSRS wetland are also an important source of income.
- In the dry season, small numbers of people migrate inside SSRS with herds of domestic buffaloes, so that they can feed on the grasslands and bathe in the remaining ponds and streams. Seasonal migrants also fish for household consumption and grow and harvest Indian lotus (*Nelumbo nucifera*) in dry season ponds.
- A few families living on floating homes inside SSRS specialize in eel fishing using several traditional and modern methods.

Eel fishers inside SSRS

2.2.4 Land tenure and land use rights

The government of Cambodia has not recognized land use rights for local people in Stung Sen Ramsar Site. Local floating houses move from one place to another during both dry and rainy seasons, within and outside SSRS. One CFi has been established including Fisheries Conservation Areas (FCAs), one CPA is already functioning to improve community-led natural resource management and another is being developed, both with the support of NL/BL.

2.2.5 Governance

Stung Sen Ramsar Site is a unique wetland in Tonle Sap Great Lake covering 9,293 hectares and was recognised internationally as the fifth Ramsar Site (Wetland of International Importance) in Cambodia in 2018. MoE plays an important role in protecting SSRS biodiversity and natural resources including flooded forests and wildlife, whereas FiA has responsibilities over fisheries management and tackling illegal fishing. The Provincial Department of Environment (PDoE) and the Provincial Department of Agriculture, Forestry and Fisheries (PDoAFF) work together regularly. In addition, FiA officers and SSRS MoE rangers collaborate at the local level (Figure 11).

The management plan of Stung Sen Core Area (2007) was produced as a guide for natural resource management during the five-year period 2008-2012, and it was divided into two parts. Part one of management plan aimed to describe Stung Sen Core Area and determine its significance and conservation values. Part two of the Stung Sen Core Area management plan described both management objectives and identified priority activities to accomplish these objectives such as responsibilities, deadlines and important stakeholders (MoE, 2007). To date, there is no specific management plan for Stung Sen Ramsar Site or plans to cope with climate change and drive adaptation, and to address critical issues such as ensuring sustainable local livelihoods, preventing fire, regulating commercial fishing, developing ecotourism, and managing Ramsar site implementation and funding.

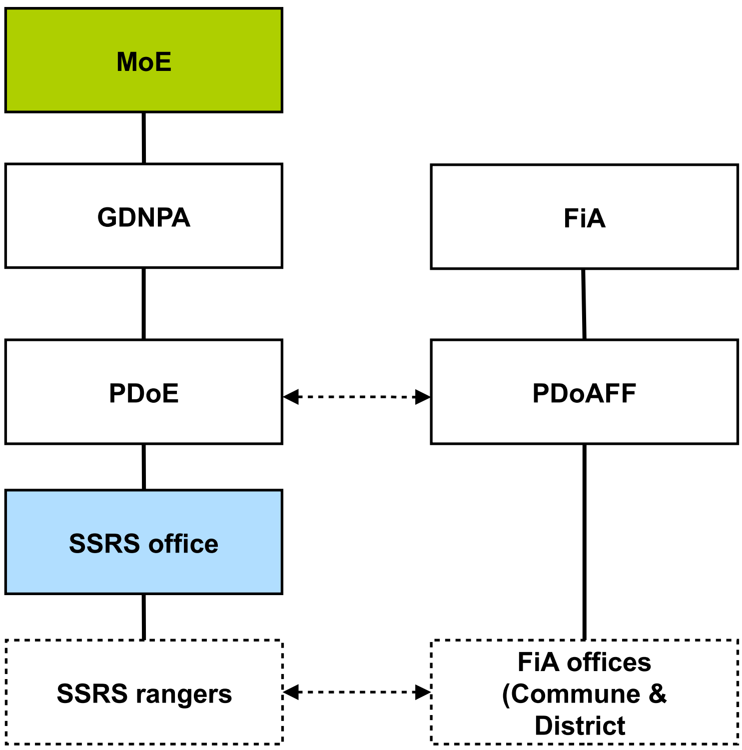


Figure 11: Governance structure of SSRS

2.2.6 Stakeholder analysis

Many actors have been working in SSRS and it is essential to acknowledge all these interests for effective site management and key decisions. There are many different stakeholders such as: governmental departments, local authorities, community representatives, NGOs, the private sector, and knowledge institutes.

Primary stakeholders: These are critically important key actors, which work directly to provide effectiveness in all management activities of SSRS. Primary stakeholders include: SSRS officers, MoE/GDANCP/PDoE (responsible agencies), commune councils (local authorities), Fisheries Administration (FiA), Community Fisheries (CFi), Community Protected Area (CPA) and schools (awareness/environmental education). MoE/GDANCP is responsible for national coordination in order to provide both policies and technical activities on implementation of SSRS management. PDoE supports provincial coordination on implementation of SSRS management. FiA supports fisheries and develops both laws and policies to ensure food security and socio-economic development. The CFi is responsible for coordination and implementation of fisheries policies by following the coordination of FiA/MoE and is supported by local and international NGOs. Commune councils (local authorities) support socio-economic development and protection of the environmental and natural resources.

Secondary stakeholders: These are key actors involved indirectly in SSRS management. These key actors consist of provincial/district authorities and different governmental departments, such as the Department of Agriculture, Forestry and Fishery (DoAFF), the Department of Planning (DoP), the Department of Health (DoH), the Department of Tourism (DoT), and the Department of Youth, Education and Sport (DoYES). Secondary stakeholders also include various NGOs and private sector actors such as NatureLife Cambodia / BirdLife International, IUCN, Fishing Cat Ecological Enterprise Co., Ltd, and the Ministry of Environment of the Government of Japan (Figure 12).

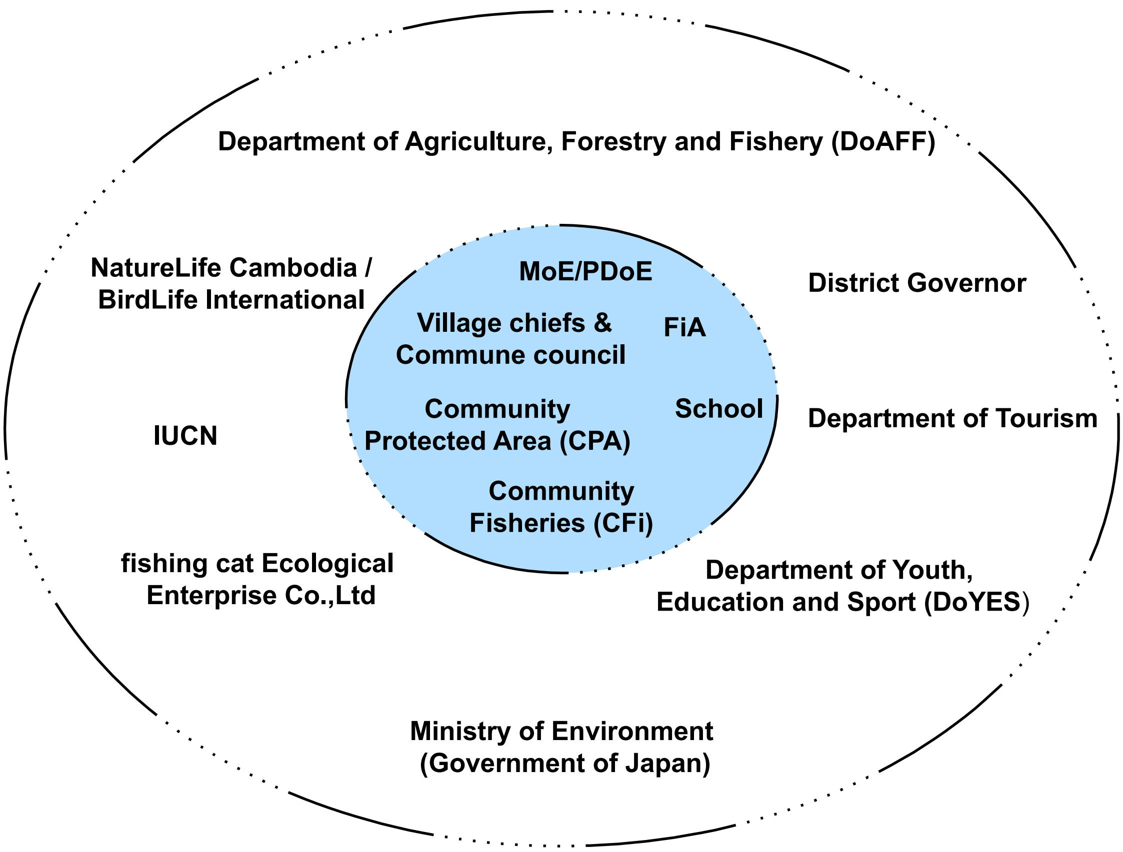


Figure 12. Overview of primary and secondary stakeholders relevant to decision making in SSRS

2.2.7 Gender and vulnerable groups

Fisheries are considered the main source of income and food consumption for women and men in Stung Sen Ramsar Site. Men play an important role, often fishing far away from villages, and repairing gears and boats. Women spend a long time on household roles and they can make decisions about resource use and income. Female-headed households have more difficulties obtaining income, increased burdens of looking after young families, and have fewer opportunities for joining in community decision-making since Khmer tradition ascribes a passive role to women. For instance, all village chiefs, which are chosen by commune councilors, and commune chiefs are men, although this position could be filled by men or women (Johnstone *et al.*, 2013). Essential fisheries activities, such as fish processing, are mainly carried out by women, however they have not been paid enough attention by the sector (FiA, 2015).

Migrant (mainly Vietnamese) families, which make up around 70% of households in Koh Tapov village, have difficulties participating in community decision making, accessing services, taking advantage of opportunities and participating in NGO or local community activities, due to language barriers. They are also less knowledgeable than Khmer fishers in terms of fishing techniques and gears.

2.2.8 Perceived threats to wetland habitats and livelihoods

Invasive species

- ***Mimosa pigra:*** *Mimosa pigra* is an invasive alien plant species found in high densities in Stung Sen Ramsar Site, possibly more so than at other areas around Tonle Sap Lake. It has a negative impact on biodiversity and ecosystem function, colonizing large areas and stopping regeneration of native species. The income of each family in the villages surrounding Stung Sen Ramsar Site decreased dramatically after the invasive plant *M. pigra* invaded the wetland, due to the loss of large areas of fishing grounds (Chan & Mihara, 2018). Chan & Mihara (2018) suggested two possible policies to manage the spread of *M. pigra* and its impact on local livelihoods, ecosystems and natural habitats, a short-term strategy and a long-term strategy. The short-term strategy is to suppress new seedlings and sprouting of *M. pigra* on agricultural land and either grow native vegetables and other local native species, or use water plants such as water spinach or water hyacinth to cover the land and stop *M. Pigra* from re-growing. The long-term strategy is to implement restoration programs with native species on abandoned agricultural land and implementing rehabilitation of invaded areas.
- **Water hyacinth** (*Eichhornia crassipes*) can grow in open water, rivers, and ponds, and can spread rapidly, doubling the size of floating mats every few weeks on the water surface. The presence of water hyacinth provides disadvantages and advantages for people and the environment. Water hyacinth reduces both the amount oxygen and nutrients around the area where it grows and boat traffic is blocked, which significantly impacts fisheries. However, water hyacinth is also considered a useful plant because it contains valuable chemicals are such as lignin, cellulose and hemicellulose which can contribute to synthesize a bioethanol for biofuel and other applications. Moreover, water hyacinth can absorb various heavy metals from water, contributing to remove pollution from agro-chemicals (Mitan, 2019). In SSRS, vast mats of water hyacinth accumulate on southern areas near the Tonle Sap lake and on streams connecting villages, wetland, lake and river.

Mimosa pigra

Illegal fishing: Fish populations in Stung Sen Ramsar Site are threatened by the use of illegal fishing techniques such as electro-fishing, bag nets and other illegal fishing gears, as well as fishing during the breeding season.

Clearing of flooded forests: Clearance of flooded forests is reported to occur both inside and outside of SSRS to grow flood-recession rice, build reservoirs for irrigation and to hunt animals (Ratner *et al*., 2017). The clearing and conversion of natural vegetation correlates with flood duration and occurs more intensely in flooded habitats inundated for less than 7 months per year. Vegetation clearance is known to occur in the floodplain during the dry season and these open areas provide opportunities for water buffalo grazing and rice cultivation, which subsequently reduce the chance of natural re-vegetation of burned and cleared areas (Arias *et al*., 2013).

Water infrastructure: The Tonle Sap Lake has complex hydrological interactions with the Mekong River, which makes it highly vulnerable to changes in the volume and timing of its water flow. Water infrastructure in the Mekong River Basin has developed rapidly, impacting the flood pulse of the Tonle Sap Lake during the peak monsoon season, leading to significant socio-ecological implications for the Tonle Sap Lake, the floodplain wetlands, forests, aquatic ecosystems and local livelihoods (MRC, 2022). Arias *et al* (2012) found that the impact of water infrastructure development (hydropower, irrigation, flood control and water supply) on the Tonle Sap Lake habitats could lead to extending the area of open water and rainfed areas, reducing the area covered with seasonally flooded habitats and gallery forest. Changes in water level and flood duration in the Tonle Sap Lake were predicted to moderate average monthly change of water levels, and to shrink the magnitude of the flood pulse by reducing water levels during the wet season, while increasing water levels during the dry season. More recent projections predict flow reductions of 9 to 29% in the 2030s and of 7 to 41% by the 2060s, with a decrease in extreme flows and increased drought (Arias *et al.,* 2019). Water storage operations in the Upper Mekong Basin (UMB) have contributed significantly to the unprecedented low volume and short duration of the flood pulse to the Tonle Sap floodplain during 2019, 2020 and 2021 (MRC, 2022).

Flooded forest fires: The flooded forests and floodplains in Stung Sen Ramsar Site are essential to provide shelter for fish to breed and are critical fish feeding areas. Both accidental and intentional fires have led to severe forest fires in Stung Sen Ramsar Site and many areas around Tonle Sap Lake, which have been intensified by climate change and drought conditions. Fires on the Tonle Sap floodplain, including SSRS, were particularly devastating in 2016 (CI, 2019). Accidental forest fires occur when people use smoke to harvest honey, burn firewood, or leave cooking fires unattended, whereas intentional fires are provoked during dry season to convert flooded forest to rice fields, or with various purposes such as to hunt animals, to cut paths through the forest to lay long fishing nets or to make trails to find scattered water buffaloes when is time to move them out of the wetland.

Recently burned forest just outside SSRS in August 2021

2.3 Climate projections for the site

This section provides an overview of climate projections up to 2050 for SSRS, as well as details of likely scenarios by 2030. The climate change vulnerability assessments of Boeung Chhmar Ramsar site (Meynell *et al.,* 2014, 2019) followed the 2013 ICEM downscaling of IPPC4 global projections for the region (ICEM, 2013), and presented climate change projections for Kampong Thom province. All analyses of the study were based on data from a 25-year baseline period of 1980-2005 and the assessments focused on a 25-year time period from 2045 to 2069 (referred as “2050”). A conservative scenario (A1b), modeling moderate emissions, rapid economic growth, more efficient technologies, global population peaking by 2050 and a balance between fossil intensive and non-fossil energy sources underlies the ICEM (2013) assessment.

GHG emissions in previous periods have been realized to exceed even the most extreme IPCC scenarios (Meynell *et al.,* 2014). However, the climate change projections presented in the assessment may still serve as guidance. The main climate change projections and trends are summarized in Table 2 below:

Table 2: Main climate trends for Kampong Thom Province up to 2050 (source: Meynell *et al.*, 2014)

Variable	Climate projections up to 2050
Temperature	Temperatures are expected to increase 3ºC in dry season and increase 4ºC in wet season. Maximum temperature in March is predicted to increase from 32 to 35ºC, with high temperatures extending into May. In the wet season, temperatures will rise by 4ºC, increasing maximum temperature in August to 31ºC. Annual number of hot days above 35ºC will increase from 11 to 51.
Rainfall	The total average annual rainfall may increase from 1,249 mm/year to 1,381 mm per year, increasing both in wet and dry seasons. Rainfall will become more variable and irregular throughout the year.
Extreme events	Increase in the number of events of heavy rainstorms from 7 to 11 events per year and greatest rainfall from 170 to 190 mm per day. Strong wind events in late dry season (April/May) which disturbs shallow waters, releasing low quality water and leading to mass fish deaths, will increase.

In 2020, ICEM developed a web-based platform called Cambodia Mekong Delta Data and Scenario Explorer to visualize up-to-date climate change information for decision making, connecting to data from several agencies of the Royal Government of Cambodia (ICEM, 2020). The digital atlas (CAM-MeDiA[1]) allows the user to visualize temperature and rainfall scenarios corresponding to the Representative Concentration Pathways (RCP) 4.5, 6.0 and 8.5, which convey lower, middle and high emission pathways (van Vuuren *et al.*, 2011); projections to 2030 or 2060; and three Global Climate Models (GCM) IPSL-CM5A-MR, GFDL-CM3 and GISS-E2-R-CC over a map of Cambodia.

To inform on the most likely short-term scenarios for SSRS, RCP 8.5 projections to 2030 according to the three GCMs were visualized, and the details of each scenario were compiled and added to the graphic below (Figure 13). The graphic shows that by 2030, temperatures in SSRS may rise 0.74 to 0.96ºC in the dry season, and 0.85 to 1.12ºC in the wet season. Average annual precipitation in the dry season may decrease between 1 and 4% depending on the area, according to two of the GCMs, but may increase up to 12% according to the third.

[1] http://dss.icem.com.au/camatlas/

In the wet season, precipitation may increase between 1 and 4% according to two of the GCMs and may decrease by 6-7% according to the third. These projections show that precipitation will become more unpredictable. Changes in rainfall patterns in the Mekong region are determined by climate change, the timing and duration of the monsoon rains and the *El Niño* - *La Niña* phenomenon. Between 2018 and 2021 substantial anomalies have been recorded, mainly pointing towards lower-than-normal and delayed onset of rains (MRC, 2022).

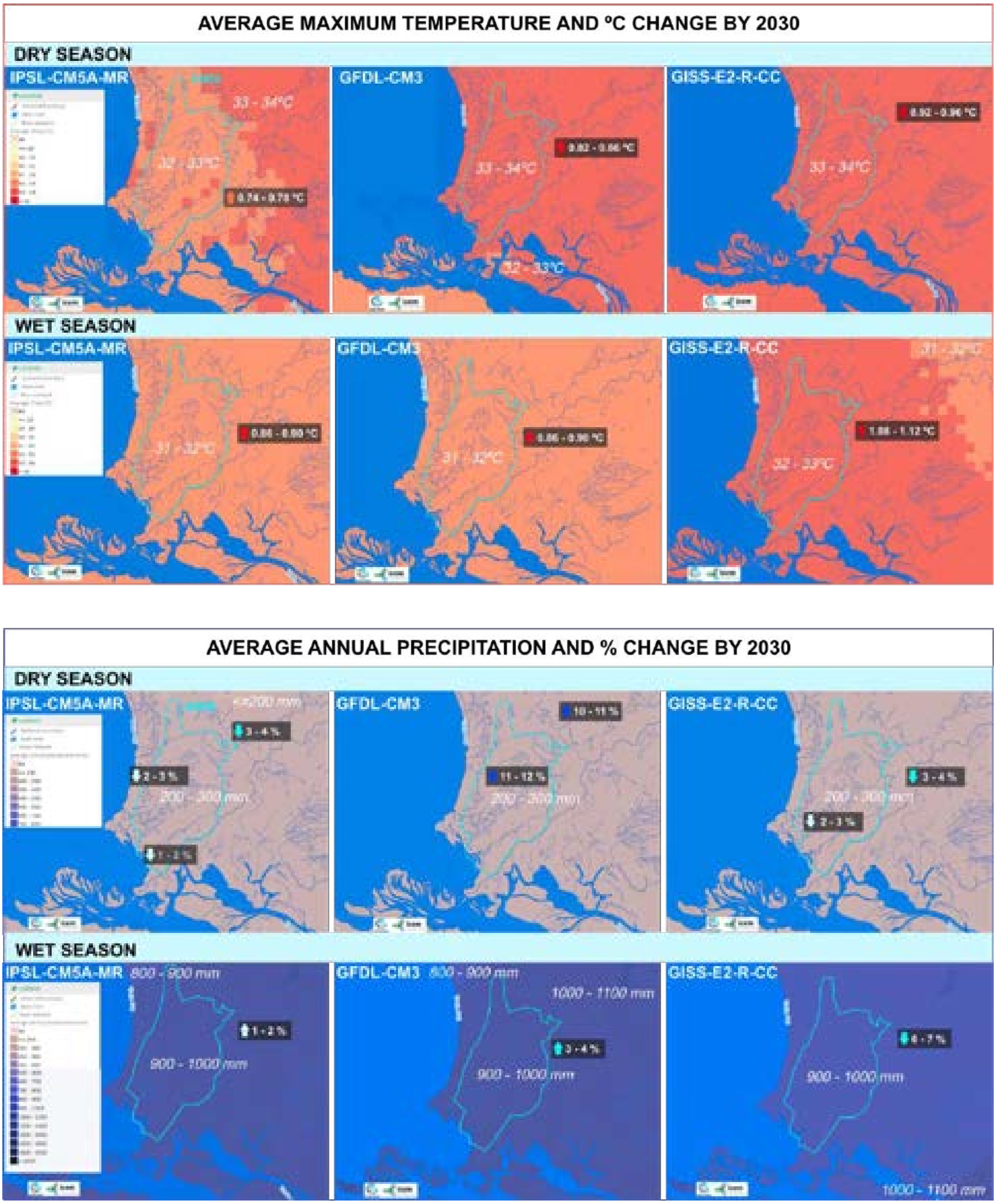


Figure 13. Average maximum temperature, average annual precipitation and changes projected by 2030. Data, background maps and legends from CAM-MeDiA (2022). Graphic compiled by the authors.

3. VULNERABILITY ASSESSMENT

3. VULNERABILITY ASSESSMENT

3.1 Habitat Vulnerability

Stung Sen Ramsar site hosts four types of habitat which are characteristic of the Tonle Sap floodplain: open water, flooded forest, shrubland and grassland. The extent of the areas covered by these habitats has changed substantially over the last century due to a variety of human interventions such as agricultural conversion, fires and the increase in extent of the area taken over by invasive species. Previous research on the potential combined effect of climate change and water infrastructure development in the region, estimated their effects on flood duration and extent (the main factor underlying habitat dynamics) may counteract each other, and result in an increase in the extension of flooding (Arias *et al.*, 2012, 2014; Meynell *et al.*, 2014, 2019). During 2019, 2020 and 2021 however, the Tonle Sap floodplain has had some of the lowest water levels and shortest flood seasons in the last few decades, which puts the lake and floodplain habitats, species and livelihoods under much higher pressure (Arias *et al.,* 2019; MRC, 2022).

The habitat vulnerability assessment was conducted through consultation with local key informants, field observations and remote sensing information.

Following the IUCN Mekong WET methodology, each habitat was assessed with regards to its baseline conservation status, including non-climate related threats, and level of exposure, sensitivity and adaptive capacity in relation to climate threats. The overall scores are presented in Figure 14. Climate change vulnerability matrices including specific threats to SSRS and each habitat, and evaluation of the same elements, were also designed and completed.

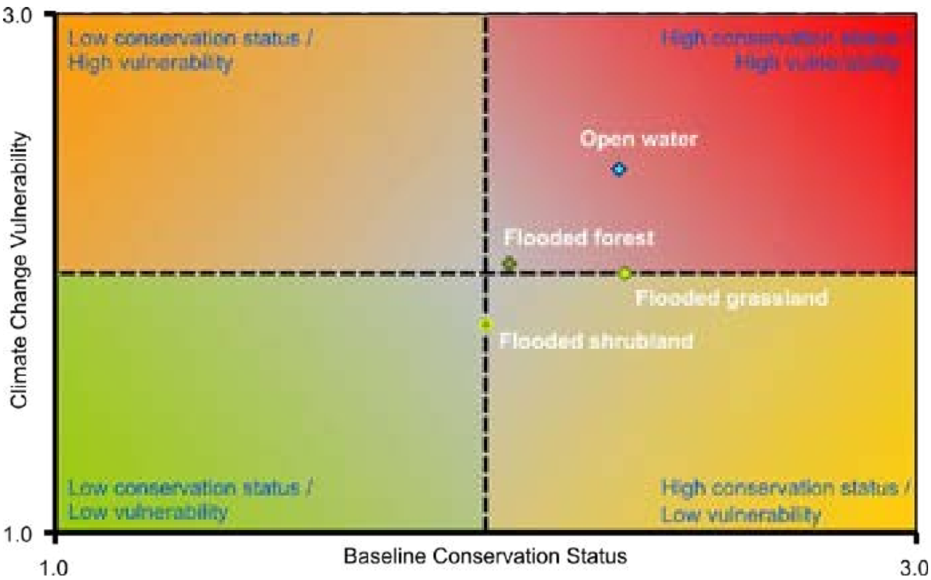


Figure 14: Baseline conservation status and climate change vulnerability of habitats in SSRS.

Open water habitats scored relatively high both on conservation status and vulnerability, because of their huge significance at the most basic level of the entire ecosystem, and due to being highly exposed to all threats and having no adaptive capacity at all without human intervention. Flooded grasslands scored high on conservation status due their importance for many species and the stark losses already suffered by this habitat, which have rendered it very rare in the region. The flooded forest habitat scored high on both conservation status and vulnerability due to their importance as higher complexity, slowly regenerating habitat, and the likely impact of climate change on tree reproduction. Finally, flooded shrublands have a high conservation status due to their importance as fish nurseries and the high pressure it suffers from human induced threats including invasive species, but scored moderate on vulnerability due to having higher adaptive capacity to climate change.

3.1.1 Open water

The open water habitat in SSRS encompasses permanent water ponds and streams which provide a critical refuge for many species in the dry season; in the wet season the extent and duration of flooding determines the surface of open water habitat available. Water hyacinth has taken over large areas of open water habitats in SSRS. Shallow water in the dry season will become much hotter with increased temperatures under climate change, which will also increase evapotranspiration, leading to further loss of water volume. Invasion by water hyacinth further reduces water quality, depriving it of oxygen, but in some instances it may help cool water and avoid some evaporation. Shallow open water habitats are highly vulnerable to late dry season strong wind events because water is overturned and low quality water from the bottom renders it toxic, causing mass fish deaths (Meynell *et al.*, 2014, 2019). Mekong water infrastructure management has induced dramatic reductions and flood extension, timing and duration in recent years (MRC, 2022), and open water habitats that depend on it were severely affected (Table 3).

Table 3: Climate change vulnerability matrix for open water habitats

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
High temperature	VH	VH	VH	L	VH
Increased rainfall in wet season	H	M	M	M	M
Irregular rainfall in dry season	VH	VH	VH	VL	VH
Longer period of dry season	VH	VH	VH	VL	VH
Strong winds	VH	VH	VH	VL	VH
Storm events	VH	M	M	M	H
Invasive species	VH	VH	VH	VL	VH
Development threats					
Decreased flood level & duration	VH	VH	VH	VL	VH
Agricultural conversion	VH	VH	VH	VL	VH
Fire	VH	VH	VH	VL	VH

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

Water hyacinth clogs open water habitats in SSRS

3.1.2 Flooded forest

Flooded forests are vulnerable to changes in water level and duration of floods (Meynell *et al.,* 2014, 2019), and will therefore be severely impacted by the extreme reductions seen in recent years due to water infrastructure management. Distribution of one of the flooded forest keystone species, the fresh-water mangrove (*Barringtonia acutangula*), was shown to be determined by annual and warmest period precipitation, and evapotranspiration of trees, rendering it highly vulnerable to hotter and dryer conditions and irregular rainfall under climate change (Deb *et al.,* 2016). Furthermore, temperature has also been shown to impact the reproductive phenology and fertility of the species (Nath *et al.,* 2016). Dryer conditions will also worsen the impact of fires, and the spread of *Mimosa pigra* at the expense of slower regenerating flooded forest species (ICEM, 2013).

Table 4: Climate change vulnerability matrix for flooded forest habitats

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
High temperature	VH	VH	VH	VL	VH
Increased rainfall in wet season	M	M	M	H	M
Irregular rainfall in dry season	VH	VH	VH	VL	VH
Longer period of dry season	VH	VH	VH	VL	VH
Strong winds	H	M	M	H	H
Storm events	H	M	M	H	H
Invasive species	H	H	H	H	H
Development threats					
Decreased flood level & duration	VH	VH	VH	VL	VH
Agricultural conversion	H	VH	H	VL	H
Fire	VH	VH	VH	VL	VH

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

3.1.3 Flooded shrubland

Flooded shrubland in the Tonle Sap floodplain may have taken over from more a interspersed flooded forest and shrubland configuration in the past. Shrubland habitats in SSRS has been describe as "short-tree" shrubland and consists mainly of 2 – 4 m high dense stands of Euphorbiaceae, Fabaceae and Combretaceae, as well as woody lianas in wetter areas (ICEM, 2013). Shrublands have been heavily converted to agriculture in the last 25 years, and due to their important role as fish nurseries, this drastic reduction is likely to have had an impact on fish catch declines (Mahood *et al.,* 2019). This habitat also provides breeding grounds for water snakes and turtles (ICEM, 2013). The flooded shrubland habitat is severely threatened by the unrelenting advance of invasive shrub *Mimosa pigra,* which is likely to be able to extend ever further under climate change (Kariyawasam *et al.,* 2021). Shrubland habitats however, can adapt to changes in water levels and drying our seasonally, making them more resilient to climate change (Meynell *et al.,* 2014, 2019), but higher temperatures will increase the risk posed by fires ICEM, 2013).

Table 5: Climate change vulnerability matrix for flooded shrubland habitats

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
High temperature	VH	M	M	M	M
Increased rainfall in wet season	L	L	L	H	L
Irregular rainfall in dry season	H	M	H	M	H
Longer period of dry season	VH	M	M	M	M
Strong winds	L	L	L	H	L
Storm events	L	L	L	H	L
Invasive species	VH	VH	VH	VL	VH
Development threats					
Decreased flood level & duration	H	M	M	H	M
Agricultural conversion	VH	VH	VH	VL	VH
Fire	VH	VH	VH	VL	VH

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

3.1.4 Flooded Grassland

Grasslands on the Tonle Sap floodplain occur within areas of shorter stature flooded forest and shrubland in the mid-range inundation belt, and used to form a band around the outer shrubland, much of which was converted to agriculture. Its current formation is likely the result of thousand of years of human modification. Grasslands on the outer floodplain are particularly important for threatened grassland birds such as the Critically Endangered Bengal florican (*Houbaropsis bengalensis*) (Davidson, 2006). Flooded grasslands are also important feeding and breeding grounds for waterbirds, including wintering migratory species, as well as many black and white fish species. Black fish may remain in pools within grassland areas in the dry season and move through this habitat when undertaking overland migrations (ICEM, 2013). Grasslands in the inner floodplain are maintained by domestic water buffalo grazing performing the role of extirpated large herbivores, and used to constitute the largest remaining grassland in SE Asia (Davidson, 2006; Packman *et al.* 2013; Mahood *et al.,* 2020). In the last three decades, loss of grassland has been severe: from covering approximately 23% or more than 3000 km^2 in 1993, to occupying only about 4% or less than 600 km^2 in 2018 (Mahood *et al.,* 2020). Flooded grasslands are also threatened by the fast expansion of invasive water hyacinth, and outer grasslands, by regeneration of shrublands following fires, and the invasive shrub *Mimosa pigra.* Grass and herb species however, may be resilient to changes in temperature and precipitation under climate change (Meynell *et al.,* 2014, 2019).

Table 6: Climate change vulnerability matrix for flooded grassland habitats

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
High temperature	H	M	M	M	M
Increased rainfall in wet season	L	L	L	H	L
Irregular rainfall in dry season	H	H	H	M	H
Longer period of dry season	VH	VH	VH	VL	VH
Strong winds	L	L	L	H	L
Storm events	L	L	L	H	L
Invasive species	VH	VH	VH	VL	VH
Development threats					
Decreased flood level & duration	VH	VH	VH	VL	VH
Agricultural conversion	VH	VH	VH	VL	VH
Fire	VH	VH	VH	VL	VH

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

3.2.1 Fish

SSRS harbors essential habitats for all three main categories of fish of the Lower Mekong Basin: "Black fish" are floodplain residents which undertake limited lateral migrations from the river to the floodplain; "Grey fish" leave the floodplain when floods recede and spend the dry season in local tributaries; and "White fish" perform long distance migrations between the Tonle Sap floodplain and the Mekong mainstream and its tributaries. Due to these distinct life history strategies, each group is affected differently by climate change and other threats (ICEM, 2013). Fish vulnerability assessments were completed in collaboration with experts from Wonders of the Mekong Project. (Figure 15).

Black Fish. This group includes the Channidae (snakeheads), Clariidae and Bagridae (catfishes) and Anabantids. The SSRS flooded habitats are vital for these species throughout their entire life-cycle as floodplain residents. Black fish are resilient to poor water quality conditions such as low DO, low pH, high turbidity and high ammonia, and their ability to undertake overland migrations allows them to find refugia more easily. Black fish are therefore considered less vulnerable to the impacts of climate change than other groups (ICEM, 2013; Meynell *et al,* 2014; 2019).

Grey Fish. This group includes some of the Mystus catfishes most often caught around SSRS, such as key indicator species *Mystus mysticetus* and *M. singaringan* (Ngor *et al.,* 2018). Grey fish spend the wet season in the wetlands and move to rivers, such as the Stung Sen mainstream during the dry season. Given their life-history traits, this group may not be strongly affected by changes in precipitation, but might be moderately affected by increases in temperature and changes to hydrology (ICEM, 2013; Meynell *et al,* 2014; 2019), and are therefore considered moderately vulnerable to climate change .

White Fish. The white fish group is made up of many Cyprinid species such as *Henicorhynchus* spp. and *Cirrhinus* spp, as well as most Pangasiidae catfishes. The majority of white fish species undertake long distance migrations between the floodplain, where they spend the wet season growing, and the Mekong mainstream and its tributaries where they breed in a variety of habitats. White fish make up to 87% of Mekong fish species and 50% of the total fish catch. Local communities rely heavily on white fish for their livelihoods and food security. White fish require high quality water conditions and are highly vulnerable to increased temperatures; they also depend on the timing and duration of floods for their migrations (ICEM, 2013). Migrations of economically important species *H. lobatus* and *H. siamensis* are negatively impacted by water infrastructure on the Mekong (Fukushima *et al.,* 2014). These characteristics make white fish highly vulnerable to climate change, changes in hydrology and impacts of water infrastructure.

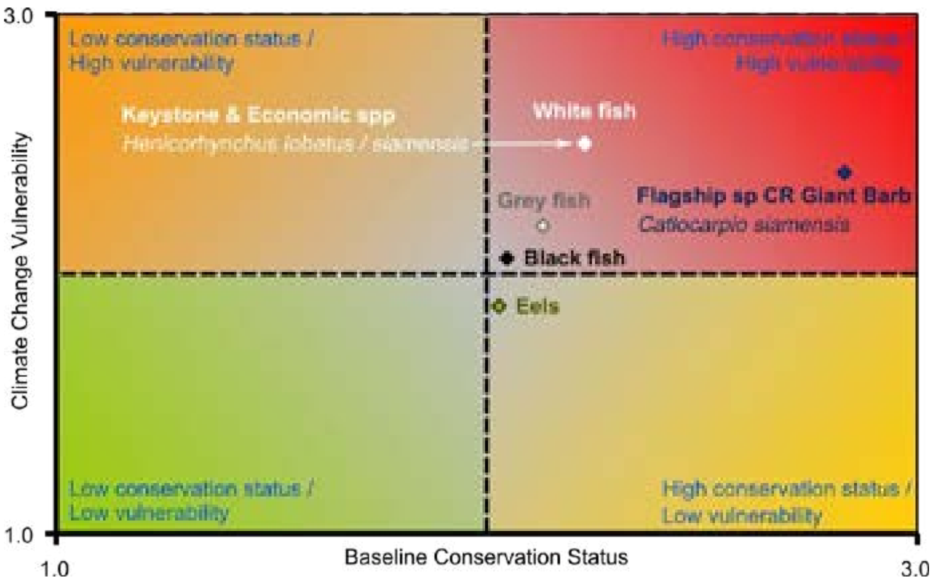


Figure 15: Baseline conservation status and climate change vulnerability of fish in SSRS.

Flagship species. SSRS provides essential habitats for Critically Endangered giant barb (*Catlocarpio siamensis*), the Cambodian National fish (Figure 16), and other highly threatened megafish species such as Critically Endangered Mekong giant catfish (*Pangasianodon gigas*), Jullien's golden carp (*Probarbus jullieni*) and giant pangasius (*Pangasius sanitwongsei*) (MoE, 2007; Jenkins *et al.,* 2009; Hogan, 2011; Ahmad, 2019). In Cambodia, according to tradition, giant barbs are special creatures which must be honored and protected and can bring curses upon the fishers and their families if they are killed. However, despite traditional and legal protection, megafishes are highly threatened by illegal trade, and often captured using illegal and highly destructive fishing methods such as electro-fishing (Campbell *et al.,* 2020). Indiscriminate fishing has led to severe declines in abundance and body size of large-bodied species in the Tonle Sap, where the total fish catch biomass has remained relatively stable by increasing the catch of smaller species while larger species declined (Ngor *et al.,* 2018b). Their large body size, long generation time and long range migratory behavior renders megafish species highly vulnerable to non-climate and climate related threats.

Figure 16. An 11 kg giant barb (*Catlocarpio siamensis*) was caught in a net and handed over to MoE rangers for release in Boeung Tonle Chhmar Ramsar Site in January 2022.

Eels. Eel species are generally considered hardy and resilient to climate threats and poor quality water due to their ability to move overland to find better quality habitat. According to the climate change vulnerability assessment of eel-like species *Mastacembelus armatus* (ICEM, 2013a), they are tolerant to high temperatures and low DO, and projected temperature increases up to 28ºC were within its tolerance range. Current short-term and 2050 projections (see Section 3.2) however, situate temperature increases on the 33 – 34ºC range, which will impact eels by increased drying out of seasonal pools during longer and hotter dry seasons, especially if it becomes harder for them to find other bodies of water to burrow in the mud for refuge. Eels should therefore be considered to have low to moderate climate change vulnerability.

3.2.2 Birds

SSRS provides important habitats for large water birds most notably outside the breeding season (wet season), while most breeding colonies are located further north in Preak Toal Ramsar Site (van Zalinge *et al.,* 2011). Flooded forests and shrublands also provide habitat for many other bird species. NatureLife Cambodia / BirdLife International conducted a waterbird survey in late 2020, including counts of individuals to contribute to the International Waterbird Census (IWC) in collaboration with Wetlands International, and another in early 2021 monitoring the presence of waterbirds and other bird species. A camera-trap survey was also conducted by FCEE in parallel with the current assessment between December 2020 and December 2021, obtaining data from 27 sites, including areas of the Lower Stung Sen IBA/KBA outside SSRS (more details in Section 3.2.3). Results of these surveys are summarized on Table 7.

Species assessed

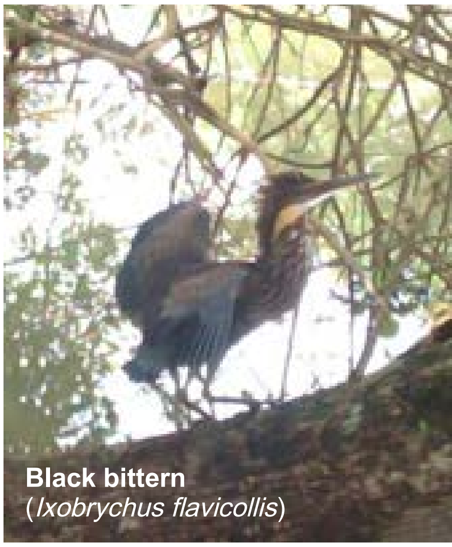
Spot-billed pelican. Near Threatened spot-billed pelicans (*Pelecanus philippensis*) use SSRS most prominently between August and October, with large groups of around 30 individuals recorded in September in the literature (van Zalinge *et al.,* 2011) and observed during the course of the current assessment in September 2021. Known breeding populations of spot-billed pelican are only found in India, Sri Lanka, Cambodia and potentially Thailand (W. Limparungpatthanakij *in litt.* 2016), and the global population is in decline (Birdlife International, 2017). The only known breeding site in Southeast Asia is found in Prek Toal Ramsar Site (Sun and Mahood, 2015). Spot-billed pelicans in India showed a preference for relatively shallow waters where they fish, and tended to move out of sites when water levels increased (Leo and Velayutham, 2019), therefore timing and duration of floods, and effects of increased water temperatures on fish populations in shallow waters will impact the species. The climate change assessment situates this species as highly vulnerable (Figure 17).

Table 7. Bird species, scientific name, counts of individuals for IWC, presence recorded by NL/BL, number of sites where the species was photo-captured by FCEE.

Species	Scientific name	IUCN Status	IWC Count	NL/BL Record	FCEE #Sites
Lesser Adjutant	*Leptoptilos javanicus*	**VU**	6	-	-
Grey-headed Fishing Eagle	*Icthyophaga ichthyaetus*	**NT**	3	•	-
Oriental Darter	*Anhinga melanogaster*	**NT**	1	•	-
Spot-billed Pelican	*Pelecanus philippensis*	**NT**	-	•	-
Asian Openbill	*Anastomus oscitans*	LC	952	•	-
Whiskered Tern	*Chlidonias hybrida*	LC	523	•	-
Black-winged Stilt	*Himantopus himantopus*	LC	233	-	-
Intermediate Egret	*Ardea intermedia*	LC	155	•	-
Little Cormorant	*Microcarbo niger*	LC	100	•	-
Great White Egret	*Ardea alba*	LC	89	•	-
Little Egret	*Egretta garzetta*	LC	52	•	-
Javan Pond Heron	*Ardeola speciosa*	LC	35	•	-
Indian Cormorant	*Phalacrocorax fuscicollis*	LC	21	•	-
White-breasted Waterhen	*Amaurornis phoenicurus*	LC	14	•	4
Pied Kingfisher	*Ceryle rudis*	LC	8	-	-
Purple Swamphen	*Porphyrio porphyrio*	LC	5	•	-
Garganey	*Spatula querquedula*	LC	5	-	-
Grey Heron	*Ardea cinerea*	LC	4	•	1
Comb Duck	*Sarkidiornis melanotos*	LC	3	-	-
Spot-billed Duck	*Anas poecilorhyncha*	LC	2	•	-
Black Bittern	*Ixobrychus flavicollis*	LC	1	•	2
Purple Heron	*Ardea purpurea*	LC	1	•	-
Black-capped Kingfisher	*Halcyon pileata*	LC	1	-	-
Common kingfisher	*Alcedo atthis*	LC	1	-	-
Little Grebe	*Tachybaptus ruficollis*	LC	1	-	-
Barn Swallow	*Hirundo rustica*	LC		•	-
Black-winged Kite	*Elanus caeruleus*	LC		•	-
Blue-tailed bee-eater	*Merops philippinus*	LC		•	-
Great Cormorant	*Phalacrocorax carbo*	LC		•	-
Greater Coucal	*Centropus sinensis*	LC		•	11
Greater Racquet-tailed Drongo	*Dicrurus paradiseus*	LC		•	1
Green-billed Malkoha	*Phanicophaeus tristis*	LC		•	2
Indochinese Roller	*Coracias affinis*	LC		•	-
Large-Billed Crow	*Corvus macrorhynchos*	LC		•	4
Lesser Whistling Duck	*Dendrocygna javanica*	LC		•	-
Oriental Dollarbird	*Eurystomus orientalis*	LC		•	-
Red Collared Dove	*Streptopelia tranquebarica*	LC		•	-
Tufted Duck	*Aythya fuligula*	LC		•	-
Yellow Bittern	*Ixobrychus sinensis*	LC		•	1
Ashy Drongo	*Dicrurus leucophaeus*	LC		-	1
Black Drongo	*Dicrurus macrocercus*	LC		-	3
Black-Headed Woodpecker	*Picus erythropygius*	LC		-	1
Black-Naped Monarch	*Hypothymis azurea*	LC		-	1
Blue-Winged Pitta	*Pitta moluccensis*	LC		-	2
Brown Fish Owl	*Ketupa zeylonensis*	LC		-	1
Changeable Hawk Eagle	*Nisaetus cirrhatus*	LC		-	1
Chestnut-Winged Cuckoo	*Clamator coromandus*	LC		-	1
Chinese Pond Heron	*Ardeola bacchus*	LC		-	1
Crow-Billed Drongo	*Dicrurus annectens*	LC		-	1
Forest Wagtail	*Dendronanthus indicus*	LC		-	1
Hainan Blue Flycatcher	*Cyornis hainanus*	LC		-	1
Laced Woodpecker	*Picus vittatus*	LC		-	2
Lesser Coucal	*Centropus bengalensis*	LC		-	4
Oriental Magpie-Robin	*Copsychus saularis*	LC		-	12
Puff-Throated Babbler	*Pellorneum ruficeps*	LC		-	1
Ruddy Kingfisher	*Halcyon coromanda*	LC		-	1
Spotted Dove	*Spilopelia chinensis*	LC		-	1
Striated Heron	*Butorides striata*	LC		-	8
White-Browed Crake	*Porzana cinerea*	LC		-	1
White-Rumped Shama	*Kittacincla malabarica*	LC		-	1
White-Throated Fantail	*Rhipidura albicollis*	LC		-	1
White-Throated Kingfisher	*Halcyon gularis*	LC		-	1

Lesser adjutant
(*Leptoptilos javanicus*)

Whiskered Tern
(*Chlidonias hybrida*)



Black bittern
(*Ixobrychus flavicollis*)

Asian Openbill
(*Anastomus oscitans*)

Asian openbill (*Anastomus oscitans*). The population of Asian openbills nesting in Prek Toal showed a remarkable increase over successive monitoring periods between 2004 and 2015, reaching over 13,000 pairs (Sun and Mahood, 2015). Recent surveys during the 2020 wet season show that SSRS is a highly significant site for Asian openbill as well, with nearly 1000 individuals recorded (NL/BL, 2021). This species has a broad temperature tolerance range, and is currently expanding its geographical range, possibly in response to changing climate (Lei & Liu, 2021). Openbills have been recorded to feed intensely on invasive golden apple snails (*Pomacea canaliculata*) in Thailand (Sawangproh *et al.,* 2012, 2021), and promoting Asian openbill populations has been suggested as a method of biological control (Horgan, 2017). High population numbers and high adaptive capacity means Asian openbills exhibit low vulnerability to climate change.

Grey-headed fish-eagle. This specialist eagle species is scarce throughout its South and Southeast Asian range, and the global population is declining due to pollution and over-fishing (BirdLife International, 2017). In the Tonle Sap floodplain, grey-headed fish-eagles (*Icthyophaga ichthyaetus*) are known to nest in Prek Toal, where 40 nests were recorded in 2015 (Sun and Mahood, 2015). Grey-headed fish-eagles showed a preference for tall trees near permanent water and distant from human settlements for nesting in Prek Toal. Other flooded forest sites, such as Stung Sen are possibly used as pre-breeding grounds and post-breeding nursery areas (Tingay *et al.,* 2010, 2012). Over-exploitation of water snakes (one of their most important prey) to feed crocodiles in commercial farms and changes to hydrology are the most significant threats to the Tonle Sap grey-headed fish-eagle population (Tingay *et al.,* 2012). Populations along the Mekong river are also in decline (Mittermeier *et al.,* 2019). SSRS is also an important site for the species, which was recorded in surveys during the 2020-2021 season (NL/BL, 2021). The grey-headed fish-eagle was assessed as highly vulnerable to climate change.

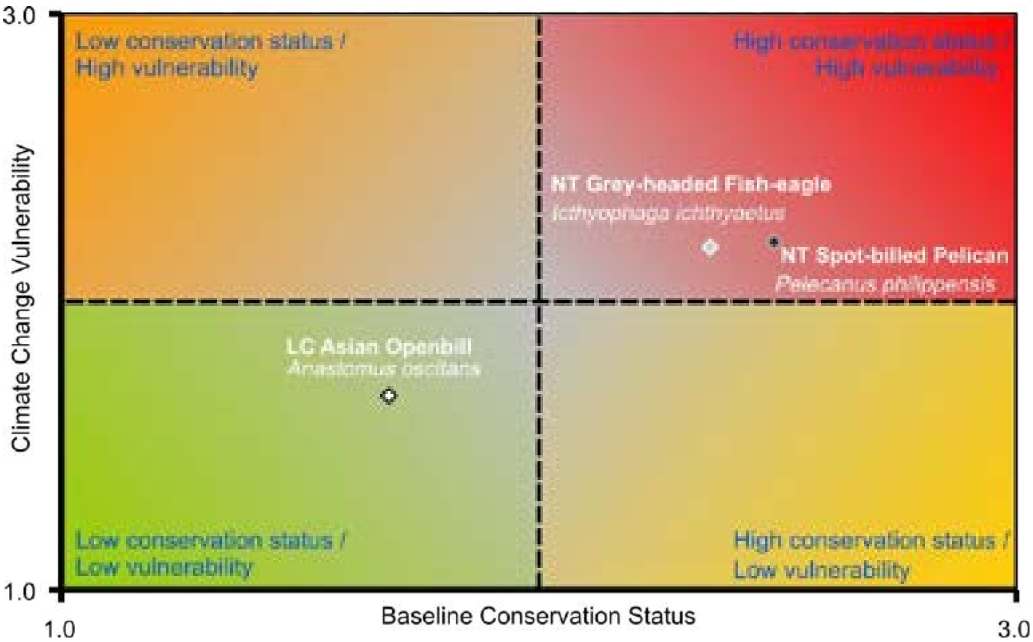


Figure 17: Baseline conservation status and climate change vulnerability of bird species in SSRS.

Grey-headed fish-eagle
(*Icthyophaga ichthyaetus*)
Photo: Conservation International

3.2.3 Mammals

Camera-trap survey

In parallel with the current assessment, the authors conducted a camera-trapping survey within and around SSRS including areas of the Lower Stung Sen IBA / KBA, between December 2020 and December 2021, focused on searching for fishing cat (*Prionailirus viverrinus*) presence and identifying important areas for hairy-nosed otter (*Lutra sumatrana*). During this period, data was obtained from 27 cameras over 1117 camera-trap days.

Presence of 45 species, 31 birds (Table 7), 10 mammals and 3 reptiles was recorded (Table 8), including 3 globally threatened mammals.

Table 8. Species photo-captures, IUCN Red-List Status, number of sites, frequency of capture per 100 camera-trap nights, season (D: Dry season; W: Wet season) and habitat type (FF: Flooded Forest; GF: Gallery/Semi-evergreen Forest; FS: Flooded Shrubland).

Species	Scientific name	IUCN Status	# Sites	Freq. /100CTN	Season	Habitat
Mammals						
Hairy-Nosed Otter	*Lutra sumatrana*	**EN**	2	0.2	D/W	FF
Indochinese Silvered Langur	*Trachypithecus germaini*	**EN**	5	1.5	D/W	FF/GF
Long-Tailed Macaque	*Macaca fascicularis*	**VU**	2	0.3	D/W	FF
Common Palm Civet	*Paradoxurus hermaphroditus*	LC	5	1.0	D	GF/FS
Leopard Cat	*Prionailurus bengalensis*	LC	5	2.1	D/W	FF/GF/FS
Northern Treeshrew	*Tupaia belangeri*	LC	18	16.6	D/W	FF/GF/FS
Greater Bandicoot Rat	*Bandicota indica*	LC	3	1.3	W	FF
Red Spiny Rat	*Maxomys surifer*	LC	15	16.3	D/W	FF/GF/FS
Small Asian Mongoose	*Herpestes javanicus*	LC	7	2.3	D/W	FF/GF
Variable Squirrel	*Callosciurus finlaysonii*	LC	9	6.4	D/W	FF/GF
Amphibians & Reptiles						
Yellow Large-Toothed Snake	*Dinodon flavozonatum*	LC	1	0.1	D	FF
Asian Common Toad	*Duttaphrynus melanostictus*	LC	4	1.1	D/W	FF
Common Water Monitor	*Varanus salvator*	LC	1	0.1	W	FF
Red-Tailed Racer	*Gonyosoma oxycephalum*	LC	1	0.1	W	FF
Human & Domestic						
Cat		NA	1	0.1	D	FS
Dog		NA	3	2.1	D	GF/FS
Human		NA	11	3.4	D/W	FF/GF/FS
Water Buffalo		NA	8	8.3	D	GF/FS

Small Asian mongoose (*Herpestes javanicus*) taking advantage of the water hyacinth mats to reach isolated trees within SSRS

Endangered hairy-nosed otter (*Lutra sumatrana*) and Indochinese silvered langur (*Trachypithecus germaini*) were photographed within SSRS and outside in nearby flooded forests within the Lower Stung Sen IBA/KBA. Vulnerable long-tailed macaques (*Macaca fascicularis*) were photographed deep within the flooded forest in the wet season, only at two sites, which indicates they may be less abundant in SSRS than Indochinese silvered langurs. Despite being considered a common species throughout its range, excess hunting and persecution due to negative interactions with humans have led to steep Long-Tailed Macaque population declines, which are expected to continue. Lack of attention to and focused conservation action on an apparently "abundant" species will continue to drive declines (Eudey *et al.,* 2020). In Cambodia, capture of macaques for the international biomedical industry has decimated populations. The practice was outlawed in 2010, however poaching of live animals, is still prevalent throughout the country and can pose a threat to other primate species such as Indochinese silvered langurs captured as "by-catch" (McGrath and Behie, 2021).

Common palm civets (*Paradoxurus hermaphroditus*) were photographed in the dry season in gallery/semi-evergreen forests by the Stung Sen River and in shrublands. Common Palm Civets are also an apparently abundant species, but in Cambodia they are often targeted using specialized traps for live capture to sell animals to civet-coffee farms through illegal wildlife trade networks.

Fishing cat presence was not recorded during the survey, but leopard cat (*Prionailirus bengalensis*) was recorded both using dry land areas and permanently inundated flooded forest areas. Vulnerable smooth-coated otters (*Lutrogale perspicillata*) were not recorded by cameras either, but their signs were observed along the mainstream of the Stung Sen river, and presence of a significant population was confirmed by local community members during interviews.

As expected in floodplain habitats, mammal diversity in SSRS is not particularly high (Campbell *et al,* 2006), however it is likely that some species using the area during the dry season were not detected during the camera-trap survey due to gaps in the data obtained. Endangered large-spotted civet (*Viverra megaspila*), small Indian civet (*Viverricula indica*) and golden jackal (*Canis aureus*) were recorded in central areas of the floodplain in 2011 - 2014 (CI personal communication) and could still be present around SSRS. Jungle cat (*Felis chaus*), was recognized by some community members, and there was possible sighting during field work in the dry season on the northern half of SSRS.

Only a few common species of amphibians and reptiles were detected during the survey, but additionally two monocled cobras (*Naja kaouthia*) were sighted during fieldwork, one on a tree and another one swimming in central flooded forest areas of SSRS.

Common palm civet (*Paradoxurus hermaphroditus*)

Species assessed

Hairy-nosed otter (*Lutra sumatrana*). This species of otter is endemic to Southeast Asia, and is considered the rarest and least known of the five otter species occurring in Asia (Sasaki *et al.,* 2021). The literature widely reported that it was believed to be extinct in 1998 after a decade without records, but the source of this statement is unclear, and between 1999 and 2008, small populations were recorded in Thailand, Viet Nam, Cambodia and Sumatra (Wright *et al.*, 2008). Long (2000) reported a single hairy-nosed otter seen in a market in Cambodia, and the first confirmed records in the country were of captive animals kept in floating houses on the Tonle Sap Lake (Poole, 2003). One camera trap record and a skin confirmed presence in unspecified areas of the Tonle Sap flooded forests in 2007 (Olsson e*t al.,* 2007 in Wright *et al.,* 2008). Between 2006 and 2013 camera-trap photographs and other evidence confirmed its presence in BTCRS and flooded forests on the southwest of the lake (Heng *et al.*, 2016) and from 2014 in Prek Toal (Willcox *et al.,* 2016). Other significant sites for hairy-nosed otters in Cambodia are found in the coastal mangroves, particularly Peam Krasop Wildlife Sanctuary (Heng *et al.,* 2016). In the Tonle Sap flooded forests, hairy-nosed otters seemed to select areas with more tree cover, and clumps of trees or bushes forming an umbrella to mark, as opposed to more open latrine sites used by group living Smooth-coated Otters. In the Tonle Sap flooded forests, both otter species were found to feed on at least seven fish species (particularly black fish such as *Channa striata*), with the tentacled snake (*Erpeton tentaculatum*) composing a major proportion of the diet of both, which also included crab and rat species (Heng, 2010 *in litt.*).

Hairy-nosed otters were assumed to be present in Stung Sen (MoE, 2007), and the first confirmed evidence was obtained during the camera-trap survey conducted in parallel with the current assessment. The species was recorded at two sites within flooded forest in the central area of SSRS and outside within the Lower Stung Sen IBA/KBA, close to the lake shore. These records suggest that the species may stay within flooded areas, going further into SSRS in the wet season and retreating to areas closer to the lake in the dry season. Dry season ponds and streams likely provide important habitat connectivity and opportunities for catching their preferred water snake and black fish prey.

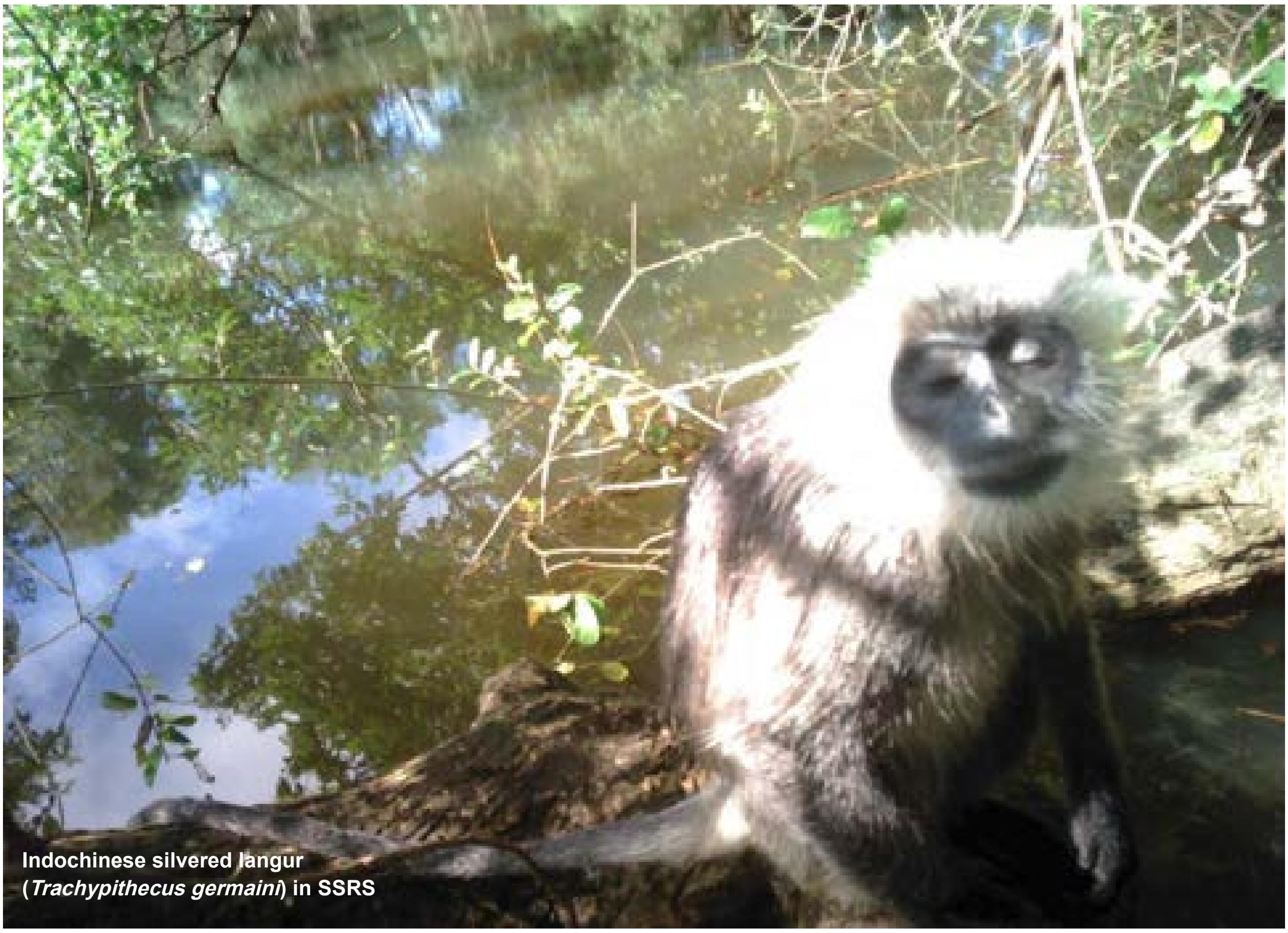
The Tonle Sap flooded forests and particularly the better conserved flooded forests found in the three Ramsar sites may form one of the most significant global strongholds for this rare otter species. The impacts of climate change on flooded forest habitats and fish populations will affect hairy-nosed otters, but they might be able to retreat to permanently flooded areas to find refugia. Following this evidence, the hairy-nosed otter population in SSRS has a very high conservation status and is moderate to highly vulnerable to climate change impacts.

Hairy-nosed otter (*Lutra sumatrana*) in SSRS

Indochinese silvered langur (*Trachypithecus germaini*). This primate species is only found in Cambodia and parts of Lao PDR, Viet Nam, Thailand and Myanmar, with the Cambodian Northern plains considered a stronghold (Moody *et al.,* 2011; Duc *et al.*, 2021). In Cambodia, the Indochinese silvered langur is widely distributed west of the Mekong, from the Tonle Sap flooded forests and the Northern plains up to the border with Lao PDR, to the Cardamom mountains in the Southwest (Moody *et al.,* 2011), as well as along the Mekong River between Kratie and Stung Treng towns (Bezuijen *et al.,* 2009). East of the Mekong in Mondulkiri province, there is a large population that is intermediate between *T. germaini* and *T. margarita* (Duc *et al.,* 2021). Indochinese silvered langurs are found in a variety of primarily lowland forests, including mangroves and inundated *Melaleuca* forests in Viet Nam, and evergreen and semi-evergreen forest patches within dry dipterocarp forest, mixed deciduous patches, riverine strips and gallery forests (Kong and Tan 2002, Moody *et al.* 2011) as well as the Tonle Sap and Mekong floodplains (Davidson, 2006). Loss of habitat, use in traditional medicine, hunting and collection for the pet trade are major threats to this species (McGrath and Behie, 2021; Duc *et al.,* 2021).

In Stung Sen, Indochinese silvered langurs are locally considered common and are easily observed on tall trees along the river mainstream. During the camera-trap survey, they were photographed at five locations both within SSRS and outside in the IBA/KBA, in areas with high forest cover, getting down to dry ground to feed, and in flooded areas occasionally swimming between trees.

The Tonle Sap flooded forests are essential habitats for Indochinese silvered langurs, and the SSRS population is likely to be significant given the species' limited global range and affinity for lowland habitats which are being converted at an accelerated rate in the region. Flooded forests are very important for the species but they are able to find refuge on other types of lowland forest. Indochinese silvered langur is therefore considered to have a high conservation status and moderate to high vulnerability to climate change.



Indochinese silvered langur (*Trachypithecus germaini*) in SSRS

Fishing cat (*Prionailirus viverrinus*). Fishing cats are medium-sized, stocky and muscular, weighing from 7 to 16 kg, with body length of 65 – 85 cm and a relatively short tail of 20 – 30 cm. Their short, coarse fur is gray or olive brown with black lines on the face, neck and shoulders, small black spots and lines throughout the body, and white underparts. Fishing cats are the largest of the Prionailurus genus and are often confused with leopard cats (*Prionailurus bengalensis*), which are smaller (approximately the size of a domestic cat), more slender with a longer tail, and brighter fur with leopard-like rosettes.

Fishing cats range from South to Southeast Asia, closely following the patchy distribution of wetlands. Major strongholds are found in South Asia, but the Southeast Asian population is in a much more perilous situation. (Mukherjee *et al.,* 2016). Habitat loss, poaching, persecution and roadkills are the main threat to their survival throughout their range. In Cambodia, a population of fishing cats persist in the coastal mangroves (Thaung *et al.,* 2017), and wetlands around the Tonle Sap and the Mekong River are priority areas for targeted surveys to search for other possible remaining populations (Adhya *et al.*, 2022).

The seizure of a dead individual near the Tonle Sap floodplain in 2018 suggests that fishing cats might still inhabit the area. In September 2018, a dead fishing cat was recovered by the WRRT at a bushmeat stall near the Tonle Sap wetlands. The animal was handed over to the Museum of Zoology of the Royal University of Phnom Pehn and a veterinarian specialized in small wild cats from the Iberian Lynx Conservation Programme (Spain), invited by the Cambodian fishing cat Project, conducted a necropsy of the body in October 2018. Results of the necropsy indicated that the animal was a 1.5 to 2 years-old male, which weighted 17 kg and was 87.6 cm long (excluding the tail), making it a considerably large individual. The cat seemed overall healthy and had good fat reserves. A number of injuries were documented throughout the body, mainly several blunt, deep, puncture wounds on its right side, possibly caused by electro-fishing implements. The cause of death were blunt force trauma injuries to the head. The claws and teeth had been removed post-mortem (V. Herranz Muñoz and R. Grande Gómez, article in preparation).

In Cambodia, most people use the term “kla trey” loosely to refer to both fishing cat (*Prionailirus viverrinus*) and leopard cat (*Prionailirus bengalensis*). Considering this, the authors designed a questionnaire with ten questions including photo identification questions, targeted to ascertain whether people could properly identify fishing cat. The questionnaire also included sections on threats to wildlife and wildlife conflict. A total of 51 people were interviewed at 5 villages around SSRS.

Results of the questionnaire showed that most people could not identify fishing cat and called leopard cat “kla trey.” Only a few people had ever seen “the big one” (fishing cat), which some people called “the mother of kla trey,” and reported to have seen it within the last three years, in areas deep within flooded forests.

Fishing cats were not detected during the camera-trap survey in SSRS, however the high suitability and quality of the SSRS wetland habitats and flooded forests in particular, make the site an important refuge for the potential population remaining around the Tonle Sap, especially as natural habitats in the floodplain are being intensely encroached by agriculture. Fishing cats inhabit wetland sites spanning broad temperature and precipitation ranges throughout their global distribution.

The rationale behind assessing the species here is that fishing cats may still use SSRS, may recolonize the area due to conversion of surrounding habitats, or may be considered for re-introduction to the site as a flagship species. Fishing cats would have a high conservation status and moderate to low climate change vulnerability in SSRS.

Fishing cat killed in the Tonle Sap wetlands in 2018.

Fishing cat in the coastal mangroves.

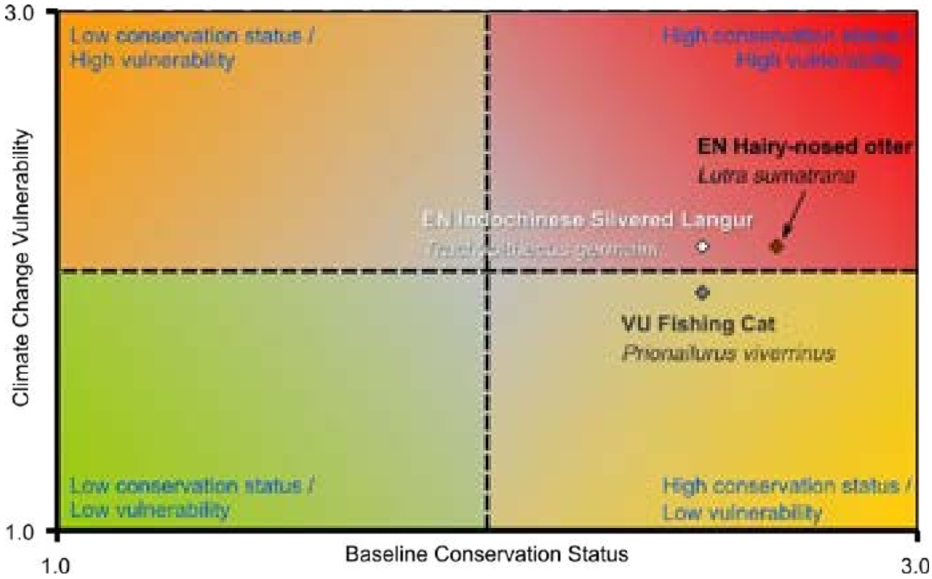


Figure 18. Climate change vulnerability assessment of mammal species in SSRS.

Threats Questionnaire

The questionnaire also showed that hunting of mammals and birds may happen often in SSRS, and hunters may target Leopard Cats for consumption. These results are concerning both for the conservation of wildlife in SSRS, and for the wider implications of wildlife consumption, including heightened risk of zoonotic disease transmission (IPBES, 2020). Conflict with smooth-coated otters (*Lutrogale perspicillata*) over destruction of fishing nets was also reported, however respondents declared that in most instances there was little retaliation beyond occasionally using scarecrows to keep the otters away from nets.

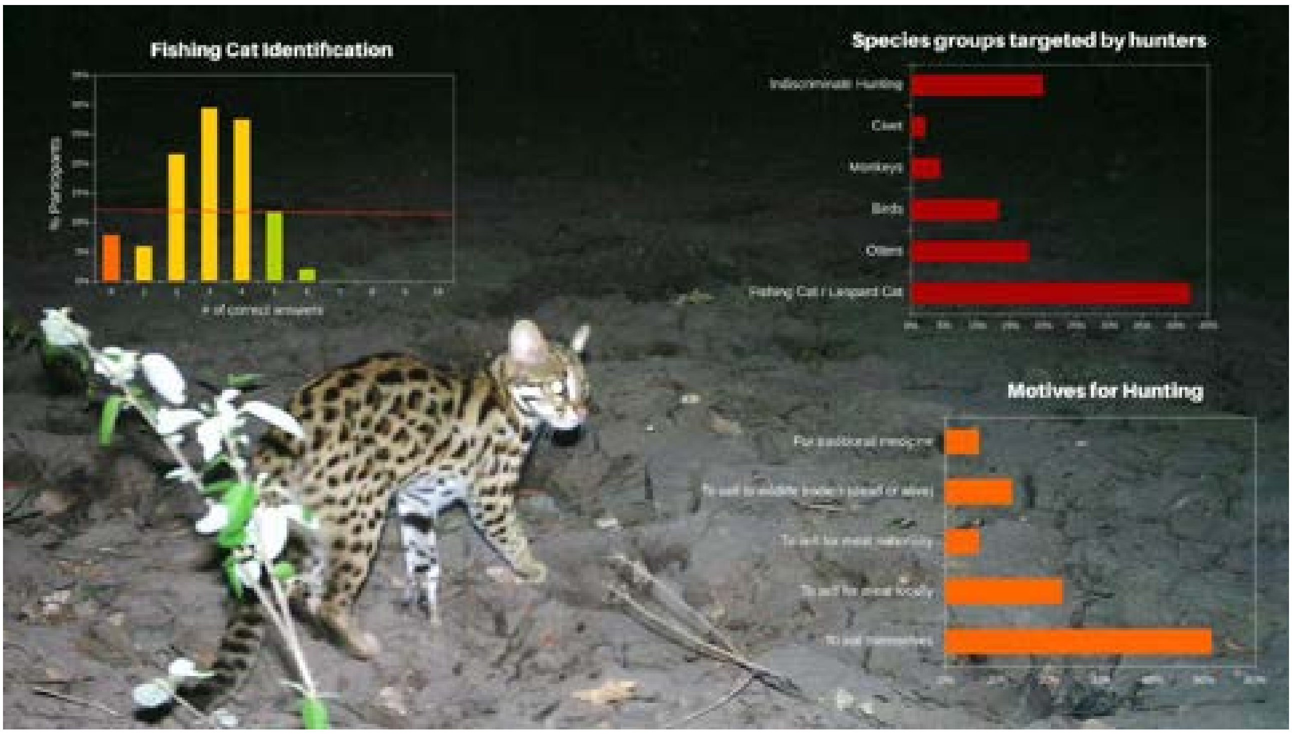


Figure 19: Main results of the questionnaire on fishing cat identification and threats to wildlife conducted in SSRS in December 2020.

Reptiles

Turtles. SSRS is likely to serve as an important breeding area for Critically Endangered yellow-headed temple turtle (*Heosemys annandalii*) and giant Asian pond turtle (*Heosemys grandis*), Endangered Southeast Asian box turtle (*Cuora amboinensis*) and black marsh turtle (*Siebenrockiella crassicollis*), Vulnerable Asiatic softshell turtle (*Amyda cartilaginea*), and Near Threatened Mekong snail-eating turtle (*Malayemys subtrijuga*). Illegal collection of turtles using specialized cylinder traps is a significant threat to their populations (Figure 20). Turtles are dependent on temperature for sex determination, and increased temperatures during the incubation phase in the dry season can affect the sex of hatchlings and skew the sex ratio of populations. Higher temperatures also affect the behavior of turtles which swim slower and hatchlings swim closer to the water surface when they have been incubated at higher temperatures, making them more vulnerable to capture and predation. High temperatures will also decrease the area of dry season pond habitats available (Meynell *et al.,* 2019). SSRS is therefore highly significant for turtle conservation, and turtles are highly vulnerable to climate change.

Water snakes. Water snake sex determination is not dependent on environmental factors, and therefore temperature increases may not directly affect populations. However, increases in temperature may promote longer eastivation periods in late dry season making them more vulnerable to collection. Habitat changes brought about by climate change may not impact water snake breeding dynamics but populations already under severe collection pressure may become over-exploited if other livelihood activities are impacted by climate change and changes in hydrology.

Figure 20. In 2019, 50 yellow-headed temple turtles (*Heosemys annandalii*) were rescued from the illegal wildlife trade and released back into the Tonle Sap Lake by the WRRT in collaboration with FiA.

3.3 Community and livelihoods

The assessment of community and livelihood vulnerability was conducted in five villages within Phat Sanday commune, focusing on local community reliance on wetland resources for livelihoods. Village chiefs, CPA committee members, the commune council and local fishermen participated in focus discussion groups and identified the main wetland resources which are essential for local community livelihoods. Several participatory tools were used for the appraisal:

- Resource ranking: Women and men in villages identified the top 10 wetland resources which are essential to their livelihoods.
- Resource map: A map was produced to illustrate the spatial distribution of key areas for different types of wetland resources.
- Seasonal calendar: A seasonal resource calendar was produced to show wetland resource harvesting activities of local people over a 12-month period.

Climate change vulnerability was assessed through a total of 56 individual interviews with local community members in all five villages. Interviews were conducted using a modified version of the Village VA tool, with additional questions about fish catch details and trends in recent years, use of other wetland resources and aquaculture activities.

3.3.1 Resource dependency

Table 9 shows an overview of the top 10 most important wetland resources used by local people in Phat Sanday commune. Resources were chosen based on their value as food, for income generation, and for providing other services. The most important wetland resources were the river or canal water, fish (black, gray and white), snails (*Pila scutata* and *Pomacea* spp.), small shrimps, eels, firewood, wild vegetables, crabs, frogs and bushmeat. River water is the most essential resource because of its importance to provide clean water for drinking, cooking and growing vegetables. The main river, streams and canals serve as roads for people to travel by boat. Men and women use river water intensely for daily activities and ranked it with similarly high values. Women and men identified fish as the most important resource for all local people living in and around Stung Sen Ramsar Site. The daily fish catch is the most important source to sustain people's livelihoods through the sale of fresh fish, fish processing to sell throughout the year (e.g. drying, fermenting into *prahoc*), and use for household consumption. Around SSRS, the local community has few other ways to generate income, only a few people have access to land to grow rice and other vegetables, and possibilities to own livestock are also limited. Snails (*Pila scutata*) also play an important role for household consumption and income generation due to their availability for harvesting all year-round; huge amounts of snails are transported to sell at the nearest landing site, Chhnouk Tru, and in Phnom Penh. Bushmeat scored lowest among important wetland resources but is consumed or sold opportunistically. For most wetland resources, the scores assigned are not significantly different between men and women.

Table 9. Ten most important wetland resources in SSRS scored by men (M) and women (W).

Item	Score		Use	Local names of main species utilized
	M	W		
River water	10	9	For household consumption and transportation	
Fish	8	8	Food and income. Sold fresh or processed as Prahoc, dried fish, etc.	Trey Pra, Trey Chapin,Trey Chunteas Pluk,Trey Kranh,Trey Riel, Trey Chtor, Trey Touk, Trey Chkoak,Trey Chkoak, Chlang
Snails	6	6	Food and income	Kyorng
Small shrimps	4	1	Food and income	Kompeus
Eels	1	2	Food and income	
Firewood	4	5	Cooking fuel	
Wild vegetables	6	4	Food and income	Trouy Raing, Ta Erk, Andat Trokourt, Tro Koun, Kantaing Hae, Pka Snor, Khnay Mornn, Kamping Pouy, Komloak, Sandann Trouy Kontouk, Prolit and Kanhchaet
Crabs	1	0	Food and income	Kdam
Frogs	0	1	Food and income	Kang Keb
Wildlife meat	0	0	Food and income	Snack, Anderk and Trokourt

Table 10: Fish species local names in SSRS

Local name	Species
Trey Pra	*Pangasianodon hypophthalmus; Pangasius bocourti*
Trey Chpin	*Hypsibarbus lagleri; Hypsibarbus malcolmi; Hypsibarbus pierrei; Hypsibarbus vernayi; Hypsibarbus wetmorei; Barbonymus gonionotus*
Trey Chunteas Pluk	*Parachela oxygastroides; Parachela siamensis; Parachela williaminae; Parachela maculicauda*
Trey Kranh	*Anabas testudineus*
Trey Riel	*Henicorhynchus siamensis*; *Henicorhynchus caudimaculatus*; *Albulichthys albuloides*; *Amblyrhynchichthys truncatus*
Trey Chdoar or Derb	*Channa micropeltes*
Trey Touk	*Channa striata*
Trey Chakaeng	*Puntioplites falcifer; Puntioplites proctozysron*
Trey Chlang	*Hemibagrus spilopterus*

A resource map was produced by local community members to give deeper insight into the spatial distribution of the most important wetland resources and where local people harvest these wetland resources (Figure 21). Villagers drew a map of the area and placed pictures of the top ten wetland resources in specific locations spreading throughout the landscape.

According to the map, local people preferred to harvest resources in 15 main sites including two sites in the SSRS core area where collection is prohibited located in Chan Chrokeang and Tung Chorngkor. Local people mainly harvest fish, snails, eels, small shrimps in deep pools. Lotus is grown for collection at several locations such as Youn Srat, Boung Taneng, Pahal Touch, Boung Smaouv, Tae Sngab, Ang Prolit, Pdov Pen, Sbov, Bat Daiy, Tlouk Apdouv, and Touk Tla. Firewood and frogs are collected both in flooded shrublands and flooded forests located near canals and particularly along the Stung Sen River. Some activities related to collection of NTFPs such as harvesting honey and ant nests also provide income for local people. Capacity building for sustainable collection NTFPs should be implemented to ensure ecosystem functions are protected.

Figure 21: Resource map of SSRS. Local community members in SSRS draw the resource map

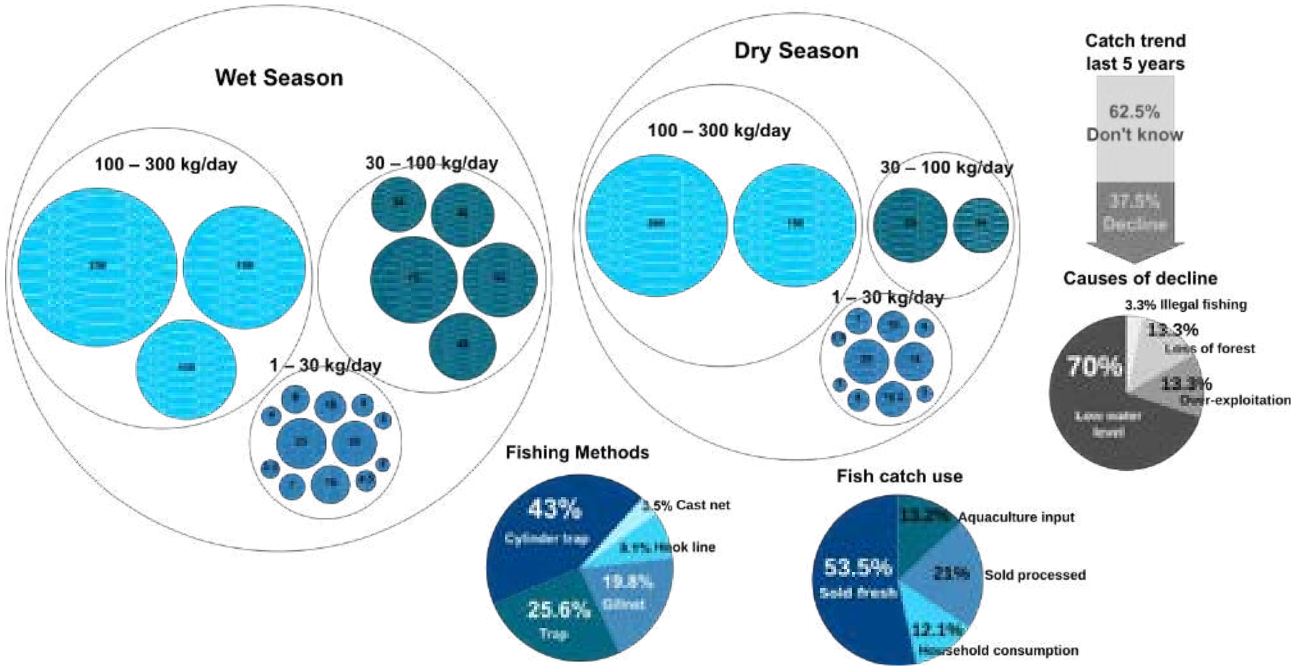
Local community members also produced a seasonal calendar for wetland resource collection and livelihood activities over a 12-month time-frame (Table 11). According to the seasonal calendar, local villagers catch fish all year-round but different fish species provide different harvesting yields depending on the time of the year. The most abundant fish yields are obtained between early wet season starting in May and the middle of the dry season in January. Lower intensity fishing occurs between February and April due to only small areas of open water remaining in SSRS, such as pools and small watercourses. Irregular rainfall, storms and high temperatures happen in April-May and impact fishing and other livelihood activities. On the other hand, snails and eels are harvested at high intensity in the wet season from May until January, but lower intensity snail collection also occurs from February to April. Rice farming and aquaculture are practiced starting early during dry season from January to April. Lotus are planted in the dry season from January to June in small watercourses and pools. Lotus growing areas provide habitat for fishes, snails and eels. Flowers of plants in genus Sesbania are collected from January to June for food consumption and stems are used as floats for fishing gear and floating houses. In the dry season, water hyacinth is a major obstacle for fishers to reach fishing sites, as well as to be able to travel in and out of the villages, even in emergencies, due to severe blockage of navigation canals. Complementary activities, such as fixing fishing nets are usually conducted during the dry season. The seasonal calendar indicates that fishing, harvesting snails, collecting eels, aquaculture, and growing lotus are the most important livelihood activities conducted in different seasons in SSRS.

Table 11. Seasonal calendar of wetland resource use/collection and livelihood activities in SSRS. Darker gray denotes higher intensity of use.

Livelihood Activities	Month of year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fishing	●	○	○	○	○	●	●	●	●	●	●	●
Rice farming	○	○	○	○							○	○
Snail & Eel collection	●	○	○	○	○	●	●	●	●	●	●	●
Lotus growing	○	○	○	○	○	○						
NTFP collection						○	○	○	○			
Aquaculture	○	○	○	○	○			○	○	○	○	○
Fixing nets	○	○	○	○	○	○	○	○				

Additionally, during individual interviews (n=56) local community members provided further details on the size and trend of the fish catch in different season over the last five years, the fishing methods/gears utilized and how the fish catch is normally used (Figure 22). More people fish and obtain a larger catch in the wet season, with the majority yielding 1 to 30 kg/day. Only a few people harvested between 100 and 300 kg/day (those who owner more/better gears), and they mentioned that larger fish catches were growing increasingly rare. The gear used most often were cylinder and other traps, and the majority of the fish catch is sold fresh. 37.5% of respondents reported fish catch declines which they mainly attribute to the extremely low water levels experienced in recent years in SSRS.

Figure 22. Wet and dry season fish catch. Bubble size represents size of fish catch (kg). Fish catch trend in the last five years, and perceived causes of decline (right). Fishing methods and use of fish catch (bottom).



Interviewees were also asked to score how stable their livelihoods felt, with the lowest score (1) meaning *"Not stable, sometimes not even enough for food"*, the middle score (5) meaning *"Stable, but not enough for saving"* and the highest score (10) meaning *"Very stable"*. Almost 50% of respondents gave scores below 5, adding that due to the severe decline in the daily fish catch, their livelihoods had become increasingly unstable over the last few years. Another 48% of participants scored their livelihood stability as "5"; in most cases these interviewees relied on several sources of income besides fishing, including aquaculture, growing vegetables, raising chickens, fixing nets and other paid labor. Only 2 people scored their livelihood stability above 5 (7, 8); they were government officials with additional income from owning businesses (Figure 23).

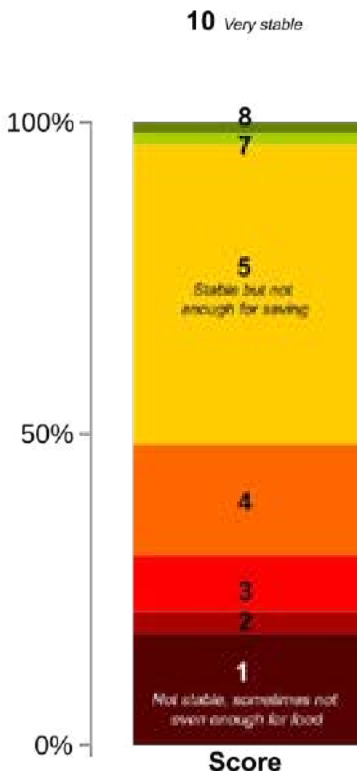


Figure 23. Self-assigned scores of livelihood stability of (n=56) local community member interviewed at five villages around SSRS.

The second major source of income around SSRS is small scale cage/pen aquaculture. Among the villagers interviewed, 50% raise fish in cages next to or under their floating houses on the mainstream of the Stung Sen River. The main species raised is *Pangasius hypophthalmus,* kept by 60% of villagers practicing aquaculture, with 10 -15% raising *Pengasius larneaudii, Channa micropeltes* and *Hypsibarbus* spp. in many cases in addition to *P. hypophthalmus.* Most people started their aquaculture activities by purchasing hatchery seed fingerlings (1000 – 8000), with around 15% sourcing fingerlings from the wild.

The great majority (~90%) of people reported a large proportion of their fish suffered from diseases involving red eyes and redness on their bodies, and died in substantial numbers (40 – 90%), attributing the cause to the river water becoming polluted from agricultural runoff upstream, and overheating from increasing temperatures and drought (Figure 24).

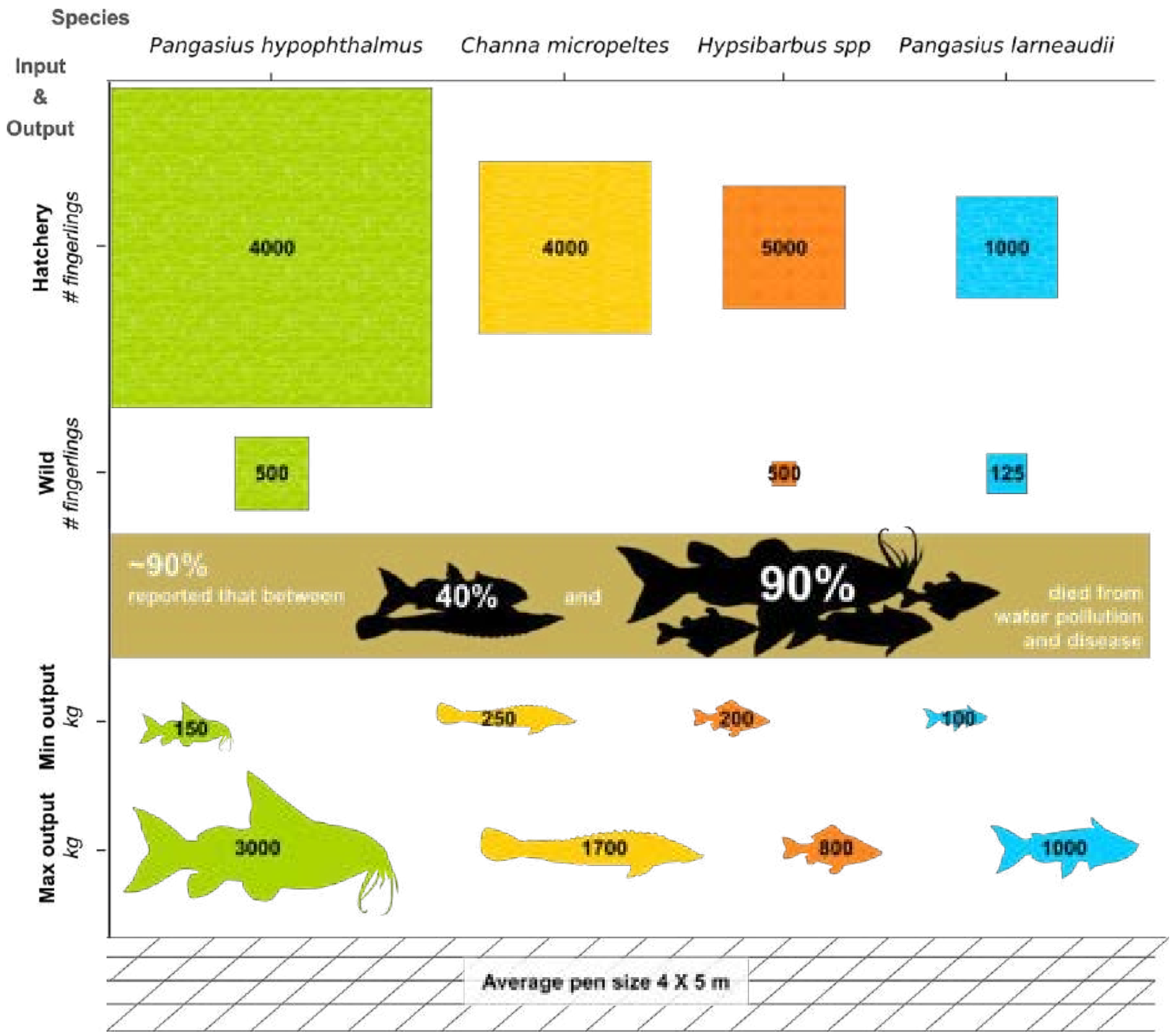


Figure 24. Fish species raised in SSRS. Median numbers of hatchery seed and wild fingerlings used as input; size of the squares indicates number of responses. Range of percentages of fish dying reported. Minimum and maximum outputs (kg) reported per species.

3.3.2 The impact of climate change on resources

Villagers were asked to identify a timeline of memorable extreme weather events which affected them and the resources they depend on over the last 10 years (Table 12). The main types of extreme events impacting SSRS wetland habitats, vital species, as well as people's well-being and livelihoods are summarized in below. In the past few years, villagers in the area described different environmental alterations caused by global climate change. Storms were reported to intensify and happen more often in recent years. All villages reported that storms impacted wetland habitats and decreased the income of local community members. Faced with more frequent and violent storms, people indicated that they found it a lot harder to catch enough fish because they were afraid to go fishing far from home and get caught in the storms or get injured by falling trees. Storms also cause severe damages to people's houses. Extreme weather events such unusually high temperatures, drought, intense storms and storm surges, and strong winds have been happening more frequently in recent years. Extreme weather events coupled with the extremely low water levels and short duration of floods in 2019, 2020, 2021 had a substantial negative impact on local incomes through severe damage to houses and significantly lower fish catch. Local villagers also reported that high temperatures leading to more intense forest fires killed wildlife, provoked mass fish deaths in dry season pools and affected people's health.

Table 12. Extreme weather events and impact over the last 10 years in SSRS.

Extreme weather events	Year	Impact on livelihoods, wetland habitats and species
Storm	2011, Recent years	Storms impact people's incomes due to difficulties to go out to fish. Extreme storms also destroy local boats and houses.
Strong winds/Big waves	2011, 2016, 2020, 2021	Big waves affected people's incomes, sinking boats and breaking houses. Strong winds turn shallow water pools contributing to mass fish deaths.
Drought	2016, 2019, 2020, 2021	Low water level during droughts lead to difficulties in transportation and lower fish catch. Drought also contributes to forest fires.
Extreme heat	Recent years	Extreme heat contributes to low fish catch, crop damage, death of livestock, mass fish death and people's health problems, as well as fueling forest fires. **Forest fires** are happening more often, with greater intensity and destructive consequences for wetland habitats and species.
Unusually low water levels	2019, 2020, 2021	Unusually low water levels impact local people's income by reducing available areas and duration of the season for high yield fishing, and having a direct impact on fish populations.

3.3.3 Current and future coping strategies

Due to the impacts of climate change, extreme weather events and low water levels and flood duration, local people in SSRS face significant challenges. Local people rely on few appropriate mechanisms to cope with extreme weather events and climate change, and lack resources to improve adaptive capacity.

In the case of storms, local people often prepare their houses by cutting tree branches nearby to prevent damage; adding more nails for structural strength; tying the house to large trees; and keeping supplies in a safe place to prevent losses. An interesting strategy for community safety in emergency storm conditions is hitting pans or pots as an alarm to get help from their neighbors. Some local people reported to leave the house and stay in the forest for safety during storms and strong winds. During longer periods of exposure to climate change impacts such as droughts, local people use several strategies to supplement their income such as fixing nets, taking up loans and seeking temporary jobs in Phnom Penh, reporting that these strategies were more helpful than staying at home with no income.

Table 13 Impact of extreme events and current coping mechanisms of men and women.

Extreme event	Impact	Current coping activities (Men)	Current coping activities (Women)
Storms	Home collapse	Adding more nails to the house, put house supply materials in a safe place to avoid losing them during storms.	
	Risk to personal safety		Shout, hit pans and pots for neighbors to help. Stay in the forest.
Strong wind	Home collapse		Adding more nails to the house, put house supply materials in a safe place to avoid losing them during storms.
	Mass fish deaths in shallow water pools	Cover pools with water hyacinth to cool the water	
Drought	Transport difficulties	Reach sites overland to find snails. Push the boat in shallow waters. Stay at home.	
	Reduced income	Collect snails, seek temporary jobs in Phnom Penh.	Fix nets for money, raise fish, Use irrigation for farming. Get loans.
Forest fires	Fire happened near house	Using water pumps to prevent the spread of fire.	Using water pumps to prevent the spread of fire.
	Forest and wildlife loss	Cooperate with authorities to put out the fire.	
Extreme heat	Health problems	Taking bath many times per day, stay under trees instead of in house, take medicines, get traditional massage.	Taking bath many times per day, stay under trees instead of in house, take medicines, get traditional massage.
	Lower income	Fishing in the early morning	Growing more vegetables
Unusually low water levels	Loss of income	Collect more snails. Seek temporary jobs in Phnom Penh. Get loans. Fix nets or do other jobs for money.	Grow vegetables. Collect snails to obtain income. Get loans. Move to land. Fix nets or do other jobs for money. Rely on home business (selling drinks and snacks).
	Aquaculture fish death and disease		Re-stock cultured fish.

Local people were also interviewed to understand how they could cope better with climate change impacts in the future and some of their answers remained rather broad and reflected a general lack of options and resources. Strategies proposed included improving income generation by raising more livestock particularly fish and chickens for household consumption and sale, with improved capacity to minimize losses. Villagers also proposed to make profit from water hyacinth, which is a resource with great potential to improve local livelihoods through the creation of handicraft businesses or sale for other purposes when sun-dried. People also elaborated on responses based around increased natural resource exploitation such as increasing extension of rice farming and burning forests to make farmland.

Table 14. Impact of extreme events and future coping mechanisms of men and women.

Extreme events	Impact	Future coping activities (Men)	Future coping activities (Women)
Storm	Home collapse	Seek safer place for the house and make it stronger.	
	Risk to personal safety		Develop other mechanisms for local community support
Strong wind	Home collapse		Seek safer place for the house and make it stronger.
	Mass fish deaths in shallow water pools	Deepen and restore pools with native vegetation and lotus to provide shade and cooling.	
Drought	Transport difficulties	Improve and deepen water channels.	Remove water hyacinth
	Reduced income	Seek jobs in Phnom Penh, get loans.	Fix nets for money. Collect snails. Improve capacity to raise fish and chickens.
Forest fire	Fire happened near house		Establish early warning/alarm system and fire risk protocols. Use water pump to fight fires near houses.
	Forest and wildlife loss	Build watch tower/s to observe forest fires early and to prepare equipment on time.	Restore wetland habitats.
Extreme heat	Health problems	Taking bath many times per day, stay under trees instead of in house, take medicines, get traditional massage.	
	Lower income		Grow vegetables. Improve capacity to raise fish and chickens.
Unusually low water level	Loss of income		Find alternative sources of income (as above). Find ways to generate income from water hyacinth.
	Aquaculture fish death and disease	Improve capacity to maintain aquaculture fish healthy. Reduce river water pollution from agriculture upstream.	

4. CONCLUSIONS

4. CONCLUSIONS

4.1 Summary of vulnerabilities

SSRS in the fifth and newest (2018) Ramsar Site designated in Cambodia, and the third situated on the Tonle Sap floodplain, after being considered one of the core areas of the Tonle Sap Biosphere Reserve since its inception in 2001. SSRS presents a complex socio-ecological system highly dependent on the flood pulse of the Tonle Sap Lake, which radically changes the structure of habitats between the dry and wet seasons, and creates livelihood opportunities. The Tonle Sap Lake floodplain, and especially flooded habitats such as those in SSRS store enormous amounts of “irrecoverable carbon” that, if released could not be recovered by 2050, when the world needs to achieve net-zero to avoid the most disastrous consequences of climate change (Goldstein *et al.,* 2020).

SSRS flooded habitats (forests, shrublands and grasslands) have suffered severe loss and degradation over the last two decades, and are currently threatened by climate change, agricultural encroachment, invasive species and the alterations to the flood pulse experienced in recent years due to the storage of water in reservoirs upstream of the Mekong River. These habitats are in dire need of improved protection to halt further destruction and degradation, and will need decisive, active restoration actions to combat invasive species, recover and increase extent of habitats previously lost, and promote resilience to climate change. If the grave alterations to the flood pulse extent and duration experienced during 2019, 2020 and 2021 (MRC, 2022), were to continue, the flooded habitats will be deeply affected.

The Tonle Sap floodplain sustains a $2 billion fishing industry, and provides two-thirds of the protein consumed in Cambodia. It cannot be stressed enough how essential the fish populations of the Tonle Sap Lake and floodplain are to Cambodian livelihoods in general, and to the survival of the local communities in particular. However, habitat degradation, over-exploitation and climate change are putting fish populations under immense pressure, and the recent alterations to the flood pulse have resulted in sharp declines in the last three years.

In SSRS, fish populations need to be better protected from illegal fishing, and it would be highly beneficial to increase the areas dedicated to fish sanctuaries (where fishing is prohibited) to promote their recovery. Reducing harvesting pressure on fish and other aquatic animals by promoting alternative sources of income for local communities would also be essential. On the other hand, the bulk of the fish catch in the Tonle Sap Lake are migratory white fish whose populations are highly dependent on the habitats and the flow of the mainstream of the Mekong River, and will therefore continue to be hugely affected by water infrastructure management decisions.

SSRS also supports important populations of water birds such as spot-billed pelicans (*Pelecanus philippensis*), and rare mammals such as hairy-nosed otter (*Lutra sumatrana*) and Indochinese silvered langur (*Trachypithecus germaini*) which depend on its flooded habitats to survive. It should be noted that the integrity of this ecosystem has already been substantially eroded, and in the past it would have sustained many more species, especially when different habitats were connected and large mammal species undertook seasonal migrations to seek available water in the dry season. Nonetheless, SSRS is a globally significant refuge for the rare species remaining which are threatened by poaching, as well as highly vulnerable to the effects of climate change.

Local communities in SSRS have experienced extreme weather events such as storms, strong winds, drought and increasing temperatures intensely in recent years. Their livelihoods mainly depend on fast declining fisheries, and adaptation options hinge on the development of alternative sources of income, as there is very little they can do to protect themselves from the direct impacts of climate change. In the last three years, the combination of climate change and extremely low water levels and flood duration, has pushed many people to economic instability at poverty levels, and many have had no other choice but to seek temporary jobs in cities.

In conclusion, SSRS is a globally significant site to be conserved and restored to maintain its capacity to store enormous amounts of carbon within vital flooded habitats. SSRS provides essential grounds for one of the world’s most complex inter-dependent networks of human livelihoods and fish populations, the Mekong - Tonle Sap ecosystem within the LMB. The survival of SSRS’s critical ecosystem will depend on active climate change adaptation measures such as large-scale habitat restoration and rewilding, which could be achieved through investment in local community led initiatives to reduce pressure and dependence on natural resources. Carbon credit schemes and other funding mechanisms should be urgently implemented to finance habitat and species restoration, and climate change adaptation measures, providing alternative income for local community members.

4.2 Adaptation planning

Based on the VA, three sets of recommendations, environmental, social and economic, were developed as potential adaptation measures to enhance resilience of SSRS habitats, species and livelihoods. The recommendations were discussed, evaluated and ranked by local community members during validation workshops conducted at several villages around SSRS, and run by CPA members themselves. Women and men scored recommendations in terms of priority, importance and interest in their implementation as CC adaptation measures (Table 15).

Table 15. CCVA adaptation measures and scores by women and men during the Validation workshop, with colors indicating priority levels (Red=High, Orange=Medium and Yellow=Lower).

Climate Change Vulnerability Assessment Recommendations	Score	
Environmental	**Women**	**Men**
- Habitat restoration of flooded forest, gallery forest, flooded shrubland and floating vegetation.	10	10
- Removal of invasive plant species, mainly water hyacinth and Mimosa pigra, coordinated with corresponding habitat restoration with native plants (e.g. Indian Lotus; flooded forest restoration)	10	10
- Research and implement strategies for removal of invasive snails.	10	10
- Raise community awareness to stop poaching and consumption of birds and mammals.	10	10
- Develop, deepen and improve canals and ponds as dry season refuges for fish and wildlife.	9	9
- Develop strategies and raise awareness to prevent and mitigate conflicts between fishers and smooth-coated otters.	9	9
- Improving patrolling/law enforcement capacity of community organizations and rangers for both illegal forest activities and illegal fishing activities.	8	9
- Fire prevention and mitigation actions such as capacity building for community organizations and rangers, provision of equipment, building watch towers, developing early warning systems and action plans.	7	7
- Reducing harvesting pressure on fish and other aquatic animals in SSRS.	7	7
Social		
- Improve sanitation	9	8
- Improve energy access (e.g. Solar)	9	8
- Improve access to clean water (e.g. filtering station)	8	9
- Create savings groups	8	7
- Capacity building/knowledge sharing among community members on legal, effective and sustainable fishing methods (e.g. local immigrants may have lower technical capacity for fishing than Cambodians)	7	7
- Improve waste management	7	7
Economic		
- Provide capacity and resources to raise livestock (fish, chickens, ducks, buffaloes) with high standards of health, animal welfare and safety from predators to avoid wildlife conflicts.	10	10
- Developing eco-tourism potential by establishing a Community Based Eco-Tourism (CBET) initiative, providing training, designing activities and connecting to appropriate partners.	10	10
- Develop sustainable source of income from water hyacinth collection for sale to use it to make furniture, handcrafts or other purposes.	10	10
- Develop diversified livelihood opportunities	9	9
- Capacity building to grow vegetables making use of limited space, such as vertical gardens, growing on water hyacinth floating beds, using water hyacinth and other organic compost.	9	9

According to the organizing CPA members, during the workshop, local people were interested in many of the recommendations such as improving access to clean water, improving sanitation, removing invasive snails and *Mimosa pigra*, develop and deepen canals ponds for fish refuge, and developing eco-tourism. However, people were most interested in two main recommendations: restoration of flooded habitats and improving opportunities and capacity to raise livestock (including fish). Local people spent the most time discussing the need for habitat restoration of flooded forest, gallery forest, flooded shrubland and floating vegetation, and developing strategies to conserve all types of flooded habitats. The reason local people cared about flooded forests is because they were well aware that flooded habitats support the natural resources their livelihoods are dependent on. Local people understood that flooded forests support a high variety of biodiversity such as wildlife, plant species and fish habitats. Community members expect that fish would increase to better sustain people's livelihoods if they can conserve and restore the flooded habitats.

The second main recommendation which community members spent most time talking about was livestock including cows, buffaloes, chickens, pigs, fish, as well as small scale agriculture such as growing vegetables. People would prefer to generate more of their income through livestock production, including aquaculture, practicing it with higher standards and technical capacity. People explained that generating income from livestock would be better than relying so heavily on natural resources.

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