KINGDOM OF CAMBODIA
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MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES

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Mekong Integrated Water Resources Management Project
Phase III – Component 1

TECHNICAL REPORTS

Scientific monitoring of the fish resource with Community Fisheries: project findings

2021

Inland Fisheries Research and Development Institute

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TECHNICAL REPORT

Scientific monitoring of the fish resource with Community Fisheries: project findings

Prepared by the
Inland Fisheries Research and Development Institute
for the
Fisheries Administration

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EXECUTIVE SUMMARY

The present report is a contribution to the Mekong Integrated Water Resources Management project Phase III (M-IWRM III, 2016-2020). The Monitoring and Evaluation part of the project includes the assessment of *fishery and management performance*, based in particular on a scientific biomonitoring of fishers. The latter covers fishing activity, fish species harvested; fish catch, Catch Per Unit Effort (CPUE) of gillnets, dominant species and average size of fish caught. The results of this monitoring between September 2019 and November 2020 are presented below.

The focus of the biomonitoring protocol, detailed in a companion report, was on four ecological zones: a Ramsar zone between Stung Treng and the border with Laos; a 3 S rivers zone (Sesan and Sekong); a Mekong mainstream zone between Stung Streng and Kratie, and a floodplain zone around Kratie. Four Communities Fisheries were selected in each zone, and five fishers in each Community Fishery were involved in the sampling, 2 days per week. Data gathered consisted of record identification, gear and activity description, catch weight and catch composition, with 3 fish lengths measured for each species in each catch.

Fishing activity analyses indicate that 2,125 to 2,541 operations were recorded per ecozone, i.e. a 16% variability. Dominant gears are gillnets (74%), long line (10%), cast net (8%) and traps (7%). Fishing is more active in the floodplain ecozone. An analysis of variability in seasonal use of fishing gears does not show any particular pattern.

Species diversity varies between 104 fish species (3 S zone) and 112 species (Ramsar zone). This is consistent with some previous studies, although not directly comparable. The species diversity by Community Fisheries varies between 80 and 95 species, with no discernible pattern within –or even between- ecozones. Only four species are part of top-ten species in each ecozone: C*yclocheilichthys enoplos, Hemibagrus spilopterus, Labeo chrysophekadion* and *Puntioplites proctozysron*. These species deserve particular attention in future biological and socioeconomic studies.

The **total catch** is the highest in the floodplain zone, with about 50% more biomass than in the other zones. The catch in the other zones is homogenous with less than 5% variability between zones. There is a large variability between sites and within zones, and "champion" sites can be found in all zones (Voadthonak in the mainstream zone, Ta Mau in the floodplain zone, Phlouk Meanchey in the 3 S and Phum Thmei in the Ramsar zone). Thirteen of the top 20 CFi featuring the highest catch are characterized by a good environment, regardless of governance and socioeconomic performance or of ecozone.

An analysis of the *catch per CFi per month* doesn't produce any clear trend. Acknowledging that fishers choose different fishing techniques, locations and target species in different seasons to permanently maximize their monthly catch, the absence of clear seasonal trends questions the influence of sampling with fishers on the perception of the resource, and calls for further research.

The few sites that display a clear seasonal pattern are those with the highest overall catch, which raises another question about the amount of fish catch required to accurately represent specific and overall seasonal fish abundance trends. Here too additional research is required.

Overall, the fish catch variability among CFi is higher than the seasonal variability in the area studied.

The comparison of catches during the first three months of monitoring with the same three months one year later show differences ranging between -9% and +31%, depending on the ecozone. However, these figures are indicative only, as one single year of monitoring is not enough to allow detecting a clear change in overall fish abundance given the high natural inter-annual variability in the Mekong River.

Gillnet Catch Per Unit Effort (CPUE) analysis shows that Ramsar and the mainstream are the two ecozones with the highest CPUE (27.9 and 24.5 g/m^2/h respectively). The lowest CPUE is found in the floodplain zone. Thus, despite a low CPUE the total catch is high in floodplains because fishers deploy the most intensive fishing activity there. An analysis of gillnet CPUE per site identifies three Community Fisheries with a particularly high CPUE: Chur Tameo in the 3 S rivers zone, Anlong Svay 2 in the Ramsar zone and Voadthonak in the mainstream zone. Voadthonak being also the champion site for overall fish catch is a key site for future biological studies.

The analysis of **top-20 species in catches** shows that the dominant species in all catches of the study area, i.e. in Stung Treng and Kratie provinces, is *Labeo chrysophekadion,* a large cyprinid (10.4% of all catches), followed by *Gymnostomus siamensis* and *G. lobatus* (formerly *Henicorhynchus siamensis* and *H. lobatus*) at respectively 8.6% and 6.9% of total catches. *Gymnostomus siamensis* is dominant in floodplain areas only. A comparison with results of the Fisheries Abundance and Diversity Monitoring programme of the Mekong River Commission over 4 years confirms these results and flags a shift in species composition and community structure (decline of *Hypsibarbus malcolmi, Pangasius macronema, Puntioplites proctozysron, Puntioplites falcifer, Hemibagrus wyckioides* and conversely progression of *Labeo chrysophekadion, Cosmochilus harmandi* and *Cyclocheilichthys enoplos*).

An analysis, among top-20 species, of **average standard species length** in each ecozone identifies 8 species whose average size differs by more than 40% between ecozones: *Cirrhinus microlepis* (153% variability), *Cosmochilus harmandi* (47%), *Cyclocheilichthys enoplos* (54%), *Helicophagus leptorhynchus* (42%), *Labeo chrysophekadion* (142%), *Pangasius conchophilus* (47%), *Pangasius larnaudii* (87%) and *Scaphognathops stejnegeri* (62%). Their common feature is a smaller size in the floodplain zone, which confirms the nursery role of this habitat.

In conclusion, data collection spanned over a bit more than a year, and it is not yet possible to draw clear conclusions about the effectiveness of the project management initiatives regarding fish abundance, diversity or size. However, a solid monitoring program has been initiated, and long term results can be drawn from the continuation of this programme. This biomonitoring also represents a significant capacity building initiative. It involved in particular Provincial Departments of Agriculture, Forestry and Fisheries for data collection, supervision of fishers, data entry, presentation of results and feedback. Eighty fishers from 20 Community Fisheries have also seen the materialization of their work, shared during joint meetings. Thus, beyond biology the present biomonitoring raised awareness about resource management approaches and strengthened the simpler self-monitoring approach promoted in parallel by the project, at the level of CFi. A long-term continuation of the present biomonitoring program is essential to strengthening the outcomes already achieved.

CONTENTS

1. INTRODUCTION

The present report is a contribution to the Mekong Integrated Water Resources Management project Phase III (M-IWRM III, 2016-2020). The objective of the latter is to enhance Cambodia's institutional capacity and infrastructure to sustainably manage its water and fishery resources in northern provinces along the Mekong River. Within this project, Component 1 managed by IFReDI/FiA is tasked with supporting fisheries and aquatic resources management in Kratie and Stung Treng Provinces. One of its objectives in particular is to strengthen public sector fishery management, including monitoring and reporting, in view of assessing impacts of water resources development (particularly hydropower) on fisheries.

More specifically, the Monitoring and Evaluation system put in place includes a component about the ecological performance of the project initiatives at the level of Community Fisheries (CFi). The Project Appraisal Document (PAD) dated 28 April 2016 indicates in particular, under Sub-Component 1.1 of the project (Establishment of Community Fisheries Management), that *Provincial Implementation Teams (PIT) will provide support to the key management stakeholders (PFiA, CC and CFi) for the design of monitoring and reporting programmes*, in particular on the fish catch.

The project Results framework (Annex 1 of the POD: Results Framework and Monitoring Cambodia) specifies (Indicator #7) that "*standard indicators and methodology to monitor fishery and management performance will be designed by IFReDI/FiA*", and that "*Standard indicators and methodology to monitor fishery and management performance will be developed in coordination with existing methodology used by IFReDI*".

These recommendations were implemented through the development:
- of a scientific biomonitoring protocol of the resource based on the catch of fishers (data to be analysed by the FiA for resource monitoring; Fisheries Administration 2019a);
- of a self-monitoring methodology for communities to produce information manageable by themselves and relevant to their own management (Fisheries Administration 2019b).

The present report constitutes the analysis of fishers' catch data gathered, under the scientific biomonitoring protocol, between September 2019 and November 2020.

2. THE MONITORING APPROACH

2.1. Objectives of the monitoring

The main purpose of the monitoring is to assess the impact of project investment and Community Fisheries' improved management on the fish resource. This implies monitoring:

i) the use of gears, as a reflection of fishing intensity;

ii) species biodiversity in fishers' catch[1];

iii) fishers' catch itself, i.e.:

- the total catch per fisher per time unit,
- b) the Catch Per Unit Effort for a commonly used gear comparable between zones and with a clear unit effort (usually gill net)
- the dominant species in catches and the average size or weight of individuals in catches

Assessing these parameters over several seasons or years allows identifying trends in the resource. In the case of the present data set, the two partial years of monitoring may not allow identifying clear trends, but the current analysis is to be seen as the beginning of a longer term initiative.

2.2. Study sites

The biomonitoring protocol was established on the following bases:

- four ecological zones in order to assess trends in fish resources in different habitats
- five Community Fisheries (CFi) per ecozone to integrate the variability between communities;
- four fishers per CFi to ensure sufficient sampling while integrating the variability between fishers.

The protocol is detailed and justified in the companion report "Scientific monitoring of the fish resource with community fishers" (Fisheries Administration 2019a).

The focus of the project biomonitoring was on four main ecological zones:

- **the Ramsar zone**, an area important to fisheries and characterized by multiple islands, microhabitat diversity and high biodiversity;
  Community Fisheries involved: Anlong Koh Kang, Anlong Svay 2, Koh Sneng, Krala Peas, Phum Thmei;
- **the 3 S rivers zone**: these rivers used to be are an important fish habitat and migration route, and the Sekong River remains undammed in Cambodia. Monitoring is done upstream and downstream of the Lower Sesan 2 Dam reservoir;
  Community Fisheries involved: Chur Tameo and Phlouk Meanchey downstream of Lower Sesan II Dam), Sdau 1 and Sdau 2 on the Sekong River, and Talat Samki Rungreung upstream of Lower Sesan II Dam;

[1] on a large geographic and time scale, to buffer site-specific and seasonal variability

- **the Mekong mainstream zone** is the main migration corridor between upstream Mekong and the Cambodian floodplains, and includes multiple ecologically important deep pools;
  Community Fisheries involved: Ampil Teuk, Anlong Preah Kou, Kampong Krabei, Kohsaksit, Voadthonak;
- **the floodplain zone**: floodplain areas adjacent to the Mekong mainstream serve as a wet season breeding and feeding ground for fish, and are a specific fishing habitat (black fish species);
  Community Fisheries involved: Kampi, Ou Lung, Prek Ta Am, Russey Keo, Ta Mau.

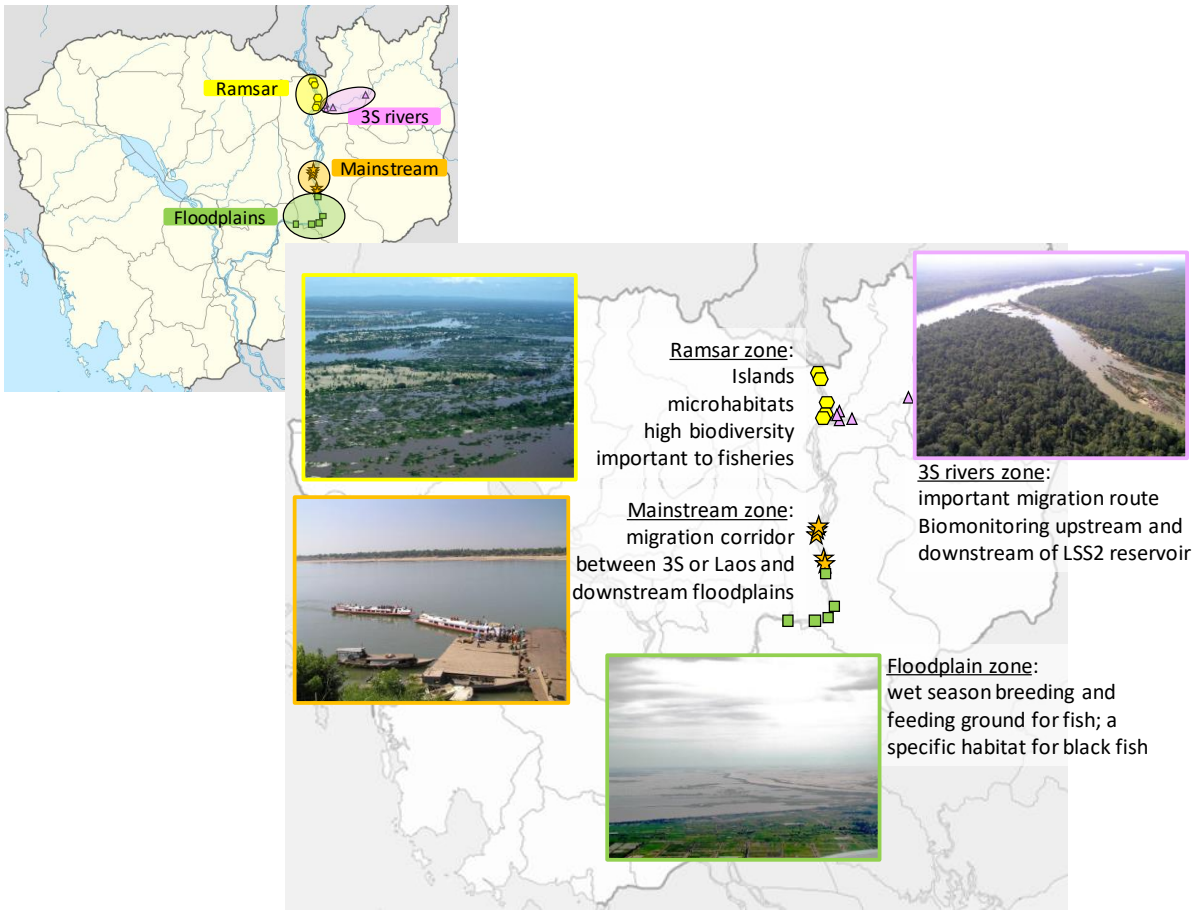


Figure 1: Main ecozones monitored

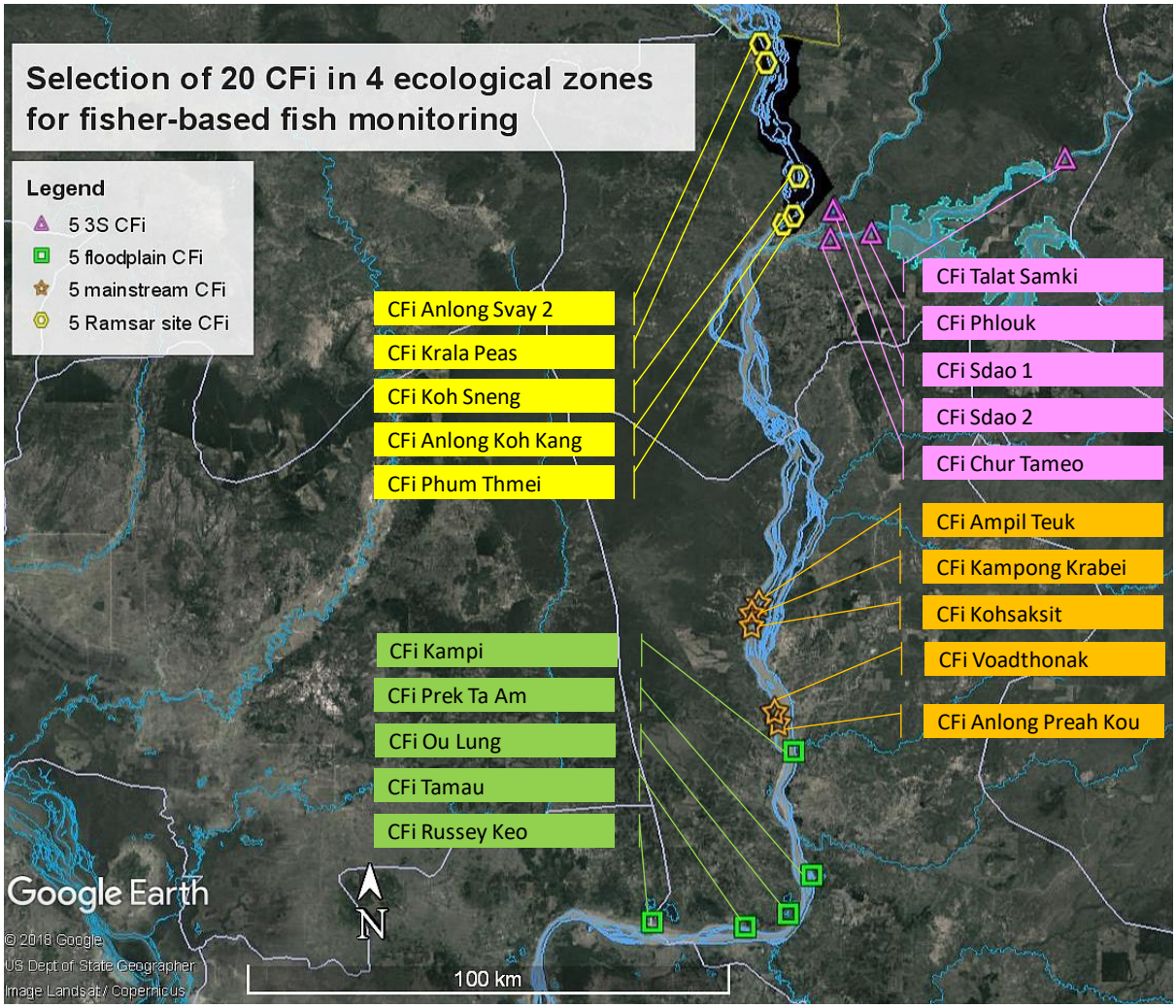


Figure 2: Community Fisheries involved in each biomonitoring zone

2.3. Sampling design and data gathered

The sampling was implemented according to the following framework (Table 1):

Table 1: Sampling framework

	Province	Ecozone	Site = CFi	Fishers	Years	Months	Fishing operations
In principle	2 provinces	4 ecozones	20 CFi	80 fishers	2 years	Each month	Up to 2 days/week/fisher, depending on fishers initiative
Actual	Stung Treng, Kratie	Ramsar, 3 S, Mainstream, Floodplains	20 CFi (5 per ecozone)	80 fishers (4 per site)	2019 and 2020	Sept. 2019 to Nov. 2020	

In each Community Fishery of each ecozone, four professional fishers were identified as partners. In total, 82 fishers were involved as two of them replaced two who dropped out. These fishers included five women.

Fishers recorded their fishing operations two days a week. They used their own gear in their own way, and all species caught were recorded, using Khmer names (the correspondence with Latin names was established using a correspondence table later on). This protocol was developed to be comparable with the protocol of the Fish Abundance and Diversity Monitoring (FEVM 2007) implemented since 2007 by the Mekong River Commission and national partners, including FiA.

Each fishing operation saw the recording of:

- date, location
- habitat (deep pool, floodplain/swamp; lake/pond/reservoir; rice field; river/stream/channel; flooded forest; others).
- gear name, number and dimensions, time spent fishing (elements for CPUE calculation)
- for each species caught,
    - total number of individuals and total weight → Catch
    - standard length and weight of 3 individual fishes randomly selected

The corresponding field survey forms are detailed in Annex 1.

3. DATA HANDLING

3.1. Data import

For easier data entry, the original data were in Excel format and entered by fishing operation (one record = one fishing operation), with species listed in successive columns. Thus, the data entry file was made of 3 basic units: i) record identification; ii) gear and effort identification, and iii) species identification, with 3 records for each species, and as many column as needed depending on the number of species caught in a fishing operation (Table 2).

Table 2: Structure of the data entry file

Record	Record # A. Date Province B. Location C. Name of fisher D. Time set E. Time checked F. Habitat
Gear and effort	G1.1. Gillnet height G1.2. Gillnet length G2.1. Line length G2.2. Nb of hooks G3.1. Trap height G3.2. Trap length G3.3. Number of traps G4. Cast net diameter G5. Other gear name G5.1 Other height G5.2. Other length G5.3. Other number

Sp 1	**H1. Species 1** H.1.1. Nb. heads H1.2. Total weight H1.3.1 Std length #1 H1.4.1 Std length #2 H1.5.1 Std length #3 H1.3.1 Weight #1 H1.4.1 Weight #2 H1.5.1 Weight #3
Sp 2	**H2. Species 2** H.2.1. Nb. heads H2.2. Total weight H2.3.1 Std length #1 H2.4.1. Std length #2 H2.5.1 Std length #3 H2.3.2 Weight #1 H2.4.2. Weight #2 H2.5.2 Weight #3
Sp 3	**H3. Species 3.** etc. etc.

The format allowed fishing operations (catch by date, species richness, etc.) to be analysed using MS Excel tools (pivot tables, pivot charts, etc.). However, the need to also analyse data *by species* led to converting this file to MS Access and reorganizing it by species (then 1 record = 1 fish caught). A number of conversion and cleaning operations were subsequently done in MS Access.
In particular, the file was reorganized with the following variables (Figure 3):

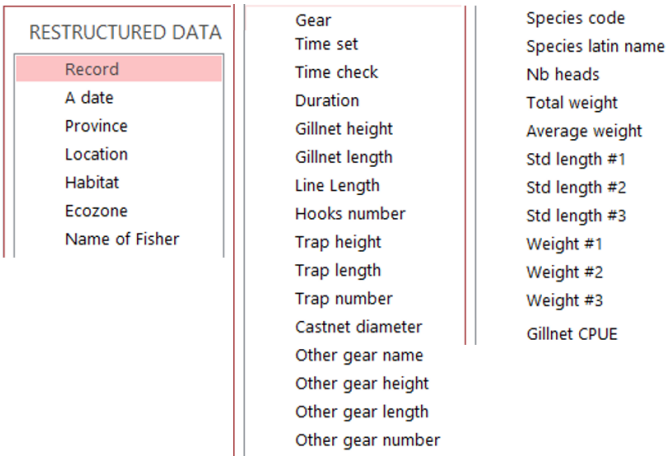


Figure 3: Variables of the Microsoft Access database

After these transformations, data in easily manageable format were re-exported to Excel for analysis and plotting.

3.2. Adjustments and data cleaning

Data cleaning included reclassification of gear names for simplification (Table 3):

Table 3: Revision of gear names in original data

Original gear name	Revised gear name
Gill net	Gillnet
Line	Line
Cast net	Cast net
Trap	Trap
Single hook line	Others
Mouse tailed trap	
Trapped hook(s)	
Hooks	
Horizontal cylinder trap for rice fields	
Santouch Bongkong (a type of line and hook)	
Barbed spear	

Each CFi was also referenced in relation to an ecozone as per Figure 2.

Data were automatically cleaned using a simple common method based on standard deviation (Burke 2001). Standard deviation is a metric of variance i.e. how much the individual data points are spread out from the mean (Figure 4). About 68% of values drawn from a normal distribution are within one standard deviation (σ) away from the mean; about 95% of values lie within two standard deviations (2σ); and about 99.7% are within three standard deviations (3σ; 68-95-99 rule or 3-sigma rule).
Thus, all data points superior to [Mean ± 2 Standard deviation] were deleted. Only a few percent of records get eliminated, and the 95-98% remaining ones keep the natural variability of biological data while staying within realistic limits.

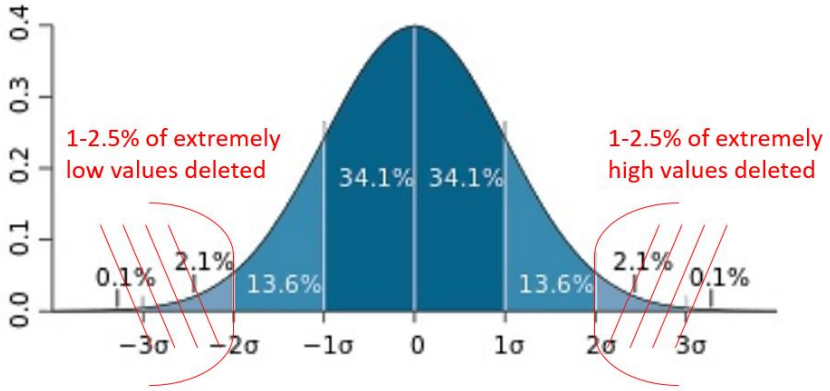


Figure 4: Cleaning process based on standard deviation

4. RESULTS

4.1. Use of gears per ecozone and province

The use of gears during the survey period varies between 2125 and 2541 fishing operations per ecozone, i.e. a 16% variability. Dominant gears are gillnets (74%), long line (10%), cast net (8%), traps (7%) and others (1% in total). The gears used in each ecozone are detailed in Figure 5.

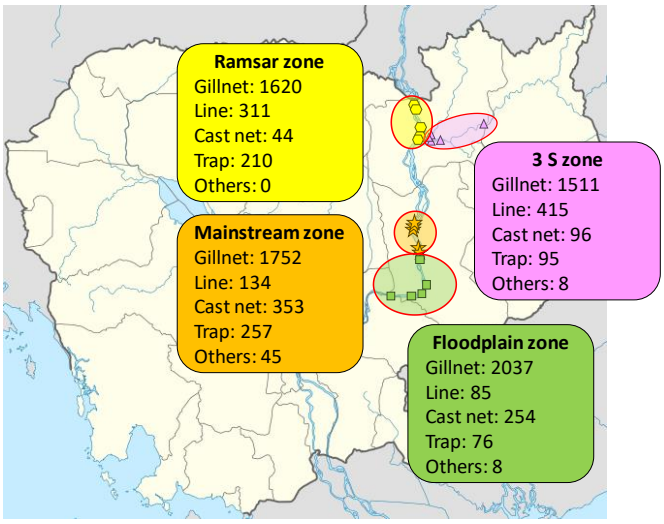
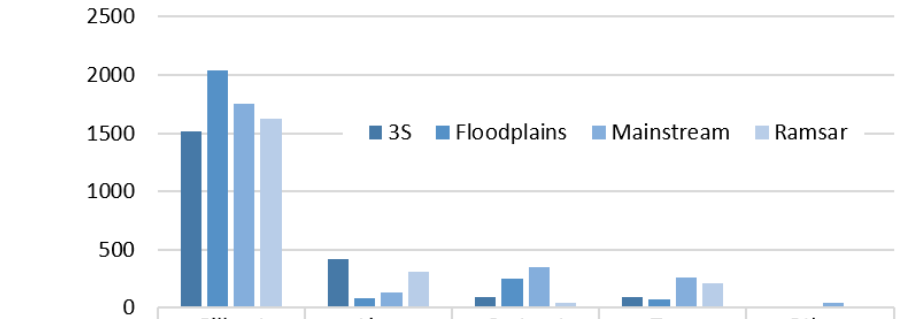


Figure 5: Use of different gears (number of fishing operations by gear) in each ecozone during the survey period

Two areas feature a higher number of fishing operations during the survey period: the mainstream and floodplain ecozones (2541 and 2460 operations respectively) and two areas are characterized by slightly less operations: the 3 S and Ramsar zones (2125 and 2185 operations respectively).

Details about the use of each gear category are given in Figure 6.



	Gill net	Line	Cast net	Trap	Others
3S	1511	415	96	95	8
Floodplains	2037	85	254	76	8
Mainstream	1752	134	353	257	45
Ramsar	1620	311	44	210	0

Figure 6: Use of each gear category in each ecozone during the survey period

Gillnet is the dominant gear by far (74% of gears used), followed by line (10%) and cast net (8%). There is a high variability in use of gears by ecozone, in particular for lines and cast nets. Gillnets are used about 25% more in floodplains than in other ecozones.

An analysis of variability in the seasonal use of fishing gears, detailed for each province (Figure 7), does not show any particular pattern, with the number of fishing operations varying between 300 and 350 per month per province in the current survey setup (slight increases in December, March and June, up to 380). Surprisingly, there is less fishing in January and February, in particular in Stung Treng (around 170 fishing operations per month compared to 300 in Kratie) –although this used to be the time of large-scale upstream migrations by *Gymnostomus spp. (*formerly *Henicorhynchus spp.)* and associated small cyprinids. Consultations with local FiA officers indicated that the cold weather and the low water level in this season explain a reduced fishing activity in Stung Treng during these two months.

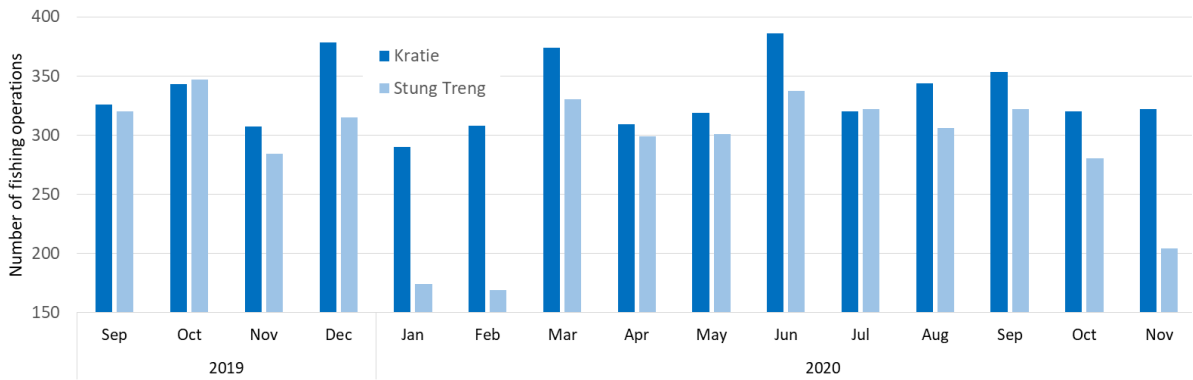


Figure 7: Fishing operations per month and per province during the survey

4.2. Biodiversity in each ecozone

A review of species caught in each zone indicates a biodiversity varying between 104 fish species (3 S area) and 112 species (Ramsar zone).

A previous review of fish biodiversity in the Ramsar area (Allen *et al.* 2008) recorded 97 individual fish species, plus 33 other taxa under a local name (total: 130 taxa, derived from a Sala Phoum study – see MWBP 2005). Our findings fit within that range, but given the difference in duration of surveys and sampling effort the results of the present study cannot be strictly compared to the Sala Phoum findings to derive conclusions about trends in biodiversity over years.

The 3 S area was also subject to a biodiversity assessment (Baran *et al.* 2013) which concluded that the biodiversity reached 213, 133 and 240 fish species in Sekong, Sesan and Srepok basins respectively. However, that assessment based on multiple studies and species lists covered each river basin extensively (including upstream in Vietnam) and results cannot be directly compared with the present survey limited in area.

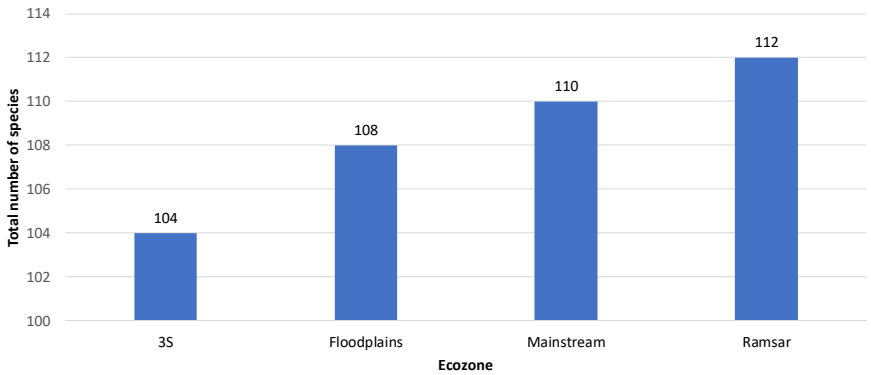


Figure 8: Number of fish species in each ecozone

When the analysis is detailed by Community Fishery, it shows a biodiversity varying between 80 and 95 species per site, with no discernible pattern within –or even between- ecozones. A particular case is Prek Ta Am in the floodplain area, characterized by a low fish diversity limited to 51 species, i.e. about 40% of the other sites. In fact, in Prek Ta Am fishers use only small mesh gillnets, unlike in other sites using a diversity of gears and of mesh sizes; this might explain the particularly low fish diversity sampled in this Community Fishery.

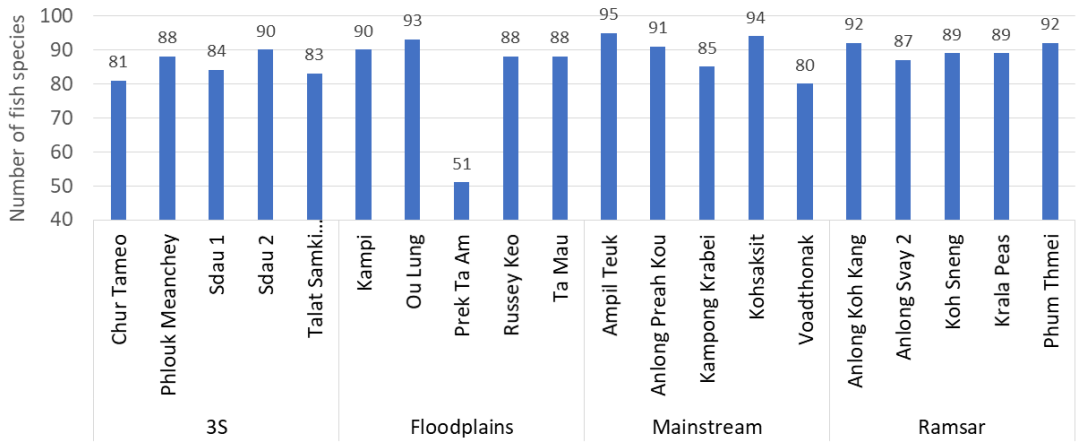


Figure 9: Fish biodiversity by CFi as assessed by the study

4.3. Total catch in each ecozone

The analysis of total catch in each ecozone (overall catch of all fishers over the whole period analysed; Figure 10) shows that the ecozone with the highest catch is the floodplain zone, with about 50% more biomass than in the other zones. The catch in the other zones is homogenous with less than 5% variability between zones.

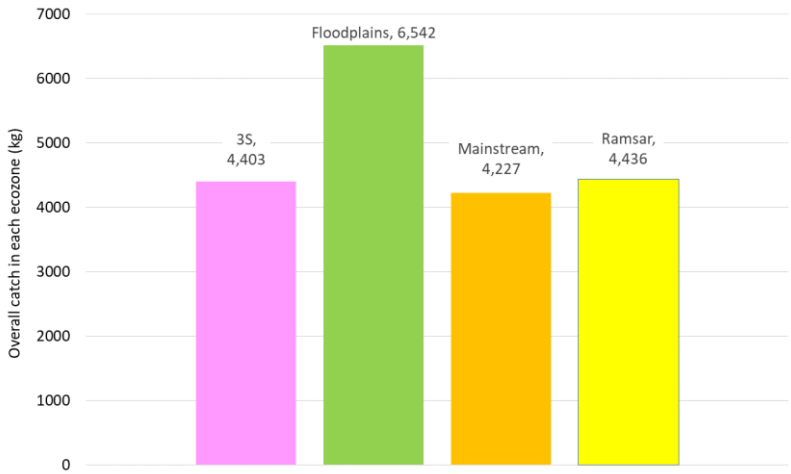


Figure 10: Overall catch by ecozone (kg) during the whole sampling period

When the total catch is detailed by site, Voadthonak (mainstream zone) stands out as the site with the highest catch, followed by Ta Mau (floodplain zone), Phlouk Meanchey (3 S) and Phum Thmei (Ramsar zone). See Figure 11. Thus, there is a large variability between sites within each zone, and "champion" sites can be found in all zones. FIA officers consulted indicated that fish abundance is indeed renowned to be higher in these special sites, and that local fishers are therefore more active and use more gears than elsewhere.

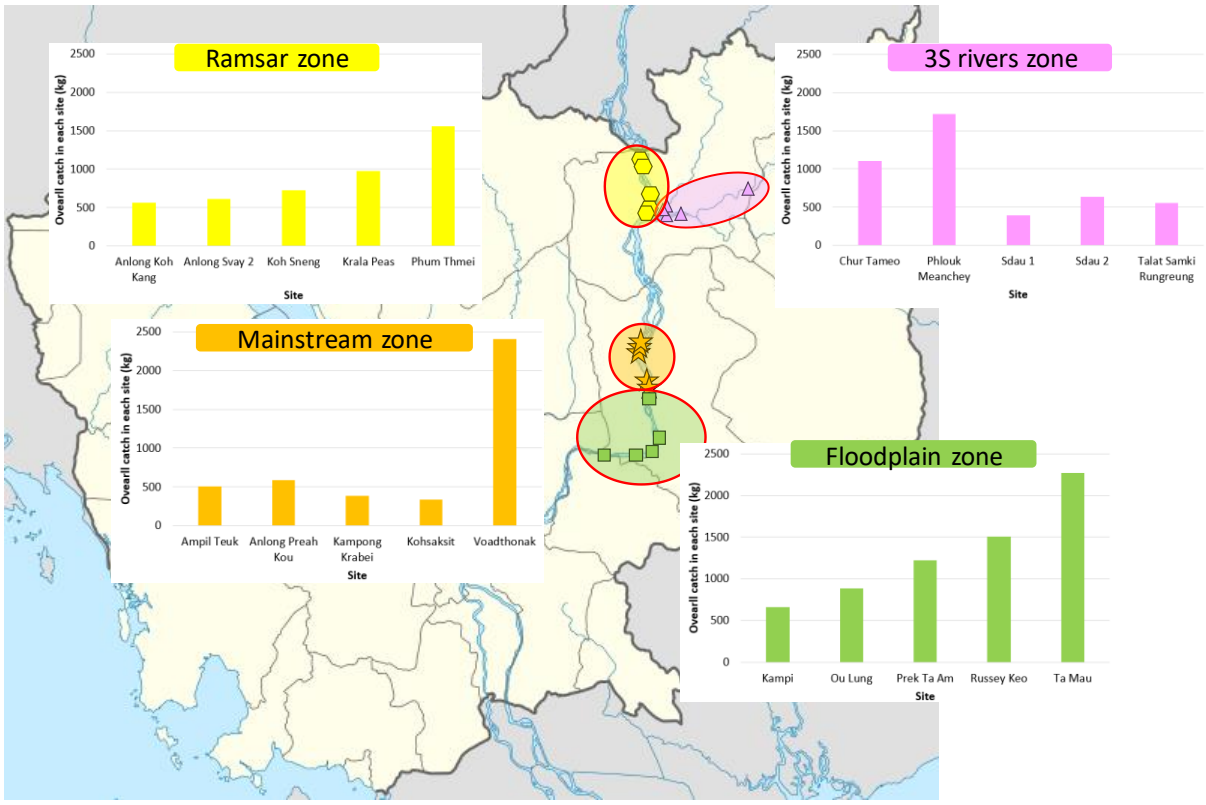


Figure 11: Overall fish catch by ecozone and by site

When the overall catch is reviewed in relation to socioeconomic potential, governance potential and environmental potential of each CFi identified during the CFi selection phase at the beginning of the project (Fisheries Administration 2019b), data show that 13 of the 20 CFi featuring the highest catch

are characterized by a good environment, regardless of governance and socioeconomic performance or of ecozone. The only site appearing as an exception is Sdau 1 in Stung Treng Province, where environment, governance and socioeconomic potential are all considered good, but the catch is among the lowest. FiA officers consulted indicated that livelihoods in Sdao 1 village are oriented towards the local forest and non-timber forest products, and that local fishers practice fishing as a complementary subsistence activity only.

These results underline the importance of environmental management and environmental protection in securing good fish catch. Also, the characterization of each Community Fishery in terms of Socioeconomic, Governance and Environment deserves being revised after 4 years, and the catch should ideally be analyzed in relation to these *updated* parameters.

Table 4: Overall catch in 20 CFi in relation to Socioeconomic, Governance and Environmental potential identified in 2017

Pro-vince	CFi name	Ecozone	Socio-economic potential	Gover-nance potential	Environ-mental potential	Total catch (kg)
KT	Voadthonak	Mainstream	Medium	Good	Good	2405
KT	Ta Mau	Floodplains	Good	Medium	Good	2268
ST	Phlouk Meanchey	3 S	Medium	Good	Good	1720
ST	Phum Thmei	Ramsar	Good	Low	Good	1554
KT	Russey Keo	Floodplains	Good	Good	Good	1506
KT	Prek Ta Am	Floodplains	Good	Low	Good	1218
ST	Chur Tameo	3 S	Low	Good	Good	1104
ST	Krala Peas	Ramsar	Good	Low	Good	976
KT	Ou Lung	Floodplains	Good	Medium	Good	886
ST	Koh Sneng	Ramsar	Medium	Low	Good	728
KT	Kampi	Floodplains	Medium	Medium	Good	663
ST	Sdau 2	3 S	Medium	Medium	Good	635
ST	Anlong Svay 2	Ramsar	Medium	Good	Good	613
KT	Anlong Preah Kou	Mainstream	Good	Good	Medium	592
ST	Anlong Koh Kang	Ramsar	Medium	Low	Good	566
ST	Talat Samki Rungreung	3 S	Medium	Good	Medium	553
KT	Ampil Teuk	Mainstream	Good	Good	Medium	509
ST	Sdau 1	3 S	Good	Good	Good	391
KT	Kampong Krabei	Mainstream	Good	Good	Low	384
KT	Kohsaksit	Mainstream	Medium	Good	Medium	337

4.4. Monthly catch by site and ecozone

When the monthly total catch is plotted for each site (Figure 12), results indicate some differences between ecozones:

- in the **Ramsar zone**, a slight increased abundance is noted between March and July, while acknowledging a 280% variability between the average catch of the most and least productive sites;
- no clear monthly pattern is visible in the **3 S zone**, with a high variability between sites and catch peaks in different months depending on the CFi considered;
- the lack of pattern is similar in the **floodplain zone**, with a large heterogeneity between sites and either no peak months or peak months in different seasons (Nov.-Dec. in one CFi, or Jul.-Aug. in the other one);
- in the **mainstream zone**, catches are more or less stable throughout the year for four out of five sites. However, the catch in Voadthonak -the fifth site- is completely different from that of other sites, and is both higher (up to 7 times) and much more extended in time.

Thus, there are no clear and consistent monthly or seasonal abundance patterns among CFi. This contrasts with the sharp pattern of some well-known fisheries such as the “dai” fishery in Cambodia or the “lee” trap fishery in Laos. However, these fisheries operate seasonally and target migratory fishes, whereas multi-gear individual fishers sampled here choose different fishing techniques, locations and target species in different seasons to optimize their monthly catch, and permanently keep it as high as possible. This point and its impact on the perception of the resource need to be further explored. A parallel deepened analysis of seasonal trends (biomass, gears used, species caught) in the villages monitored in the same provinces under the MRC Fish Abundance and Diversity Monitoring programme would be helpful for a comparison.

The few sites that display a clear seasonal pattern (Voadthonak in the mainstream, Phlouk Meanchey in the 3 S, Ta Mau in floodplains, Phum Thmei and, to a lesser extent, Krala Peas in the Ramsar zone) are those with the highest overall catch (see Figure 11). This raises a question about the amount of fish catch needed to accurately represent specific and overall seasonal fish abundance trends. This point key to resource monitoring also deserves further research.

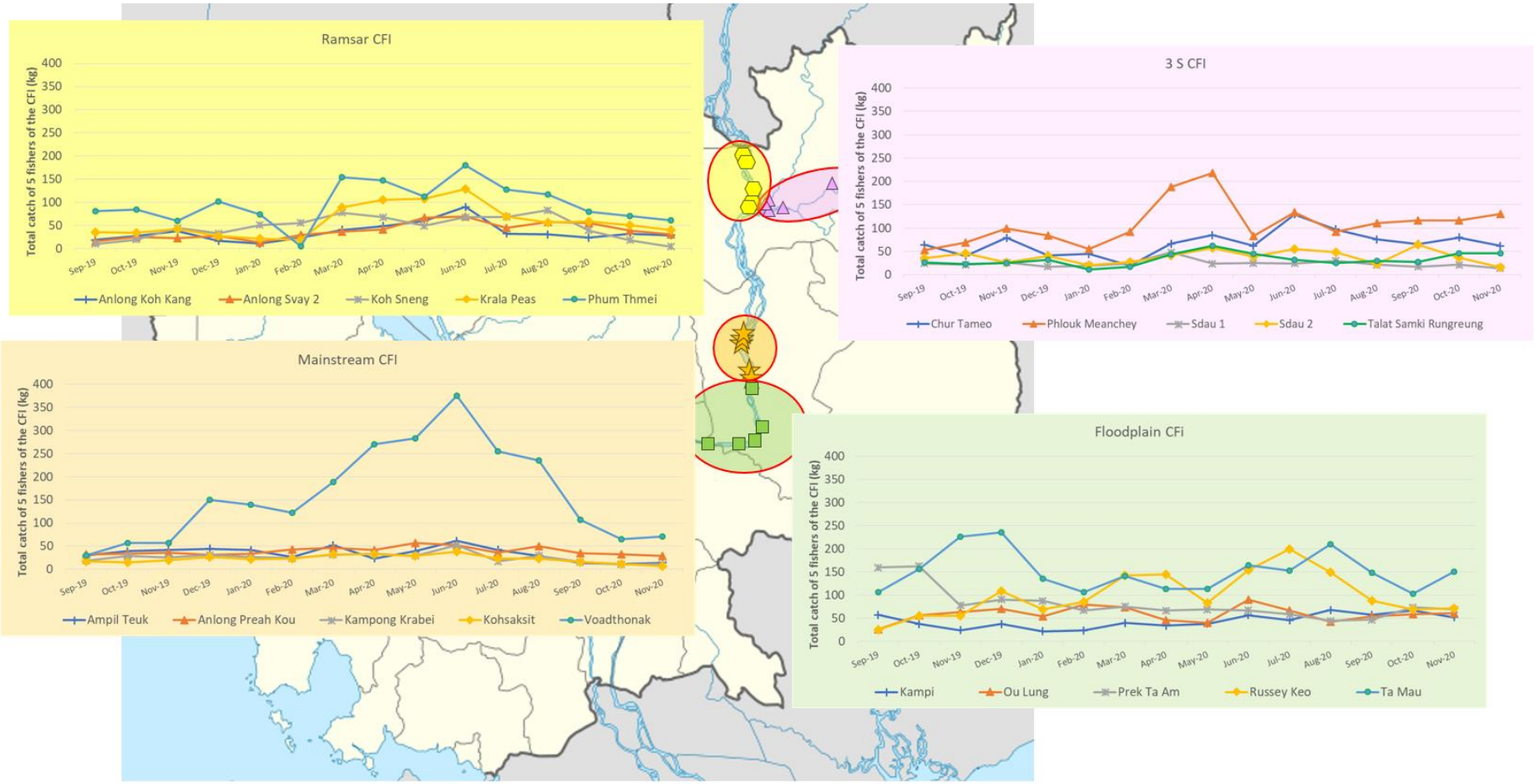


Figure 12: Monthly total catch of 5 fishers in each CFi of the monitoring programme

The above questions about the variability between sites and subsequent representativeness of seasonal patterns and trends led to combining sites together to plot data by ecozone. This corresponds to combining the catch of 5 CFi or 20 fishers to describe each ecozone each month. Results (Figure 13) indicate:

- a high catch from March to August in the **Ramsar zone**, with a peak in June. Further explanatory analyses should include rainfall pattern and water levels during this period of sampling. When similar months one year apart are compared (i.e. September to November 2019 versus Sept. to Nov. 2020), the catch of the latter period is 13% higher than one year before. However, the natural inter-annual variability does not allow interpreting this difference after on one year of monitoring only;
- in the **3 S zone** the catch also increases in March before fluctuating during the rainy season, but without any peak in June like in Ramsar zone and in the mainstream (see below). The catch in Sep.-Nov 2020 is 31% higher than the catch in Sep.-Nov. 2019;
- the **floodplain zone** displays an erratic pattern, with two periods of higher abundance (Oct.-Dec. and Jun.-Aug.) and some higher abundance in March too. Surprisingly, the floodplain fishery seem to be active in the dry season (December, March), which calls for a finer analysis of actual CFi fishing grounds in this zone. In this ecozone, the total catch in Sep.-Nov. 2020 is 9% inferior to the catch in Sep.-Nov. 2019;
- In the **mainstream zone** a clear peak in catches is visible between March and August, but this is driven by the single Voadthonak CFi, as shown in Figure 12 above. The total catch in Sep.-Nov. 2020 is 6% inferior to the catch in Sep.-Nov. 2019 for the mainstream zone.

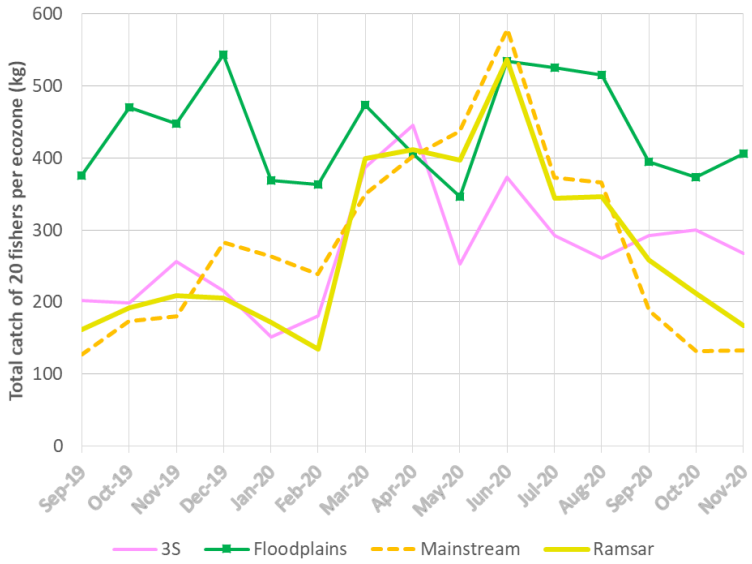


Figure 13: Monthly total catch of 20 fishers in each ecozone

In summary, the fish catch variability among CFi is higher than the overall seasonal variability in the area studied. This raises an important point, to be deepened by future research, about the representativeness of IWRM and FADM monitoring protocols, and the amount of sites and fishers necessary to reliably reflect patterns in the fish resource. The difference between catches at the beginning of the protocol and one year later ranges between -9% and +31%, but these figures are indicative only, as the natural inter-annual variability and one single year of monitoring are not enough to allow detecting at this stage any possible change in overall fish abundance.

4.5. Catch per unit effort (CPUE) in each ecozone and site

The analysis below is focused on gillnets used by fishers, and on the Catch per Unit Effort (CPUE), a proxy of fish abundance in water or water productivity. Data available, in particular i) gillnet height and gillnet length and ii) time set and time checked, allow calculating i) the surface area of net fishing (square meters) and ii) the time spent fishing (hours), these elements combining with the iii) catch of the fishing operation (grams) to define the CPUE (g/m^2/h). CPUE is calculated for gillnets only, as it is impossible to calculate a composite CPUE when several different gears are involved – the fishing effort unit varying from gear to gear and the gears from place to place.

The analysis of CPUE in each ecozone (two years together; Figure 14) shows that the two ecozones with the highest CPUE are the Ramsar and the mainstream zones (27.9 and 24.5 g/m^2/h respectively). The 3 S zone features an intermediate CPUE, and the CPUE is the lowest in the floodplain zone.
The overall picture of water productivity reflected by CPUE is different from that of total catch per ecozone; in the latter the zone with the highest catch was the floodplain zone, and there was almost no difference between the other zones.
The mismatch between total catch (highest in floodplains; Figure 10) and CPUE (lowest in floodplains, Figure 14) can be explained by the fact that floodplain fishers deploy the most intensive fishing activity, gillnets being used 25% more than in the other ecozones (see Figure 5, section 5.1). This result highlights the difference between scientific sampling with a constant effort and a sampling implemented, like here, by Community Fisheries, where fishers modulate their effort in view of maximizing their catch.
The other sites feature different combinations of CPUE (high in Ramsar and mainstream zones) and fishing intensity (lower in Ramsar and 3 S zones), resulting in similar total catches (Figure 10). The most interesting result here is that the highest productivity, as assessed through CPUE, corresponds to Mekong islands areas (both Ramsar zone in Stung Treng and the mainstream in Kratie Province), and that floodplains feature the lowest productivity of the four ecozones – although floodplains are usually considered a very productive environment. This might be explained by a smaller size of fishes in floodplains - the latter being a feeding area for juveniles in the wet season- and the large size of fishes in the mainstream, near deep pools where large breeders are known to gather, in particular in the dry season (Poulsen *et al.* 2002, Sommano Phounsavath *et al.* 2004, Chan Sokheng *et al.* 2008). T

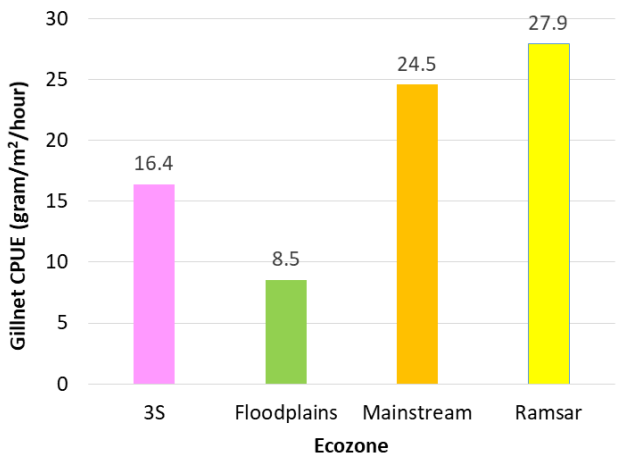


Figure 14: Catch per Unit effort of gillnets (grams of fish per square meter of net per hour) in the 4 ecozones.

When the average gillnet CPUE is analyzed per site (Figure 15), results show that in the 3 S rivers zone, Chur Tameo features a four times higher catch per unit effort than all other sites of the ecozone. Both the Ramsar zone and the mainstream zone also feature outstanding sites in which the CPUE is more than three times higher than in the other nearby villages; these are respectively Anlong Svay 2 in Stung Treng and Voadthonak in Kratie. In the floodplain zone there is no outstanding site, even though Kampi and Ou Lung catch twice more than their neighboring sites. In all these sites the environment is considered "good" (see Table 4) and Voadthonak is also the champion site for overall fish catch – making it a key site for future biological studies- but it is interesting to note a mismatch between total catch and CPUE in villages of 3 S, floodplain and Ramsar zones. The reasons for such mismatch, i.e. why the catch is de-correlated from water productivity as reflected by CPUE, should be further explored.

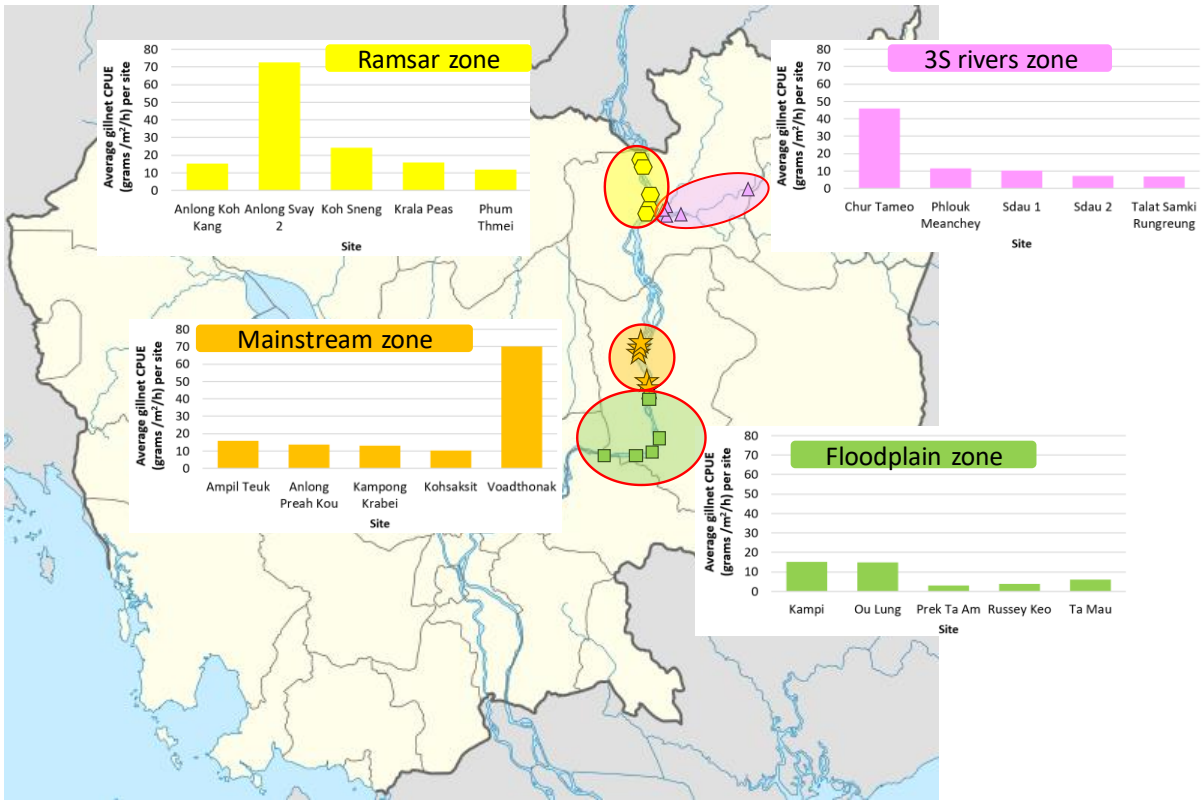


Figure 15: Catch per Unit effort of gillnets (g/m²/h) in each site surveyed

4.6. Dominant species in catches, by ecozone

The analysis of top-20 species in catches (Figure 16) shows that the dominant species in all catches of the study area is *Labeo chrysophekadion,* a large cyprinid (10.4% of all catches), followed by *Gymnostomus siamensis* and *G. lobatus* (formerly *Henicorhynchus siamensis* and *H. lobatus*) at respectively 8.6% and 6.9% of total catches. The predominance of *L. chrysophekadion* in catches is surprising and new compared to the former strong dominance of *Gymnostomus siamensis* and *G. lobatus* (46.2% together in MRC monitoring in Cambodia between 2007 and 2018, compared to 0.3% for *L. chrysophekadion,* see Fisheries Administration 2019a). The presence of *L. chrysophekadion* in upstream zones is incidentally mentioned in previous studies in this zone (Allen *et al.* 2008, Baran *et al.* 2014).

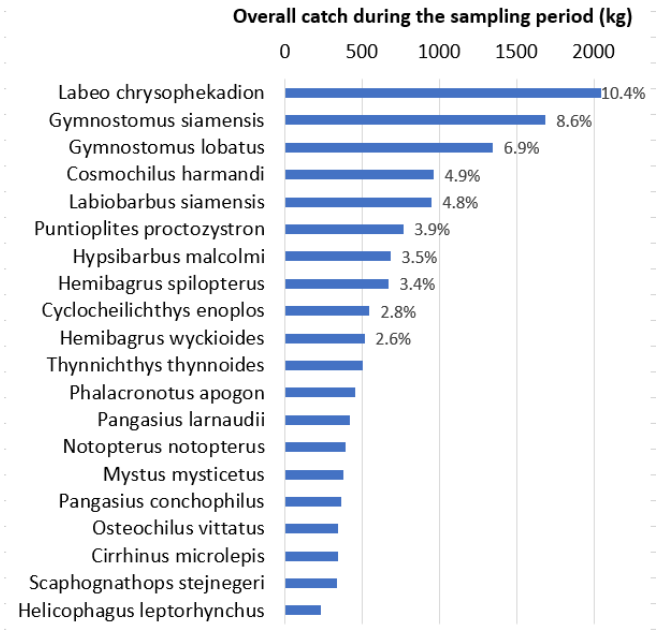


Figure 16: Twenty dominant species in all catches monitored

The comparison of these results with those of the Fisheries Abundance and Diversity Monitoring programme (FADM) of the Mekong River Commission, in six Cambodian sites[2] between 2017 and 2020, confirms the dominance of *Labeo chrysophekadion* in catches (Table 5). More specifically, an analysis focused on 10 commercially important species and their ranking in annual catches points to the decline of some species over years (*Hypsibarbus malcolmi, Pangasius macronema, Puntioplites proctozysron, Puntioplites falcifer, Hemibagrus wyckioides*) and conversely the progression of some others (*Labeo chrysophekadion, Cosmochilus harmandi* and *Cyclocheilichthys enoplos* in particular), illustrating a replacement among species (Figure 17) and possibly a shift in species composition and community structure, to be confirmed by interviews of fishers and further analyses. These FADM data, as opposed to the present IWRM monitoring, indicate a low ranking, i.e. limited abundance, of *Gymnostomus siamensis* and *G. lobatus* in catches -in particular the latter species (rank 15 to 9 for *H. siamensis*, and 55 to 64 for *H. lobatus*) and a strong variability between years for these species.

Table 5: Ranking of 10 selected species in overall catches of Cambodian FADM sites monitored by the MRC JEM programme between 2017 and 2020

	2017 rank	2018 rank	2019 rank	2020 rank
Labeo chrysophekadion	4	2	1	1
Hypsibarbus malcolmi	1	1	4	3
Pangasius macronema	2	3	3	4
Cosmochilus harmandi	6	4	2	2
Puntioplites proctozysron	3	5	10	5
Puntioplites falcifer	5	6	6	7
Hemibagrus wyckioides	7	8	11	13
Cyclocheilichthys enoplos	22	7	5	6
Gymnostomus siamensis	15	24	33	9
Gymnostomus lobatus	57	62	55	64

[2] Ou Run near the Lao border, Pres Bang on the Sekong River, Fang on the Sesan River, Day Lo on the Sre Pok River, Koh Kneh on the mainstream between Stung Treng and Kratie, and Sang Var near Phnom Penh.

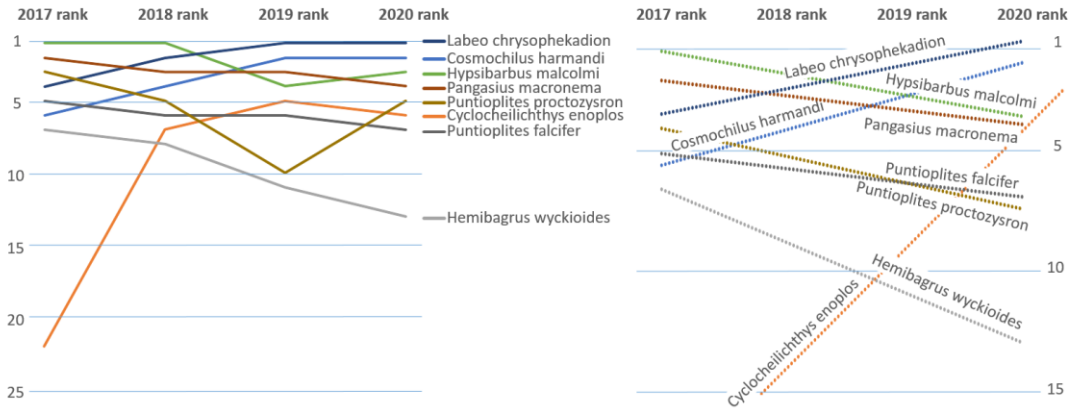


Figure 17: Ranking of 8 dominant species in catches of Cambodian FADM monitoring between 2017 and 2020. Actual ranking (left) and trend line (right)

The analysis, in IWRM data, of dominant species by ecozone (Figure 18) indicates that *Gymnostomus siamensis* is dominant in the floodplain zone, as it is in the Tonle Sap floodplains (van Zalinge and Nao Thuok 1999, Ngor Peng Bun 2000). However, the mud carp species dominant in the mainstream is *Gymnostomus lobatus*, which matches observations by Baird *et al.* (2003) and confirms the difference between the two species in terms of distribution (Hurwood *et al.* 2005). Furthermore, none of these two species is part of the top-ten species in the 3 S zone, which confirms a new trend already described a few years ago by Baran and Seng Sopheak (2011). Overall, two to four species are dominant in each ecozone, and followed by a cohort of less common species.

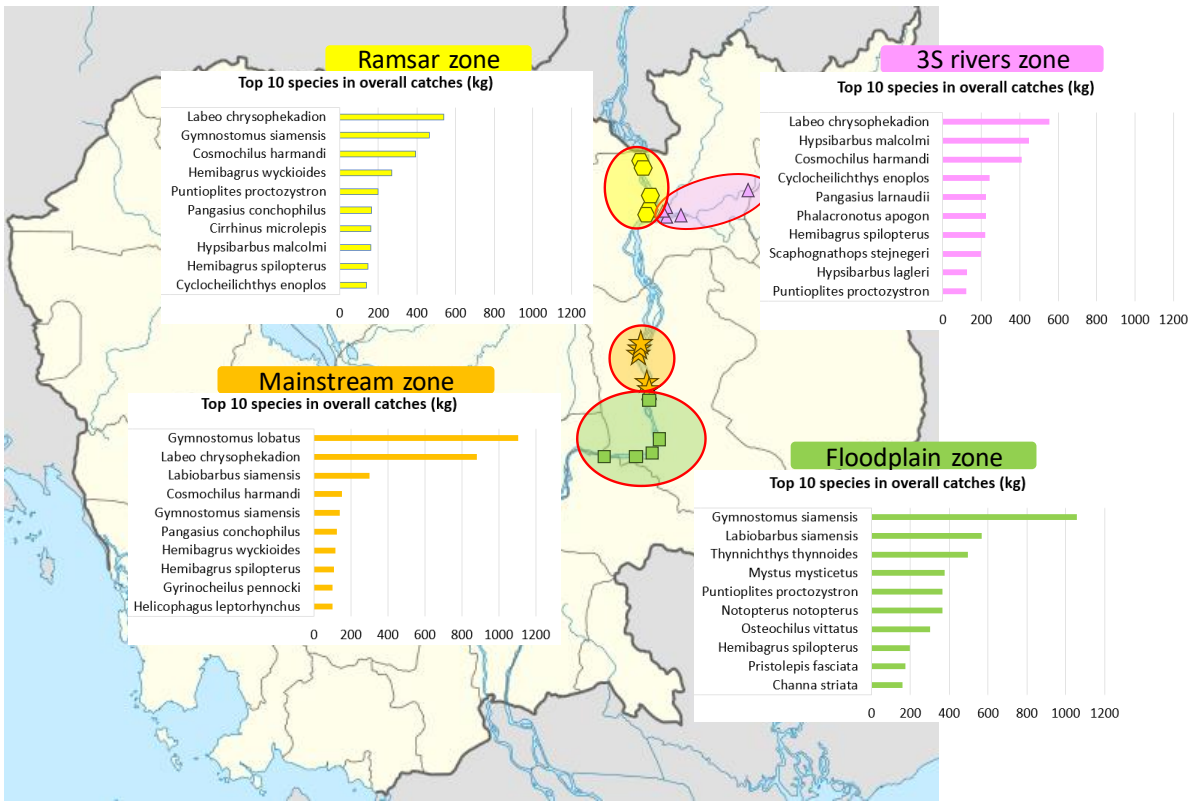


Figure 18: Ten dominant species in catches by ecozone

Here again, the comparison of the IWRM project monitoring results with those of the Fisheries Abundance and Diversity Monitoring of the Mekong River Commission available over a longer period of time confirms a strong variability in space (Figure 19), *Gymnostomus siamensis* being dominant in the Tonle Sap sub-basin (Chang Var site) but only there, and *Labeo chrysophekadion* dominant in all other sites.

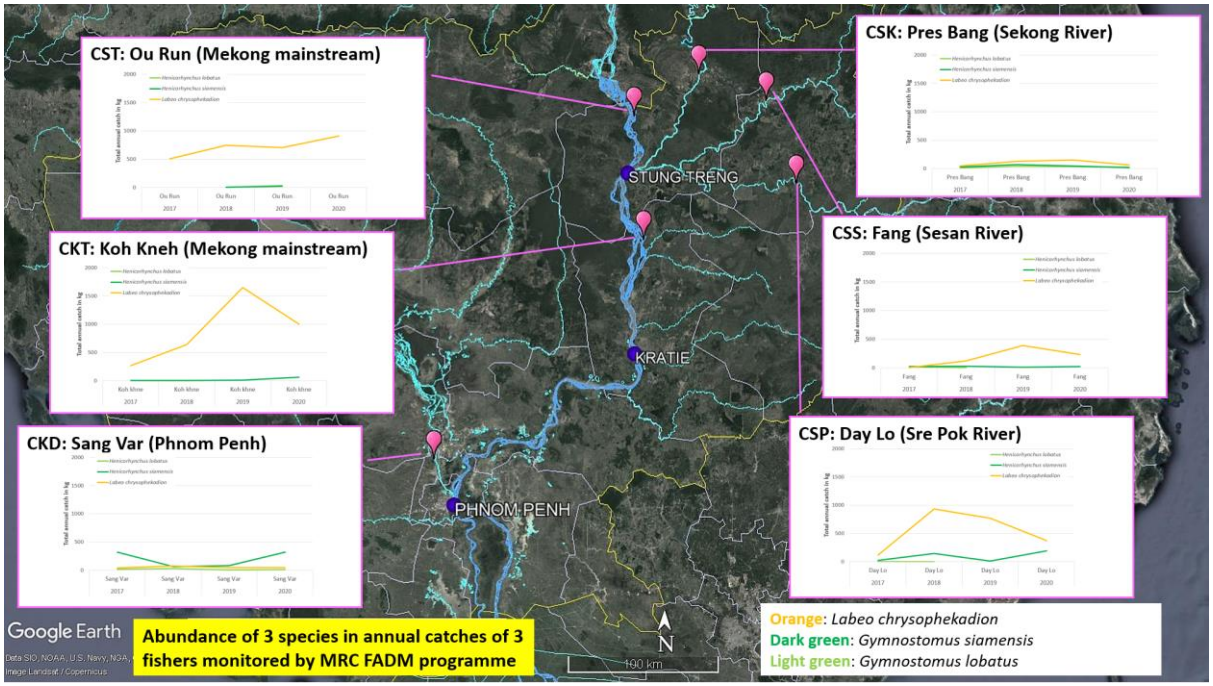


Figure 19: Comparative abundance of *Gymnostomus siamensis, G. lobatus* and *Labeo chrysophekadion* in 6 MRC FADM sites between 2017 and 2020

Last, IWRM monitoring results indicate that 95 fish species are found in all ecozones, although most of them are not dominant in catches or are even rare. When dominant species are analyzed at the level of each CFi, only four species are part of top-ten species in each ecozone; these are C*yclocheilichthys enoplos, Hemibagrus spilopterus, Labeo chrysophekadion* and *Puntioplites proctozysron*[3]. These species, being the new dominant species in catches, deserve particular attention in future biology and socioeconomic studies.

[3] In 2020, these species were part of the top-16 species in FADM data.

4.7. Average length of top 20 dominant species, by ecozone

An analysis, among top-20 species, of average standard length of species caught in each ecozone allows distinguishing two fish groups: those whose size does not vary by more than (an arbitrary) 40% between zones, and those whose size varies substantially more. The first group is illustrated in Figure 20.

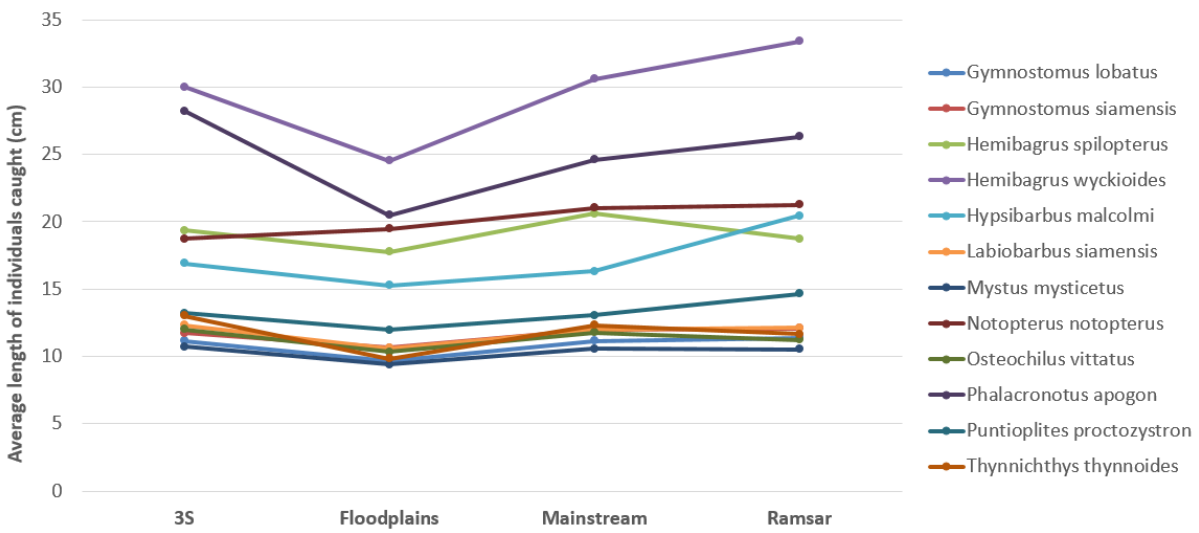


Figure 20: Dominant species whose size does not substantially vary (<40%) between ecozones

The second group corresponds to species whose individuals of very different sizes are found in the various ecozones. These species are *Cirrhinus microlepis* (153% variability), *Cosmochilus harmandi* (47%), *Cyclocheilichthys enoplos* (54%), *Helicophagus leptorhynchus* (42%), *Labeo chrysophekadion* (142%), *Pangasius conchophilus* (47%), *Pangasius larnaudii* (87%) and *Scaphognathops stejnegeri* (62%).

The common feature is a smaller size of all these species in the floodplain zone, which confirms the nursery role of this habitat and the subsequent smaller CPUE of gillnets in this zone.

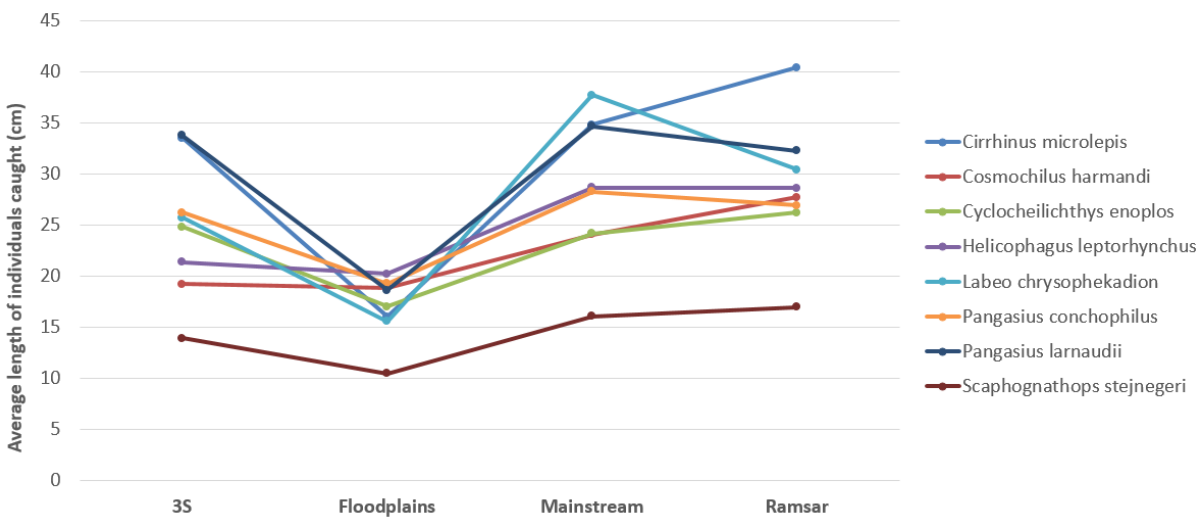


Figure 21: Dominant species whose size varies by more than 40% between ecozones

5. CONCLUSIONS

The biomonitoring results presented here correspond to 14 months of survey, between September 2019 and November 2020. Despite significant COVID-related challenges, the protocol was steadily implemented, thanks to 80 fishers -including five women- recording their catch twice a week. This makes it the most intensive inland fishery monitoring program in Cambodia to date, albeit not the longest.

Analyses indicate a 16% variability in fishing activity between zones, the most active being the floodplain fishery. Gillnets are by far the dominant gear, and are used in 74% of fishing activities. Other gears are long lines, cast nets and traps (7 to 10 % of fishing activities each).

Species diversity varies by 8% only between ecozones, the highest diversity being found in the Ramsar zone (112 species). These results are consistent with some previous studies, although not strictly comparable. The species diversity in each Community Fishery varies between 80 and 95 species. Four species are part of top-ten species in each ecozone: C*yclocheilichthys enoplos, Hemibagrus spilopterus, Labeo chrysophekadion* and *Puntioplites proctozysron*. These species deserve particular attention in future biological and socioeconomic studies.

The floodplain zone features the highest total catch -about 50% higher than in the other zones- and there is less than 5% variability between the three other zones. On the contrary, a large catch variability is identified between sites of a given zone, and "champion" sites can be found in all zones (Voadthonak in the mainstream zone, Ta Mau in the floodplain zone, Phlouk Meanchey in the 3 S and Phum Thmei in the Ramsar zone). These sites can be sampling sites for future studies requiring a large amount of fishes. Importantly, thirteen of the top 20 CFi featuring the highest catch are characterized by a good environment, regardless of governance and socioeconomic performance or of ecozone.
The catch per month in each CFi doesn't show any particular trend, and the variability is higher between sites than over months. This might be due to the fact that fishers choose different fishing techniques, locations and target species in different seasons to permanently maximize their monthly catch, and subsequently blur seasonal trends in species abundance. Further research and comparison with results of the MRC FADM programme and the monitoring in nearby Khone Falls (Lao PDR) between 1993 and 1999 (Baran et al. 2005) is desirable.
The few sites that display a clear seasonal pattern are those with the highest overall catch; this calls for additional research about the amount of fish catch necessary to accurately represent specific and overall seasonal fish abundance trends.
Comparing catches by ecozone during 3 months at the beginning of sampling and during the same three months one year later (the maximum comparison doable on the present dataset) shows that the catch varied between -9% and +31%. However, one single year of monitoring is not enough to allow detecting a significant change in overall fish abundance given the high natural inter-annual variability in the Mekong River. This calls for a continuation of the monitoring and an integration with long-term data of the FADM monitoring of the Mekong River Commission[4].

[4] The present IWRM protocol was designed to produce data compatible with the anterior MRC FADM protocol.

The analysis of Catch Per Unit Effort (CPUE) for gillnets identifies two ecozones with a high CPUE: Ramsar and the mainstream (28 and 25 g/m^2/h respectively), the lowest CPUE being paradoxically found in the floodplain zone – where the total catch is the highest. This is because floodplain fishers deploy the most intensive fishing activity compensating a lower CPUE due to abundant but small fishes (see below). An analysis by site identifies three CFi with a particularly high CPUE: Chur Tameo in the 3 S rivers zone, Anlong Svay 2 in the Ramsar zone and Voadthonak in the mainstream zone. These three sites, in particular Voadthonak that is also the top site for overall fish catch, are to be considered for future biological studies.

Dominant species in overall catches are #1 *Labeo chrysophekadion,* a large cyprinid (10.4% of all catches), followed by #2 *Gymnostomus siamensis* and *#3 G. lobatus* (formerly *Henicorhynchus siamensis* and *H. lobatus*) at respectively 8.6% and 6.9% of total catches. *Gymnostomus siamensis* is dominant in floodplain areas only. A comparison with results of the Fisheries Abundance and Diversity Monitoring programme of the Mekong River Commission over 4 years confirms these results and flags a shift in species composition and community structure (decline of *Hypsibarbus malcolmi, Pangasius macronema, Puntioplites proctozysron, Puntioplites falcifer, Hemibagrus wyckioides* and conversely progression of *Labeo chrysophekadion, Cosmochilus harmandi* and *Cyclocheilichthys enoplos*).

When the average standard length of species in each ecozone is analysed, results identify eight species whose average size differs by more than 40% between ecozones: *Cirrhinus microlepis* (153% variability), *Cosmochilus harmandi* (47%), *Cyclocheilichthys enoplos* (54%), *Helicophagus leptorhynchus* (42%), *Labeo chrysophekadion* (142%), *Pangasius conchophilus* (47%), *Pangasius larnaudii* (87%) and *Scaphognathops stejnegeri* (62%). Their common feature is a smaller size in the floodplain zone, which confirms the nursery role of this habitat.

Overall, the data collection spanned over slightly more than a year, and it is not yet possible to draw final conclusions about the effectiveness of the project management initiatives regarding fish abundance, diversity or size. However, a solid monitoring programme has been initiated, and will allow producing solid conclusions if continued over a few years.

From a social perspective, the present biomonitoring program represents a significant capacity building achievement. Provincial Departments of Agriculture, Forestry and Fisheries have been involved in organizing data collection, supervising the work of fishers and entering data. They have been consulted all along the way for information sharing and feedback, and have seen the presentation of final results. Eighty fishers from 20 Community Fisheries have also been associated to the present initiative, and, importantly, have seen the presentation of results obtained. The experience gained has also been shared between CFi during joint meetings organized by the IWRM project. Although this scientific approach at the scale of ecosystems cannot be duplicated at the level of each CFi (data analysis constraints in particular), it strengthens the simpler self-monitoring approach promoted in parallel by the project, and in which the information gathered can be analysed by CFi themselves. More generally, this initiatives raised awareness, among communities of all ecozones, about resource management and approaches to assess status and management outcomes.

Thus, for resource management as well as for social development reasons a long-term continuation of the present biomonitoring program is desirable.

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7. ANNEX: FIELD MONITORING SHEET

Fisheries Administration

Mekong-IWRMP-III / Component 1

Fish catch monitoring sheet

Date:_____ Time set:_____

Location (CFi):_____ Time checked:_____

Name of fisher:_____ Gear:_____

Habitat

Deep pool	Floodplain/ swamp	Lake/pond/reservoir	Rice field	River/stream/channel	Flooded forest	Others name:……

Gear name and dimension

Gill net	Line and hooks	Horizontal cylinder trap	Cast net	Others name:……
Height.....m	Length.....m	Height.....m	Diameter.....m	Height.....m
Length.....m	Number.....	Length.....m		Length.....m
		Number……		Number.....

Fish catch

Species code……	Total number……...heads	Total weight……..…Gram
- Fish # 1	Standard length……....cm	Weight:.....gram
- Fish # 2	Standard length……cm	Weight:.....gram
- Fish # 3	Standard length……..…cm	Weight:.....gram

Species code……	Total number……...heads	Total weight……..…Gram
- Fish # 1	Standard length……....cm	Weight:.....gram
- Fish # 2	Standard length……cm	Weight:.....gram
- Fish # 3	Standard length……..…cm	Weight:.....gram

Additional sheet

Date:_______________________ Gear:___________________________

Location (CFi):_____________ ________________________________

Name of fisher:_____________

Species code……………….…	Total number……………..heads	Total weight…………………...…Gram
- Fish # 1	Standard length…………….…cm	Weight:..............................gram
- Fish # 2	Standard length……………….cm	Weight:..............................gram
- Fish # 3	Standard length………….….cm	Weight:..............................gram

Species code……………….…	Total number……………..heads	Total weight…………………...…Gram
- Fish # 1	Standard length…………….…cm	Weight:..............................gram
- Fish # 2	Standard length……………….cm	Weight:..............................gram
- Fish # 3	Standard length………….….cm	Weight:..............................gram

Species code……………….…	Total number……………..heads	Total weight…………………...…Gram
- Fish # 1	Standard length…………….…cm	Weight:..............................gram
- Fish # 2	Standard length……………….cm	Weight:..............................gram
- Fish # 3	Standard length………….….cm	Weight:..............................gram

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- Fish # 1	Standard length…………….…cm	Weight:..............................gram
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- Fish # 3	Standard length………….….cm	Weight:..............................gram

Species code……………….…	Total number……………..heads	Total weight…………………...…Gram
- Fish # 1	Standard length…………….…cm	Weight:..............................gram
- Fish # 2	Standard length……………….cm	Weight:..............................gram
- Fish # 3	Standard length………….….cm	Weight:..............................gram

Background

The project "Mekong Integrated Water Resources Management - Phase III" is funded by the World Bank. The objective of this project is to establish the foundation for effective water resource and fisheries management in the northeast of Cambodia.
Within this project, Component 1 (Fisheries and aquatic resources management in Northern Cambodia) is executed by the Fisheries Administration and implemented by the Inland Fisheries Research and Development Institute. The objective of this component is to improve the management of fish and aquatic resources in selected areas in Kratie and Stung Treng provinces.

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