



Mekong River Commission
For Sustainable Development



Status and Trends of Fish Abundance and Diversity in the Lower Mekong Basin during 2007–2018

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**STATUS AND TRENDS OF FISH ABUNDANCE AND
DIVERSITY IN THE LOWER MEKONG BASIN
DURING 2007–2018**

MRC Technical Paper

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ABBREVIATIONS AND ACRONYMS

AB	Abundance
AB.log	Log of Abundance
ABC	Abundance-Biomass Curve
ANOVA	Analysis of Variance
ANCOVA	Analysis of covariance
BD	Beta Diversity
CA	Correspondence Analysis
CCA	Canonical Correlation Analysis
CPUE	Catch Per Unit Effort
CV	Coefficient of Variation
CR	Critically Endangered
D	Simpson Index
DD	Data Deficient
DO	Dissolved Oxygen
E	Evenness index
ED	Environmental Management Division
EN	Endangered
FADM	Fish Abundance and Diversity Monitoring
GLM	General Linear Model
HSD	Honest Significant Difference
IndVal	Indicator Species Value
IUCN	International Union for Conservation of Nature
LC	Least Concerned
LCBD	Local Contribution for Beta Diversity

LMB	Lower Mekong Basin
LMR	Lower Mekong River
MCs	Member Countries
MLR	Multiple Linear Regression
MRC	Mekong River Commission
MRCs	Mekong River Commission Secretariat
NA	Not Assessed
NT	Near Threatened
PAs	Fish Protected Areas
PCA	Principal Components Analysis
pH	Potential of Hydrogen
RDA	Redundancy Analysis
RIA	Research Institute for Aquaculture
SCBD	Species Contribution to Beta Diversity
SD	Standard Deviation
SE	Standard Error
sh	Shannon-Wiener Index
SR	Species Richness
TSA	Tonle Sap Authority
VU	Vulnerable
WL	Water Level
WWF	World Wildlife Fund

EXECUTIVE SUMMARY

Introduction

This report describes the status and trends of fish abundance and diversity from the Mekong River Commission (MRC). The Fish Abundance and Diversity Monitoring (FADM) Programme in the Lower Mekong Basin (LMB) is a routine, artisanal fisheries monitoring programme to determine both status and trends of fish abundance and its diversity in the LMB through temporal and spatial variation. The monitoring was conducted daily between 2007 and 2018 by professional fishers at 25 stations along Mekong mainstream and major tributaries. Eleven of the 25 monitoring stations were in Cambodia, four in Lao PDR, and five each in Thailand and Viet Nam.

At the regional scale, the monitoring stations were grouped based on Biological Resource Assessment (BioRA) Zones following the MRC Council Study: Zone 2 (3 stations from Nam Beng to upstream of Vientiane), Zone 3 (6 stations from Vientiane to Nam Kam), Zone 4 (3 stations from Nam Kam to Kratie), Zone 7 (7 stations in the Tonle Sap Great Lake and Tonle Sap River), Zone 8 (5 stations in the Mekong Delta), and Zone 3S (3 stations in Sekong, Sesan and Sre Pok rivers).

The study aims to: (i) evaluate the contribution of fish species and guilds to the fisheries of the LMB; (ii) evaluate the status and trends in fish catch; (iii) monitor spatial and temporal patterns in fish abundance and diversity; and (iv) assess fish community patterns and their relationship with environmental factors.

Key findings

Contribution of fish species and guilds to the fisheries of the LMB

Overall, from 2007 to 2018, the MRC-FADM programme in the LMB found 617 fish species belonging to 21 orders and 80 families; 37,530,460 individuals, corresponding to 1,095,848 kg of fishes were collected. *Cypriniformes* and the *Cyprinidae* were the dominant order and family, respectively, with more than 45% of total abundance and biomass. Over the monitoring period, the catch was driven by small-size or short-lived fish species, such as species of mud carps, *Henicorhynchus* (*H. siamensis* and *H. lobatus*).

With regard to the functional guilds, the generalist fishes (29%) were dominant in the catch in terms of relative fish abundance, followed by the floodplain spawners or grey fishes (21%) and the floodplain residents or black fishes (18%). However, for the relative biomass, it was observed that the main-channel spawners or short-distance white fishes (26%) were the dominant guild, followed by the generalists (23%). Regarding the conservation status, most fish caught were under the least concern species (around 50% of total abundance or biomass). The LMB accounted for a low but increasing rate of exotic species (<1% of abundance, or about 1.5% of the biomass), an alarming signal.

Status and trend of fish catch in the LMB

The abundance-biomass comparison curve (ABC curve) showed that the LMB is moderately disturbed, with the value of $W = -0.03$. At the BioRA Zone level, except for Zone 3S, all zones had negative W values, indicating that these zones were under stress. The highest stress was observed at Zones 2 and 4, with an ABC curve largely placed above the biomass curve. The 3S rivers were the unique, least-stressed zone of LMB, with the positive W value, and the biomass curve was over the abundance curve.

With regard to the catch rate or CPUE, in Cambodia the fish catch rate showed an upward trend at most of the FADM stations (eight out of 11 stations). In Lao PDR, the catch rate slightly dropped since the fish catch rate showed a decreasing trend at two of four stations. Unlike in Lao PDR, in Thailand, the catch rate slightly increased as four out of five stations equally showed the increasing and stable trends. In Viet Nam, the catch rate decreased, as three of five stations showed the downward trends of the catch rate.

Spatial and temporal patterns of fish abundance and diversity in the LMB

At the BioRA Zone level, Zone 4 and Zone 3S have the highest average species richness (around 115 species) compared with other zones in the LMB. Zone 7 (Tonle Sap) also has high average species richness but with a larger distribution. The upper part of Lower Mekong and the delta area have lower average richness, with only around 50 species.

Regarding the relative fish abundance, Zone 7 (Tonle Sap) was the highest, followed by the

Mekong Delta (Zone 8). The other zones had similar and constant fish abundance over the monitoring period, except for Zone 3, which had a relatively large range of abundance.

Temporally, Zones 4 and 8 decreased in richness over time, but in Zones 2, 3 and 7, richness increased slightly. Also, the richness of Zone 3S appeared to be stable during the survey period.

The temporal trends of relative fish abundance in the LMB showed different results compared to species richness. Only Zone 7 (Tonle Sap Lake) saw an increase in relative abundance during the survey period, while Zones 2, 4 and 8 decreased in relative abundance. The remaining zones had a stable trend during the same period.

Relationships between fish community and environmental factors in the LMB

Fish communities in LMB were classified into four groups based on their similarity. Cluster 1 mostly comprised fish species at the upstream of the LMB, where most part of the river shares between Lao PDR and Thailand. Also, six indicator species, found in this cluster, belonged to three guilds, namely grey fish, black fish and estuarine resident. Cluster 2 mostly comprised the floodplain, tributary and canal fish communities at Tonle Sap Lake, the middle part of the LMB and Viet Nam Mekong Delta. This cluster was also home to 14 indicator species with five guilds, whose dominant one was the short-distance white fish. Cluster 3 mostly comprised the fish communities at the north-eastern part of Cambodia with 57 indicator species and two dominant guilds, the short-distance white fish and grey fish. The last cluster mainly comprised fish communities at the stations adjacent to the sea with 19 indicator species, divided into five guilds. Estuarine resident and marine visitor were the dominant guilds of this cluster.

In the LMB, fish diversity and richness had a significant link to temperature, dissolved oxygen (DO), and the neutral pH around 7. This study indicated that fish communities of Zones 4 and 3S at the upper part of Cambodia was associated with a high DO and water levels, opposite to that of Zone 8 in the Viet Nam Mekong Delta. Moreover, the fish communities of Zone 7 at the Tonle Sap Lake and some parts of Zone 8 had a strong relationship with high temperatures in contrast to those of Zones 2 and 3 from Lao PDR and Thailand with lower temperature and higher pH.

Conclusion and recommendations

- Fish abundance and diversity need to be protected to sustain food supplies for millions of people living in the LMB. This study showed that LMB fisheries are under stressed conditions due to overfishing and habitat degradation induced by human population growth and economic development, and environmental changes (e.g. flow change) including climate change. With a constant increasing of human population, fishing pressure in LMB constantly increased, affecting the fish abundance and diversity.
- A number of hydropower projects have been built and proposed in the mainstream, although fisheries monitoring stations are not located close to the project sites. This makes it difficult to develop a baseline before the hydropower projects are operational. Thus, it is critical to set up more monitoring stations close to dam sites. This will enable hydropower projects in the Mekong mainstream to be assessed in terms of their impacts. MRC's Joint Environmental Monitoring Guidelines should be consulted when selecting monitoring stations close to dam sites.
- Data have been collected by participating fishers who use multiple types of fishing gear to catch fish. Thus, it is suggested that standardized gear, for example, multiple panel gillnets, be used in the FADM programme to strengthen the results.
- The results of ABC curves showed that fish communities in almost all zones were disturbed, so it is crucial that the governments of the four Member Countries effectively enforce their national fisheries laws and jointly implement the approved Mekong Basin-wide Fisheries Management and Development Strategy to restore these disturbed fish communities.
- In regard to key habitat connectivity within and between zones, importantly, integrated river management plans should consider threats resulting from hydropower development.
- Transboundary fish protected areas or transboundary fish conservation zones should be set up to maintain biodiversity in the LMB, especially during spawning, and egg and larvae development periods.
- Since the current study mainly focuses on the current climate regardless of future climate change, a study on the impact of climate change on fish abundance and diversity in the LMB should be conducted.
- A study on the impact of sand mining on fish populations and fisheries in the LMB should be carried out to assist policymakers in formulating policy to minimize the impact of sand mining.

1

INTRODUCTION

The Mekong River is the world's 12th longest river with a length of 4,763 km, the 8th largest by flow with a mean annual discharge of approximately 446 km³, and the 21st largest by basin area draining 810,000 km² (Mekong River Commission [MRC], 2018b). It flows through China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam before discharging into the South China Sea.

The Mekong River serves as an important source of food, transportation, and livelihood for millions of people residing in its basin. It is known for its rich biodiversity and diverse ecological systems, providing home to some of the world's highest diversities of fish and snails, as well as a number of critically endangered species, such as the Irrawaddy dolphin and the giant Mekong catfish (Campbell, 2009). A recent literature review by the MRC revealed that the Mekong Basin is home to 1,148 fish species categorized into 11 guilds as shown in Figure 1.1 (MRC, 2018a). The survey results from long-term fisheries monitoring by the MRC have recorded 617 fish species in the Lower Mekong Basin (LMB).



Figure 1.1 Number of fish species of each of the eleven guilds in the Lower Mekong Basin (Source: MRC, 2018a)

Due to the recent acceleration of water resources development, the Mekong Basin has undergone rapid change. Significant impacts downstream due to the development of hydropower dams in the upper part of the Mekong River in China (Lancang River) have been experienced, such as: (i) a decrease in peak flow and annual flood volumes; (ii) lower early flood season flows and higher late flood season flows; (iii) the late start and end of flood season conditions; (iv) increase in dry season flows; (v) habitat fragmentation; and (vi) changes in water quality and sedimentation. All these impacts contribute to the decline and degradation of fisheries resources and aquatic ecology. Mainstream hydropower dams also account for a 40% decline in fish biomass, whereas tributary dams have significant impacts on the health of river ecosystems. Increases in channel erosion due to dams is having serious effects on the availability of river and floodplain habitats, decreases in the productivity of floodplains, and fundamental changes to fish communities (MRC, 2017). A study by the MRC (2017) reported effects on migratory fish species from dam development as fish ladders might not be able to accommodate the intensity and diversity of fish.

Climate change is another major issue in fisheries development in the LMB as it can alter fish species composition and distribution leading to the loss of species abundance and diversity (Parmesan & Yohe, 2003); lead to an increase in invasive species (Sutherst, 2000); shift the habitat ranges of species (Beisner et al., 1997; Thomas et al., 2004); and change hydrological patterns of the Mekong River. The increased occurrence of extreme events and changes in flow reversal of the Tonle Sap Lake are contributing to a potential adverse effects on the Mekong River and its

tributaries in terms of ecosystem functioning and resilience, which has a major influence on fish communities (MRC, 2015). Climate change and water infrastructure development also impact on 3 mainstream flows and on the LMB's biodiversity and fisheries (Arias et al., 2012, 2014).

Fisheries resources have also been threatened in the LMB in both the Mekong River and Tonle Sap Lake due to the use of destructive fishing methods (explosives, poisons, and electrocution), and illegal fishing in spawning season and at spawning grounds (Coates et al., 2003; Nuon & Gallado, 2011; Ngor et al., 2018; Chan et al., 2020). For example, fish migration channels in Boeung Chhmar Ramsar Site have been blocked, leading to a problem in fish recruitment (WWF, 2013). Further, Tonle Sap Lake's flooded forest is facing degradation from the expansion of fishing, harvesting of the forest for fuel wood, and conversion to agriculture land.

The Fish abundance and diversity monitoring programme was established in the 2000s (MRC, 2013). This long-term monitoring programme captures the temporal change of relative fish abundance, fish diversity and communities in the LMB, which has never been done before. Therefore, the objectives of this report are to: (i) evaluate the contribution of fish species and

guilds to the fisheries of the LMB; (ii) evaluate the status and trends in fish catch; (iii) monitor spatial and temporal patterns in fish abundance and diversity; and (iv) assess fish community patterns and their relationships with environmental factors.





2

METHODS

2.1 MONITORING STATIONS

There are 38 monitoring stations from Bokeo at the Lao PDR-China border to the Mekong Delta in Viet Nam (Figure 2.1), of which 11 stations are in Cambodia, 15 in Lao PDR, 5 in Thailand and 7 in Viet Nam. The locations of monitoring stations are within each of the main river reaches as defined by the MRC (Figure 2.1) (the characteristics are summarised in Annex 1). The monitoring stations include:

- Sixteen (16) Mekong mainstems upstream and downstream of mainstream hydropower projects;
- Eleven (11) locations on larger tributaries with significant hydropower development or plans;
- Eight (8) locations in floodplain habitats: five locations in the provinces around Tonle Sap Lake in Cambodia, one location in Nakhon Phanom in Thailand and two locations in the Viet Nam Delta (Can Tho and An Giang provinces);
- Two (2) locations in the estuarine habitat in Tra Vinh province, Viet Nam; and
- One (1) location in the canal habitat in An Giang province, Viet Nam.

All the above monitoring stations, except the 3S stations (CSK, CSP and CSS) in Cambodia and 2 stations (LAP and LXX) in Lao PDR, were grouped based on BioRA zones of the MRC Council Study as shown in Table 2.1. A detailed description of each zone can be found in the MRC Council Study report (MRC, 2017).

Note that only 25 stations were included in this study due to the longevity and regularity of the collected data from 2007 to 2018. Of the 25 stations, 11 were in Cambodia, 4 in Lao PDR, and 5 in each of Thailand and Viet Nam. However, for a relationship study between fish communities and environmental factors, only 20 stations (11 stations in Cambodia, 3 in Lao PDR, 2 in Thailand and 4 in Viet Nam) could be used due to the availability of environmental data at those stations.

Table 2.1 Monitoring stations inside each BioRA zone

Zone No.	BioRA Zones	Fisheries Monitoring Stations
Zone1	Mekong River from the border with China to Pak Beng (confluence with Nam Beng)	LDK, LHT, LPN, LOX
Zone2	Mekong River from downstream of Nam Beng to upstream at Vientiane	LNS, LPB, LPO, LXB, TCK,
Zone3	Mekong River from Vientiane to Nam Kam town (near confluences with Xe Bang Fei and Nam Kam)	LBX, LVT, TKR, TSK, TNK, TUT
Zone4	Mekong River from Nam Kam to Stung Treng (Se San/Se Kong confluences)	CKT, CST, LSD, LCS, LSL
Zone5	Mekong River from Stung Treng to Kampong Cham	Note: since there is only one station in this zone, its station (CKT) is combined with Zone 4.
Zone6	Tonle Sap River at Prek dam, plus the Cambodian floodplains	Note: since there is only one stations in this zone, its station (CKD) is combined with Zone 7.
Zone7	Tonle Sap Great Lake and River	CBT, CKC, CPT, CPS, CSR, CKD
Zone8	The Vietnamese Delta from the Cambodian and Viet Nam borders to the sea	VAP, VCM, VTS, VCT, VTV, VLT, VVL
Zone3S	Sekong, Sesan and Sre Pok rivers in Cambodia (Note: these zones were not included in the BioRA)	CSK, CSS, CSP, LAP, L XK (Note: For further studies, LAP and L XK might be included in this zone since both LAP and L XK are located in the Sekong River.)

Note:

1. The full names of the stations can be found in Annexe 1.
2. The stations in red text were not included in this study due to insufficient data.

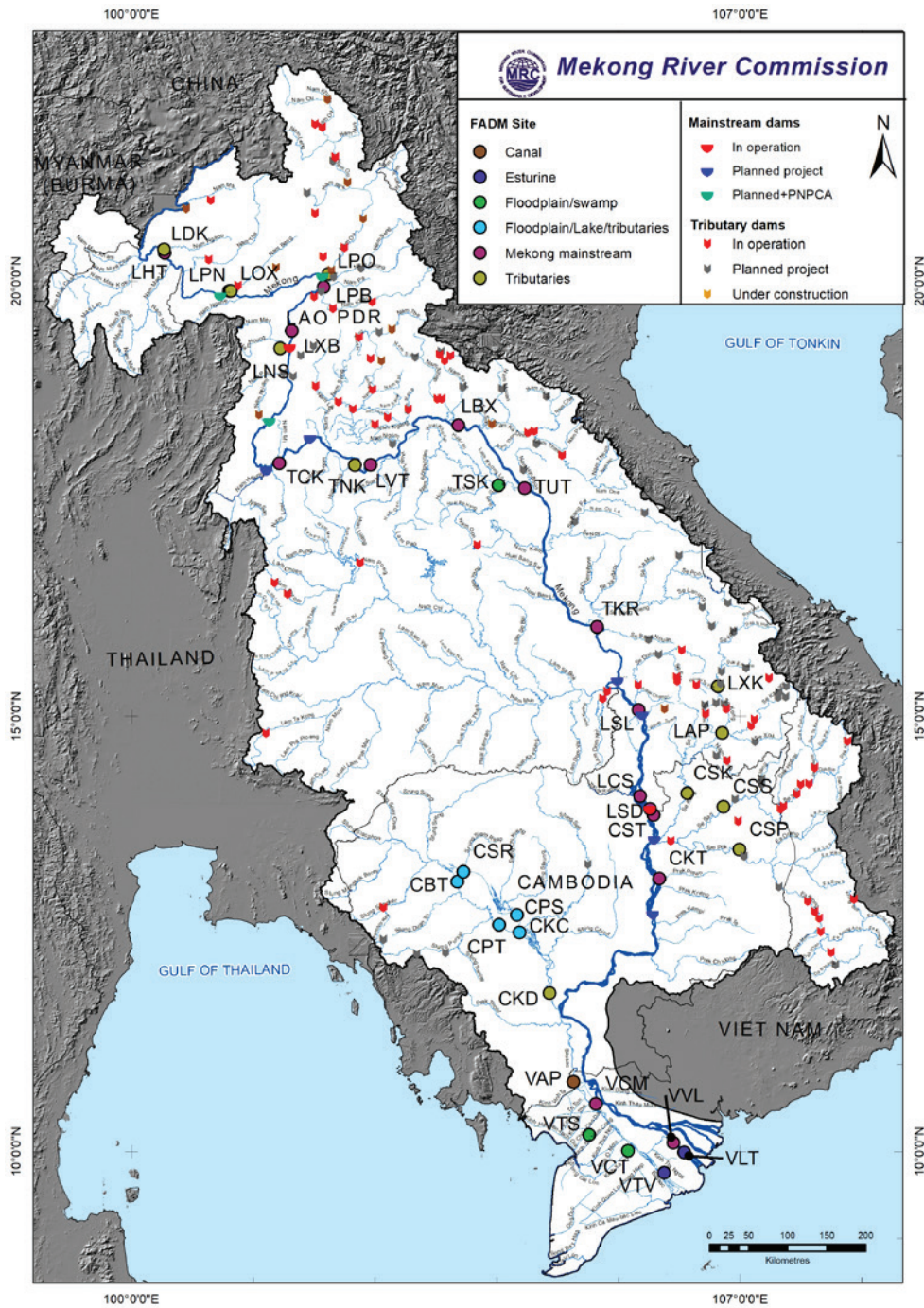


Figure 2.2 Map of the Lower Mekong Basin showing FADM monitoring stations and hydropower dams (Source: MRC fisheries and hydropower database 2019)

2.2 FISHER SELECTION

Three experienced fishers at each monitoring station were selected by national implementing agencies in the four Member Countries. The selected fishers had to meet the following criteria:

1. They are 'typical' medium-scale, full-time fishers at that location. They fish most days of most weeks (>200 days per year) and fishing is their primary occupation for income generation;
2. They fish from motorised boats and use a variety of medium-scale gear, such as gill nets, trammel nets or trawl nets depending on the season. It is recommended that all fishers use gillnets as standardised gear as it enables enhanced comparisons between locations. The mesh size of the gill nets used should be recorded on each occasion to account for selectivity;
3. They are able to read and write;
4. They are willing to participate and be honest in recording fish species and catches;
5. Priority is given to fishers associated with organized fisher groups such as community fisheries or fish refuge pond communities if these types of organisations exist in that location; and
6. Their experience and capacity, including eyesight, is adequate for identifying fish and recording data.

2.3 SAMPLING TECHNIQUES

Two sampling and recording techniques were employed; one for the whole sample and another for sub-samples of fish catches. Firstly, if the fish catch is less than 10 kg, fishers sort and weigh their entire catch and record details of the numbers, weights and prices by species and gear. Secondly, in case the catch is large (>10 kg), the whole catch needs to be sub-sampled by recording numbers, weights and prices by species and by gear following recording of the total weight of the catch for all species. In the cases of large-sized fishes (>200 g) and uncommon fish (<10 individuals), after weighing the total catch of all species, their total weight and number are recorded separately. The remaining small-sized fishes are thoroughly mixed and formed into a neat pile. This pile is then divided into 12 equal piles and combined into 3 or 6 piles depending upon its size. The total weight of all the mixed fish in either one half or one quarter of the pile is recorded and then the numbers, weights and prices of fish by species in the catch sample are recorded. The details of these techniques are described by Cowx, Nuon, and So (2019).

2.4 DATA COLLECTION

The daily fish catch data were collected by the participating fishers using various types of fishing gear (e.g. cast nets, hooks and lines, and gillnets). Note that the fishers employ about 26 types of fishing gear (Cowx, Nuon, & So, 2019), but gillnets are the most commonly used by fishers within all the major habitat types and during most months in all four countries. At each station, the fishers recorded their daily catches in logbooks including individual weights, total weights, number of fishes, maximum length of each species, and weather and hydrological conditions on each fishing day. To support fishers with fish identification, fish photo books (or flipcharts) are provided and identification is made to species level. Data are cross-checked against the contents of the logbook and cleaned by fisheries researchers from national fisheries research agencies each quarter. Moreover, the data are double-checked for errors (e.g. outliers and missing data...) by a Fisheries and Aquatic Ecology Officer of the Environmental Management Division at the MRCS every six months.

MRC survey data collected over twelve years from 2007 to 2018 were considered in this report except for stations in Tonle Sap Lake, where sampling began in 2011. **Figure 2. 2** shows the matrix of the 25 monitoring stations selected across the time period. The missing values between 2015 and 2016 were caused by financial shortages during restructuring of the MRCS.

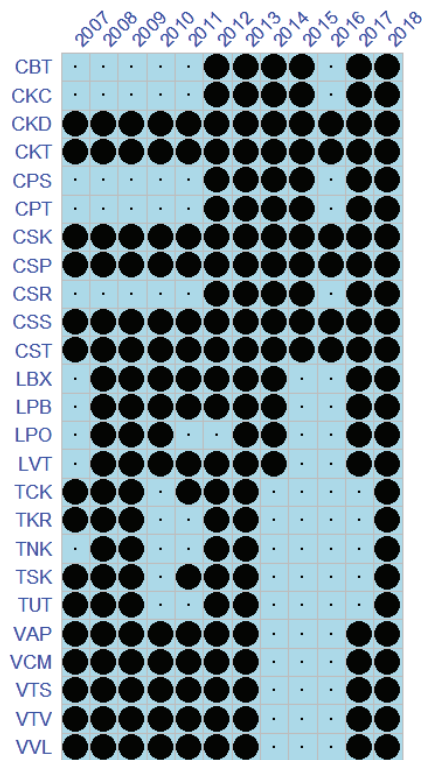


Figure 2.3 Sampling activity at each of the 25 stations across the survey period from 2007 to 2018 (big black circles).

Note:
Small dots indicate missing data

2.5 DATA ANALYSIS

2.5.1 Catch rate, Catch Per Unit Effort (CPUE)

For catch rate (CPUE), data were analysed to determine catch rates according to:

- Mean catch rates for a group of species; and
- Comparison of the mean catch rates for the different locations, seasons and habitats.

All data were reported as kg/100m²/hour for gillnets with a specific mesh size or all mesh sizes used by selected fishers and presented in graphs for each station clustered according to the Council Study's BioRA zones. To achieve this, all catch data were standardised for number or size of gear used; for example, for gillnets, catches were standardised as catch/100 m²/hour of net area.

2.5.2 Fish species richness and diversity in the LMB

Species richness and occurrence as well as species diversity were examined spatially at station (alpha diversity) or BioRA zone (gamma diversity) levels, and temporally (beta diversity) during the 12-year survey period. Spatial and temporal changes in fish species diversity in the LMB were studied by two diversity indices: Inverse Simpson and Shannon-Wiener. Pielou's evenness index was also used to show how close the numbers of each species were at each station in an environment. The regional diversity at each BioRA zone was indicated by the Shannon-Wiener Index.

Rank-species and rank-abundance curves of fish at each station were used to visualize species richness and evenness. Species richness can be shown as the number of different species on the chart; i.e., how many species were ranked. Species evenness is reflected in the slope of the line that fits the graph (assuming a linear, i.e. logarithmic series relationship). A steep gradient represents low evenness as the high-ranking species have much higher abundances than the low-ranking species. A shallow gradient illustrates high evenness as the abundances of different species are similar.

The Species Accumulation Curve or Species Discovery is a graph showing the cumulative number of species recorded in a particular environment as a function of the cumulative sampling effort. The curve can also reveal the number of additional species that will be discovered with further effort. This is usually done by fitting some kind of functional form to the curve, either by eye or by using non-linear regression techniques. Commonly used functional forms include the logarithmic function and the negative exponential function. The advantage of the negative exponential function is that it tends to an asymptote which equals the number of species that would be discovered if infinite effort is expended. However, some theoretical approaches imply that the

logarithmic curve may be more appropriate implying that although species discovery will slow down with increasing effort, it will never entirely cease; therefore, there is no asymptote, and if infinite effort was expended, an infinite number of species would be discovered. The Species Accumulation Curve was used for LMB data at BioRA zones to appreciate the richness of fish discovered relating to the effort over time.

2.5.3 Temporal change in fish diversity and abundance in the LMB

Beta Diversity was used to indicate the variation in species composition among stations in an area of interest (e.g. monitoring stations) or among survey times for a survey across years (Legendre & De Cáceres, 2013). Before measuring total beta diversity (BD_{total}), the species abundance/community composition data were transformed and then BD_{Total} was computed on Hellinger-transformed data, having a value ranging from 0 to 1. If the sampling units/stations are the same size, BD_{Total} was compared among study stations (Legendre & Salvat, 2015). Once all sampling units/stations have different species compositions, BD_{Total} is equal to 1.

BD_{total} was partitioned into Local Contributions of individual site to Beta Diversity (LCBD) and Species Contributions to Beta Diversity (SCBD). LCBD are comparative indicators of station uniqueness; thus, stations with significantly different species compositions have high values of LCBD. SCBD is essential to define which species show huge variations across the monitoring station. Note that SCBD and indicator species for groups of stations do not have the same interpretation (De Cáceres & Legendre, 2009; Dufrêne & Legendre, 1997).

2.5.4 Patterns of fish community in the LMB

Hierarchical clustering on the Hellinger-transformed species data was used to partition the monitoring stations into different groups based on their similarity of species composition. The species richness and diversity index (i.e. inverse Simpson index) of each group (cluster) was computed and then significant differences ($p < 0.05$) among groups were tested using Kruskal-Wallis and Tukey's Honest Significant Difference (HSD) tests. Afterwards, the indicator species of each group of stations were determined using the "indicspecies" package to describe the differences in the clusters identified (De Cáceres et al., 2010). For a given group, the indicator value of the species is the square root of the product of two quantities called A and B, that is: predictive value and sensitivity. Quantity A is the probability of the target group of stations given that an individual species has been found and was defined as the mean abundance of the species in the target station group divided by the sum of the mean abundance value over all groups. Quantity B is the average relative abundance of individuals of the species at a station that belongs to the target station group and was determined as the relative frequency of occurrence of the species inside the target station group (De Cáceres et al., 2010). Hence, species with high indicator values were used as characteristic members of the group.

2.5.5 Abundance/Biomass Comparison (ABC) Curve

The ABC curve method was proposed by Warwick in 1986. Theoretically, he mentioned that the distribution of the numbers of individuals among species should differ from the distribution of biomass among species when influenced by pollution-induced disturbance. This difference can be shown easily by K-dominance plots (Lambshead et al., 1983; Shaw et al., 1983).

This method involves the plotting of k-dominance curves for species abundances and species biomasses on the same graph and making a comparison of these curve forms. The species ranked in order of importance in terms of abundance or biomass on a logarithmic scale (x - axis) against percentage dominance on a cumulative scale (y - axis). The relative position of these curves has been suggested as a measure of the degree of stress. There are three levels of environmental disturbance: Under an unstressed environment the biomass curve overlies the abundance curve for its entire length as an indication of the dominance of a few large species (k-selected species). In a highly stressed environment, the abundance curve overlies the biomass curve as a result of numerical dominance of a few opportunistic species with small body sizes (r-selected species). Under moderate disturbance, the biomass and abundance curves are closely coincident and may cross each other one or more times. The degree and direction of the separation of these curves, which represents the area between the two curves is given by the W - statistic and expressed as:

$$W = 2(pA - pB)/(S - 1)$$

in which; pA and pB are the “Average Species Rank” for abundance and biomass;

S is the number of species; and

W is the statistic that takes values in the range (-1 to 1) with W close to 1 for equal abundances across species but biomass dominated by a single species, and W close to -1 for the converse case indicating that the biomass curve lies below the abundance curve and thus the more stressed the community and degraded the system. The ABC curves were drawn using the statistical package “forams” within R environment.

2.5.6 Relationship between fish species and environmental factors

To elucidate the relationships between biological assemblages of species and their environment, Canonical correspondence methods were used. The multivariate method is designed to extract synthetic environmental gradients from ecological datasets. The gradients are the basis for succinctly describing and visualizing the differential habitat preferences (niches) of taxa via an ordination diagram (Legendre & Legendre, 2012).

Redundancy Analysis (RDA) is a method to extract and summarise the variation in a set of response variables that can be explained by a set of explanatory variables. More accurately, RDA is a direct gradient analysis technique which summarises linear relationships between components of

response variables that are “redundant” with (i.e. “explained” by) a set of explanatory variables. To do this, RDA extends multiple linear regression (MLR) by allowing regression of multiple response variables on multiple explanatory variables. A matrix of the fitted values of all response variables generated through MLR is then subject to principal components analysis (PCA). See Jongman, Braak, and Tongeren (1995) for details.

RDA can also be considered as a constrained version of Principal Components Analysis (PCA), wherein canonical axes – built from linear combinations of response variables – must also be linear combinations of the explanatory variables (i.e. fitted by MLR). The RDA approach generates one ordination in the space defined by the matrix of response variables and another in the space defined by the matrix of explanatory variables. Residuals generated by the MLR step, which yield non-canonical axes, may also be ordinated. Detailed discussion is available in Legendre & Legendre (2012).





3

RESULTS

3.1 CONTRIBUTION OF FISH SPECIES AND GUILDS TO THE FISHERIES OF THE LMB

3.1.1 Basin-wide fish catch

During the survey period in the LMB from 2007 to 2018, the FADM recorded 37,530,460 individuals, corresponding to 1,095,848 Kg of fishes belonging to 21 orders, 80 families and 617 species (**Annex 4**). Note that the above record is pooled from all the existing data from 38 stations disregarding the time of data collection since the purpose is to show the actual number and catch of fish (i.e. relative abundance and biomass, respectively) and species caught from 2007 to 2018. Figure 3.1 shows clearly the dominance of three orders, with Cypriniformes representing more than 45% of the total catch in the LMB, followed by Perciformes and Siluriformes accounting for 40% of the catch.

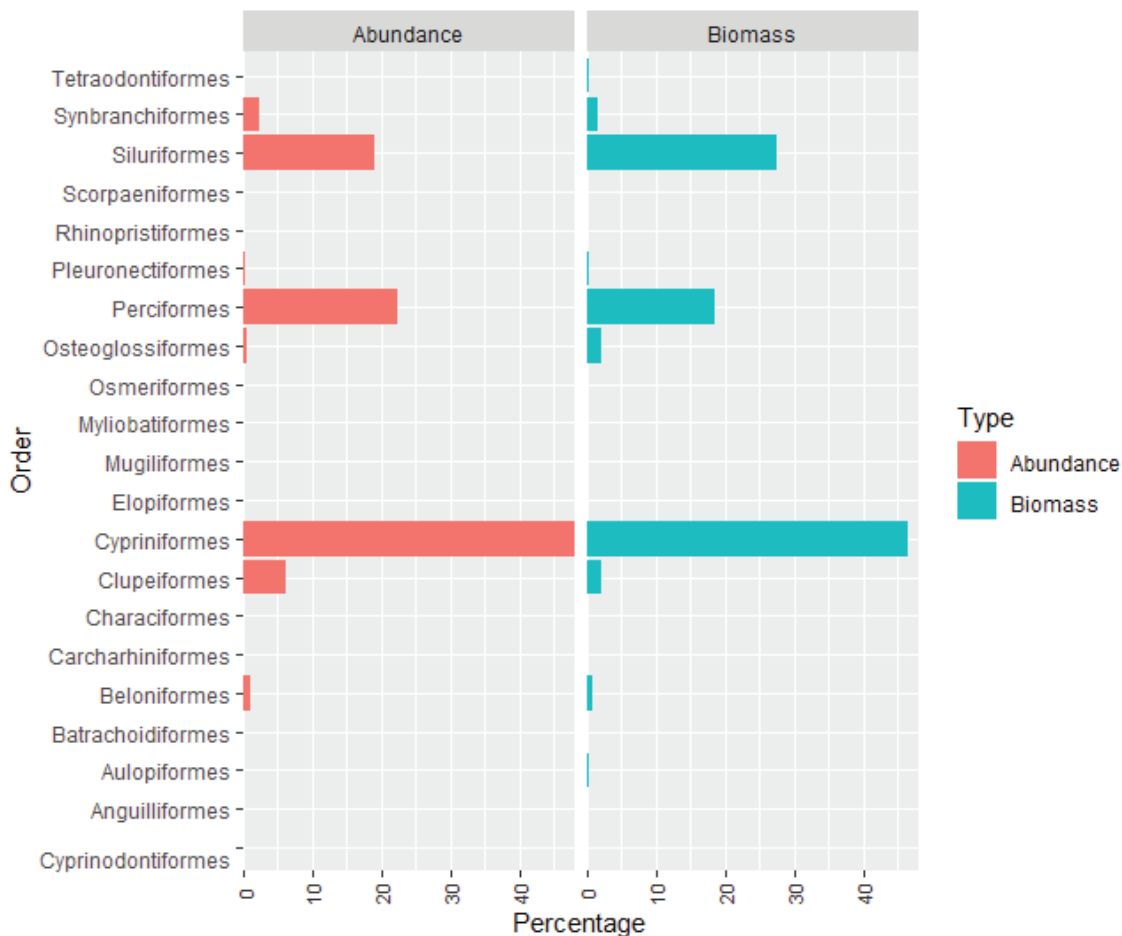


Figure 3.1 Relative abundance and biomass per fish order in the LMB

At the family level, LMB fishes were largely dominated by Cyprinidae making up more than 40% for both relative Abundance and Biomass (Figure 3.2). The other families accounted for less than 10% each. It should be noted that the relative abundance of the family Osphronemidae, Bagridae, and Anabantidae was higher than 5% each, while Bagridae, Pangasiidae and Ariidae accounted for more than 5% of biomass. The other families were scarce (Figure 3.2).



Figure 3.2 Relative abundance and biomass per fish family in the LMB

STATUS AND TRENDS OF FISH ABUNDANCE AND DIVERSITY IN THE LOWER MEKONG BASIN DURING 2007–2018

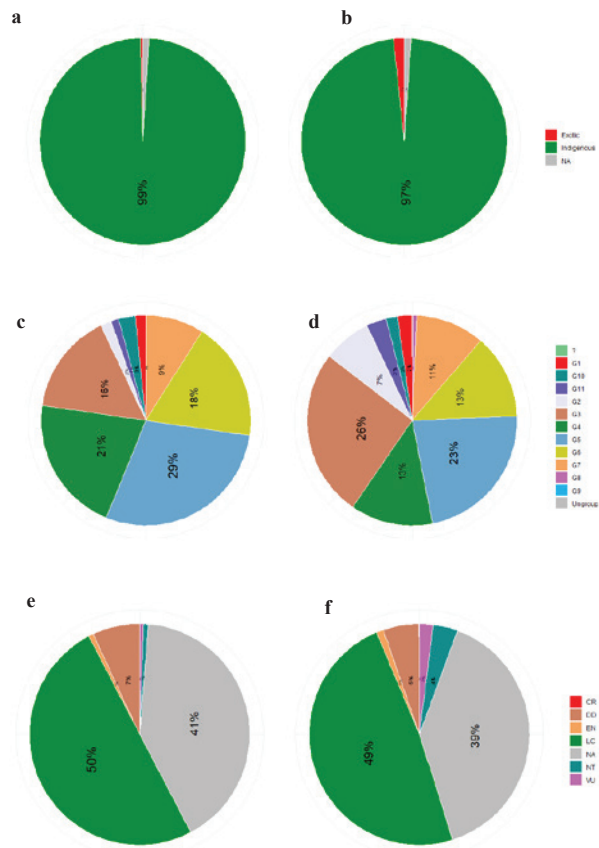


Figure 3.3 Relative abundance and biomass of fish in the LMB in relation to ecological functional characteristics. The left side represents relative abundance and the right side relative biomass

a-b) Invasion status (Exotic or Indigenous);

c-d) ecological functional guilds (G1= Rhithron residents; G2=Main-channel residents or long-distance white fishes;

G3=Main-channel spawners or short-distance white fishes; G4=Floodplain spawners or grey fishes; G5=Eurytopic or generalist fishes; G6=Floodplain residents or black fishes; G7=Estuarine residents; G8=Anadromous fishes;

G9=Catadromous fishes; G10=Marine visitors; G11= Non-Native).

e-f) conservation status (LC: Least Concerned, EN: Endangered, DD: Data Deficient, CR: Critically Endangered, VU: Vulnerable, NT: Near Threatened, NA: fish having not assessed in the IUCN Red list).

Figure 3.3 shows the catch proportions of LMB fish according to three ecological functional characteristics: native or non-native species, fish guilds and IUCN status. During the survey period, the indigenous species were largely dominant in the LMB with exotic species representing less than 1% for the relative abundance or number of individuals (Figure 3.3a) and only 1.6% in the relative biomass or catch (Figure 3.3b).

Relating to the functional guilds, the generalist fishes (G5) were dominant in the catch in terms of relative fish abundance followed by the floodplain spawners or grey fishes (G4) and the floodplain residents or black fishes (G6), with almost equal abundance (Figure 3.3c and Figure 3.3e). However, for the relative biomass, it was observed that the main-channel spawners or short-distance white fishes (G3) was the dominant guild followed by the generalists G5 (Figure 3.3d).

In regard to conservation status, the majority of the LMB fish species are in the Least Concerned (LC) category for both relative abundance and biomass (Figure 3.3e and Figure 3.3f). Near Threatened (NT), Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) fish species each represent less than 1% of the catch.

3.1.2 Rank species relative abundance distributions

A species abundance model is generated by graphing the abundance of each species against its rank order abundance from highest to lowest. One of four distributions usually arise: Log normal distribution, Geometric series, Logarithmic series, and McArthur's broken stick model (Magurran, 2004; Whittaker, 1965).

In the LMB, the species' relative abundance distributions resulting from the 25 FADM stations are shown in Figure 3.4. It clearly shows two different patterns: one group of stations (red-brown lines) with high relative abundance and richness. The differences of shape between stations in this group were linked to the degree of relative abundance of the species in the community. So, for example the convex shape of CKT, CST, and several stations from Tonle Sap indicated a good ecosystem with a community in equilibrium since their distributions were a log-normal distribution. However, another group of stations in the upper part of the LMB in Lao PDR and Thailand revealed more or less a straight-line shape (blue colour), meaning that their distribution could be explained by the dominance of a few species. Moreover, the stations in the Mekong Delta had the distribution between the two groups.

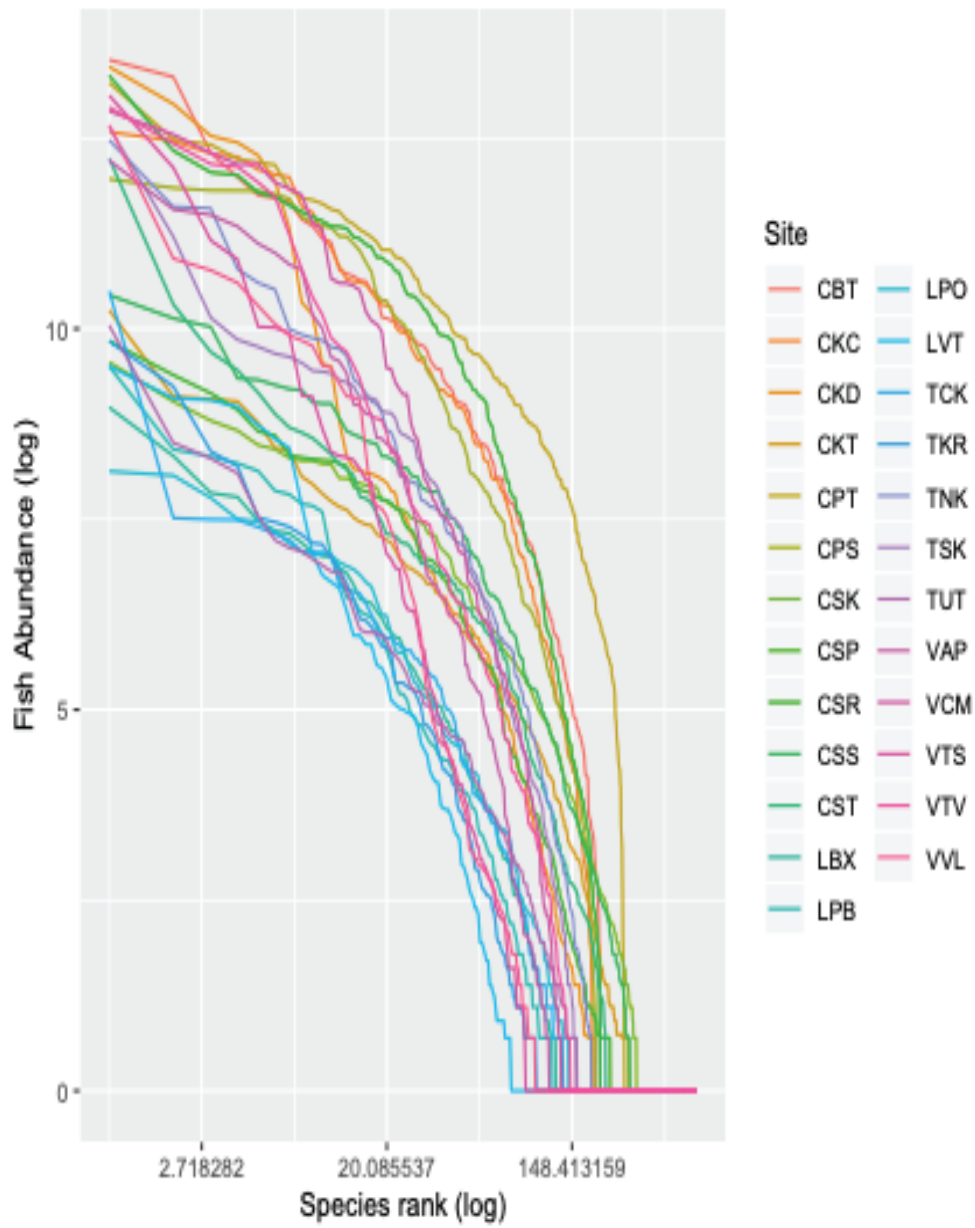


Figure 3.4 Rank species relative abundance distributions of FADM stations in log-log scale

3.1.3 Dominant species in relationship with relative abundance

By comparing the rank species relative abundance of fish composition for each station in the LMB, the dominant fish species of the five stations in Tonle Sap Lake, followed by the two stations in Mekong Delta and CKD in Tonle Sap River can be clearly observed (Figure 3.16a). The other five stations – two in Thailand (TNK and TSK) and three in the Mekong Delta (VTS, VAP and VVL) – had a relatively high rank of relative abundance. The 12 stations in the upper part of the LMB had very low rankings for fish abundance (Figure 3.5a).

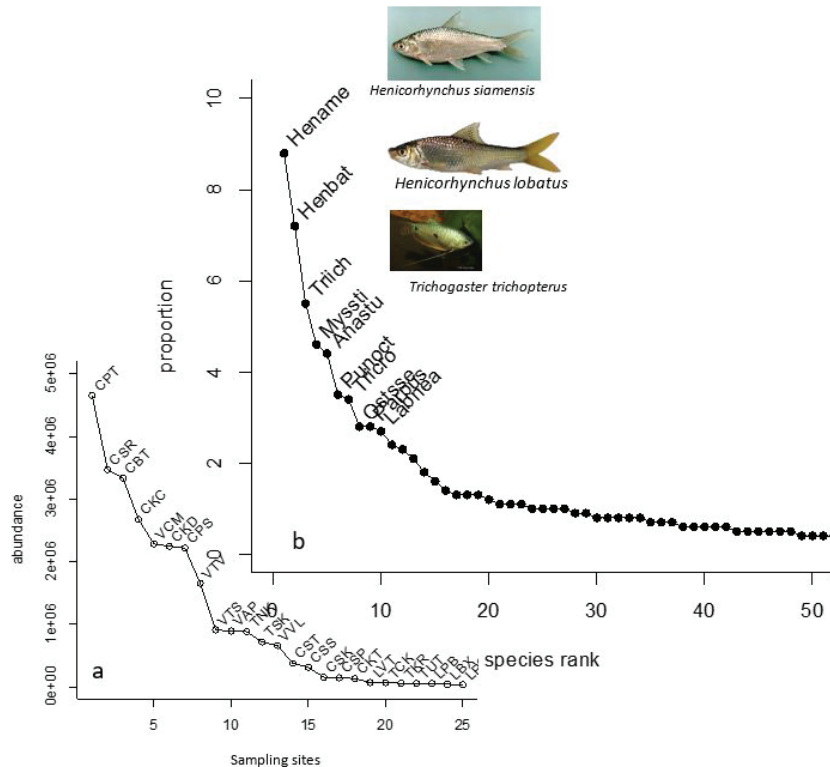


Figure 3.5 Site-rank relative abundance in the LMB; (a) the decreasing order of fish abundance by station; (b) the decreasing order of the abundance of fish species

The rank species relative abundance curve in the LMB (Figure 3.5b) clearly show the dominance of three species:

- *Henicorhynchus lobatus*;
- *Henicorhynchus siamensis*; and
- *Trichogaster trichopterus*.

These fishes are small-sized species. The observed maximum size is not larger than 15 cm with a common size of around 10 cm.

Figure 3.6 shows the rank-abundance species at each BioRA zone. Three zones (Zone 2, Zone 3, and Zone 4) were largely dominated by only one species: *Sikukia gudgeri* in Zone 2 at the upstream of the LMB (Figure 3.6a); *Henicorhynchus siamensis* in Zone 3 (Figure 3.6b); and *Henicorhynchus lobatus* at Zone 4 (Figure 3.6d). However, the 3S (Zone 3S), the Tonle Sap (Zone 7) and the Mekong Delta (Zone 8) had several dominant species in the community (Figure 3.6c, Figure 3.6e and Figure 3.6f). The abundance and richness in these zones were much better balanced.

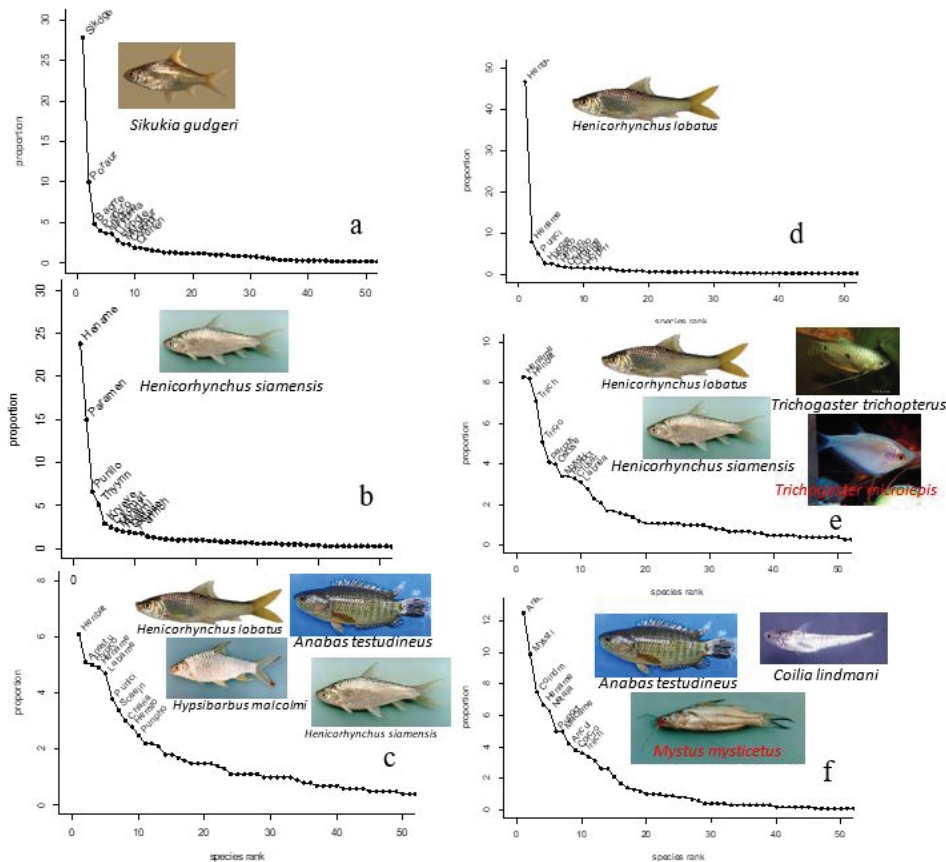


Figure 3.6 Rank-abundance distribution curve in each BioRA zone: a) Zone 2; b) Zone 3; c) Zone 3S; d) Zone 4; e) Zone 7; f) Zone 8

Note:

The most dominant species are shown at each BioRA zone

3.1.4 Relationship between relative abundance and relative biomass in LMB

Figure 3.7 shows the relationship between relative fish abundance and biomass in the LMB during the FADM period from 2007 to 2018. Figure 3.18 shows the exponential shape of the relationship between observed fish abundance and biomass recorded by fishers in the LMB. This positive effects of species abundance on productivity confirm the high resource availability in LMB (Fridley, 2003; He et al., 2002).

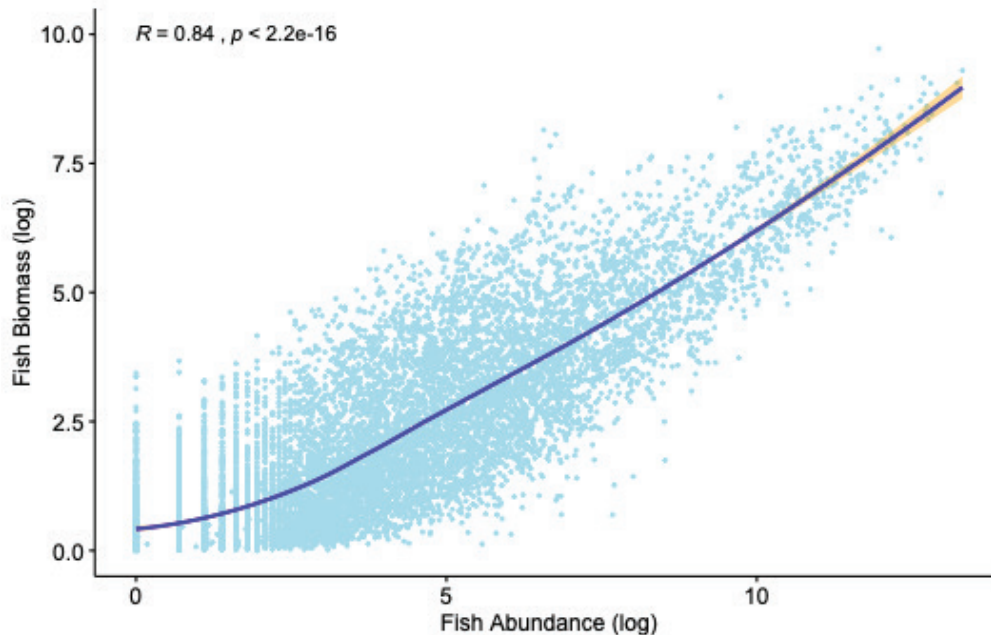


Figure 3.7 Scatterplot of relative biomass as a function of relative abundance of fish in the LMB during the FADM period, fitted by Loess smoothing

Relationship between species abundance and biomass in the LMB

The relationship between abundance and biomass of the 571 species caught from 25 monitoring stations during the FADM period from 2007 to 2018 is presented in Figure 3.8. The two species of *Henicorhynchus* (*H. siamensis* and *H. lobatus*) were the most abundant and provide the maximum biomass in the LMB fisheries (Figure 3.8a). A group of four other fish species were also well represented: *Anabas testudineus*, *Mystus mysticetus*, *Trichogaster trichopterus* and *Puntioplites proctozyron*. *Trichogaster microlepis* and *Coilia lindmani* were relatively abundant but with lower biomass. *Osteochilus hasselti*, *Netuma thalassinus*, *Barbonymus gonionotus*, *Labeo chrysophekadion*, *Cosmochilus harmandi*, *Polynemus longipectoralis*, and *Arius maculatus*

had high biomass but lower abundance. The remaining species were low in both abundance and biomass (Figure 3.8a). This is a typical log-normal distribution of a mature ecosystem.

To linearize the relationship between fish biomass and abundance, the log-log scale was used. *Figure 3.8b* shows clearly the strong linear relationship between species abundance and species biomass in the LMB fisheries, which means the LMB is a mature ecosystem with a high level of resources.

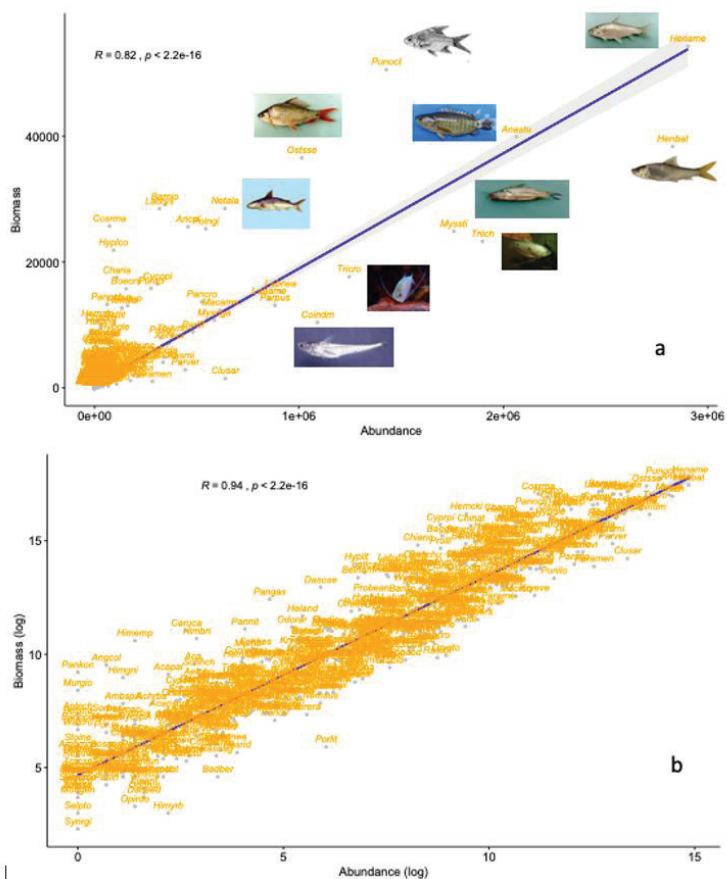


Figure 3.8 Scatterplot between yearly species abundance and species biomass from all FADM monitoring stations

Note:

a) normal scale showing the dominant species; b) log-log scale showing the trend of the linear relationship between abundance and biomass

3.2 STATUS AND TRENDS OF FISH CATCH IN THE LMB

3.2.1 Fish Abundance-Biomass Curves (ABC) in the LMB

The relative Abundance-Biomass Curve (ABC) (Warwick, 1986) was used to evaluate the quality of the river ecosystem. It is well known that this method should be a sensitive indicator of natural physical and biological disturbance as well as of pollution-induced disturbance in both space and time.

The ABC showed clearly that the fish community in the LMB was moderately disturbed due to the biomass curve situated under the abundance curve, meaning that the LMB fisheries are dominated by some small-sized and short-lived fish species (Figure 3.9). The negative values of W show clearly that the LMB ecosystem is under stress.

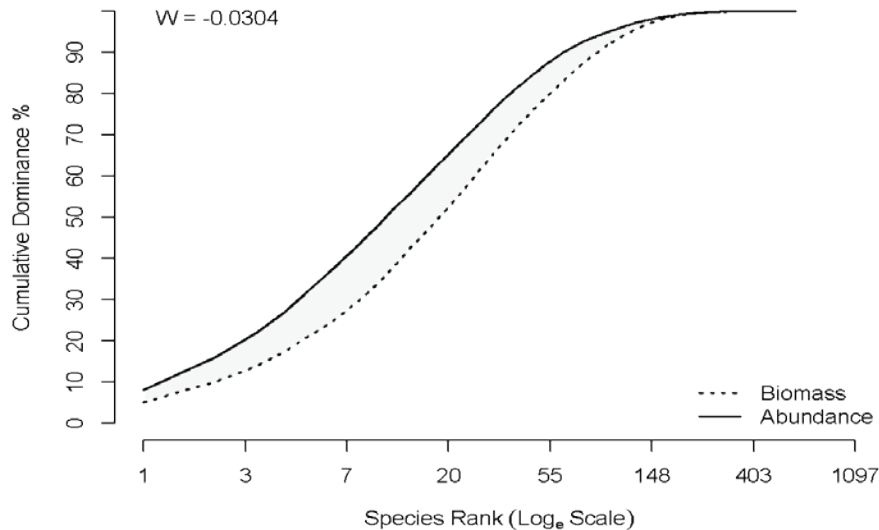


Figure 3.9 The relative Abundance-Biomass Curve (ABC) of the LMB

The spatial ABC curves of the 7 BioRA zones are presented in Figure 3.10. Except for Zone 3S, all zones had negative W values, meaning that these zones are under stress. The highest stress was observed at Zone 2 and Zone 4 with the abundance curve largely placed above biomass, and the areas mostly dominated by small species. Zone 3S was the unique zone in the LMB with positive W -values and a biomass curve over abundance. The system was in better condition or healthy, close to a natural unstressed system (Figure 3.10). The four other zones (Zone 2, Zone 3, Zone 7 and Zone 8) were considered as moderately stressed systems.

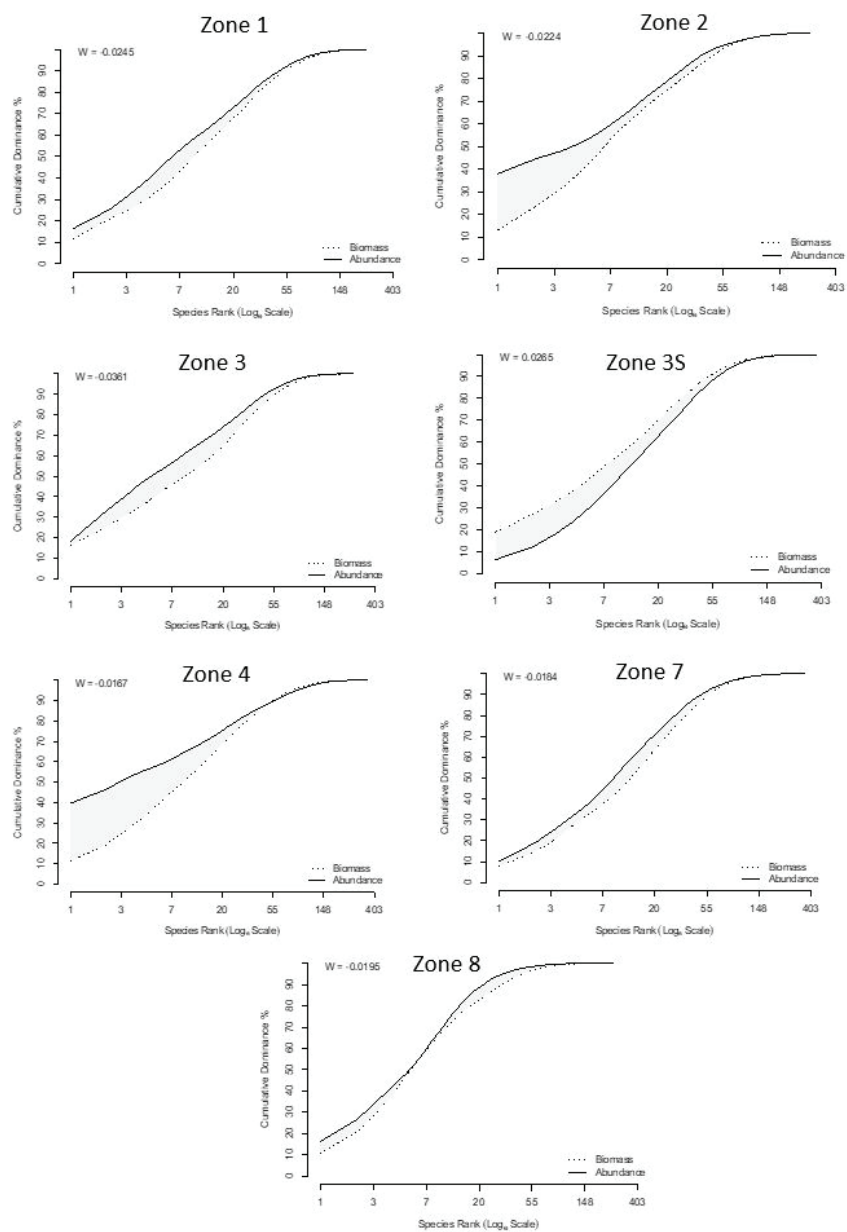


Figure 3.10 Spatial variation of the ABC curve in each BioRA zone of the LMB

3.2.2 Fish Catch Rate (CPUE)

This section describes the changes in fish catch rates at the 25 monitoring stations grouped under the six BioRA zones of the Council Study.

(a) Zone 2: Mekong River from downstream of Nam Beng to upstream at Vientiane

Zone 2 comprised three stations; two in Lao PDR (LPB and LPO) and one in Thailand (TCK). Note that the CPUE of TCK cannot be compared with other stations since the gear used in that station was stationary gillnets with two layers of nets. The purpose to show the CPUE of this station is to present the catch rate status of that station only. In TCK, the CPUE value ranged from 0.01 to 3.4 kg/100m²/hour and steadily dropped over the monitoring period (Figure 3.11a). The CPUE of LPB and LPO was from 0.01 to 0.4 kg/100m²/hour and from 0.02 to 0.2 kg/100m²/hour, respectively. It was observed that only the CPUE of LPB had an upward trend over the monitoring period. The peak period of gillnet fishing in LPB was between April and June while in LPO it was between September and November but shifted to January and April in 2018. It was noticed that the peak period of fishing in LPB was also altered to an unclear state in 2017 and 2018. For TCK, the peak period of fishing was from May to June (**Annex 2**). On average, the trend of the CPUE in this zone decreased slightly (Figure 3.12).

(b) Zone 3: Mekong River from Vientiane to Nam Kam town

There were six stations in Zone 3; two in Lao PDR (LBX, LVT) and four in Thailand (TKR, TSK, TNK, TUT). Figure 3.11b shows that TUT in Tha Uthen District, Nakhonphanom province had the highest catch rate with a range of 0.01 to 3 kg/100m²/hour, while TKR in Khemarat District, Ubon Ratchathani province had the lowest catch rate ranging from 0.04 to 0.4 kg/100m²/hour. Among these six stations, four (LBX, TKR, TSK and TNK) increased their catch rate during the survey period, while LVT and TUT decreased their catch rates. The mean CPUE of this zone indicated an increasing trend (Figure 3.12). The peak fishing period for each monitoring year was between May and July for LBX, between July and September for TUT and TKR, between September and November for LVT and TSK, and between October and December for TNK (**Annex 2**).

(c) Zone 4: Mekong River from Nam Kam to Stung Treng (Se San/Se Kong confluences)

In this zone, there were five stations; two in Cambodia (CST and CKT) in Stung Treng and Kratie provinces and three in Lao PDR (LSD, LCS and LSL) in Champasack province; however, the stations in Lao PDR could not be used for this report since their data were insufficient for the analysis. It was observed that both sites (CST and CKT) in Cambodia had similar catch rates ranging from 0.003 to 0.25 kg/100m²/hour, but CKT showed an increasing trend (Figure 3.11c), while CST showed a decreasing trend. In CST, a higher fish catch rate was observed at the end of the dry

season in April and at the onset of the wet season between May and June of each monitoring year (**Annex 2**). However, the catch rate at CKT appeared to be high at the end of the wet season between September and November in each monitoring year. The mean CPUE of this zone showed a slight upward trend (Figure 3.12).

(d) Zone 3S: Se Kong, Se San and Sre Pok rivers

This Zone comprised three stations located in Cambodia (CSP, CSS, CSK) with one station each in the Se Kong, Se San and Sre Pok rivers. In relation to catch rate, CSP in Sre Pok River had almost double the catch rate (0.01-0.65 kg/100m²/hour) compared to the two other stations (CSK and CSS). Based on the chart in Figure 3.11d, the catch rate at CSP was high between 2007 and 2009, but then it gradually dropped (**Annex 2**). On the contrary, at CSK the catch rate rose moderately from 2007 to 2018. For CSS, the catch rate appeared stable. The peak period for catch rates for the three stations was from June to December. The mean CPUE of this zone illustrated a slight downward trend (Figure 3.12).

(e) Zone 7: Tonle Sap Great Lake

There were six monitoring stations located in this zone: five in Tonle Sap Lake (CBT, CPS, CSR, CPT, CKC) and one in Tonle Sap River (CKD). The stations in the lake were located in Battambang (CBT), Pursat (CPS), Siem Reap (CSR), Kompong Thom (CPT), and Kompong Chhang (CKC) provinces, while the river station was located in Kandal province (CKD). Among all stations, CKD had the highest catch rate ranging from 0.006 to 1.14 kg/100m²/hour (**Annex 2**), yet with a slightly decreasing trend (Figure 3.11e). It can be observed that CBT, CPT, CPS and CSR had an increasing trend, while CKC and CKD had a decreasing trend. Unlike the other zones, the high catch rate of all stations in this zone was in the dry season between December and March (Figure 3.11e) when the reverse flow of Tonle Sap Lake back to the Mekong River via the Tonle Sap River occurs. The mean CPUE of this zone showed a steadily rising trend (Figure 3.12).

(f) Zone 8: Vietnam Mekong Delta

This zone covered all monitoring stations in Viet Nam, but only five stations were employed in this report due to data availability. Three stations (VAP, VCM, VTS) are located in An Giang province with the other two (VTV, VVL) at Tra Vinh and Vinh Long provinces, respectively. In regard to the catch rate, VTS and VTV had the highest with catch rates ranging from 0.1 to 1.6 kg/100m²/hour (**Annex 2**), which was also the highest catch rate compared to all other stations in the LMB. Based on Figure 3.11f, the catch rate of VAP, VCM and VTV decreased while in the remaining stations it increased. It was observed that the peak period for the catch rate in this zone was in the dry season from February–May for each monitoring year (**Annex 2**). The mean CPUE of this zone indicated a decreasing trend (Figure 3.12).

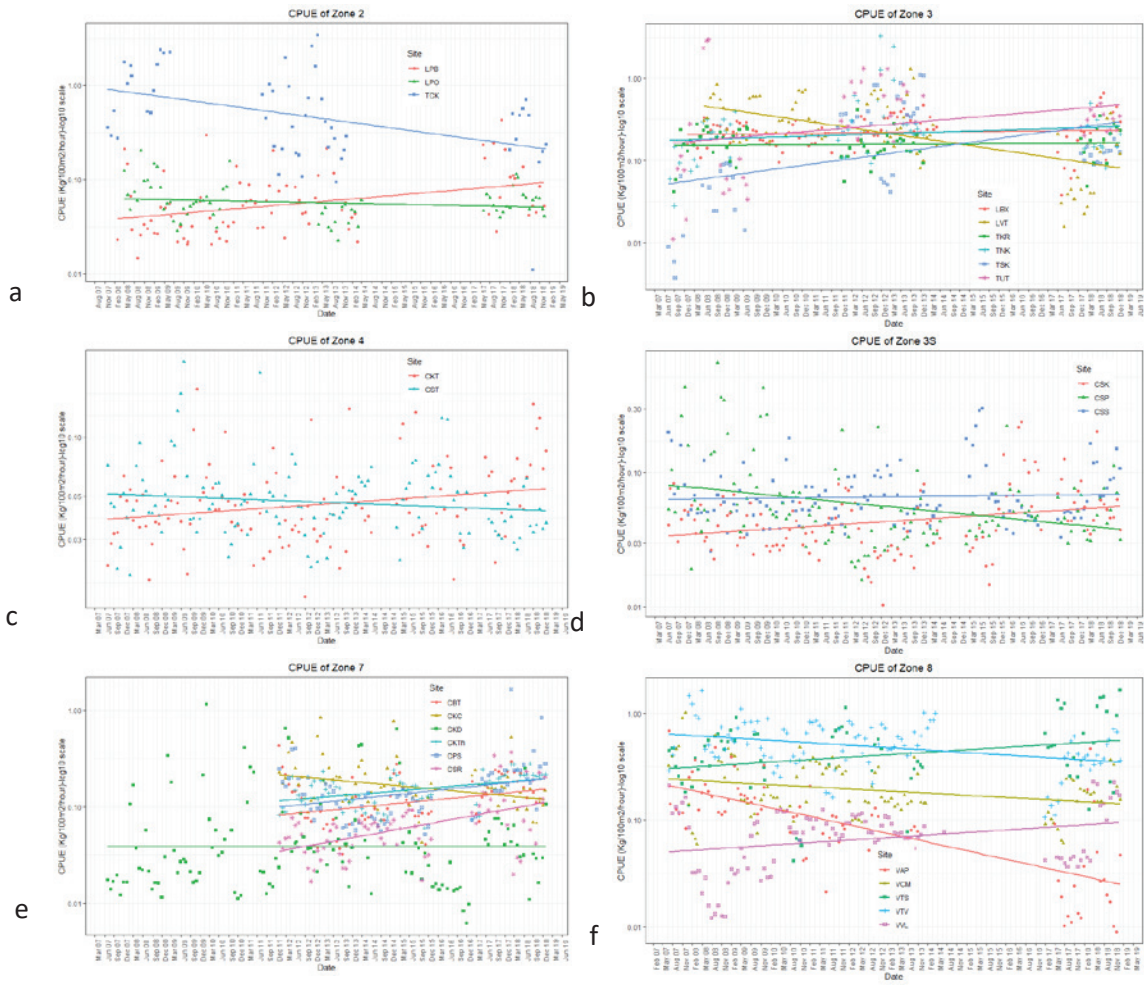


Figure 3.11 Catch per unit effort (CPUE) in log₁₀ scale of gillnets for each station under BioRA zones, a: Zone2, b: Zone3, c: Zone4, d: Zone3S, e: Zone7 and f: Zone8

Note:

See Table 2.1 for details on each zone

STATUS AND TRENDS OF FISH ABUNDANCE AND DIVERSITY IN THE LOWER MEKONG BASIN DURING 2007–2018

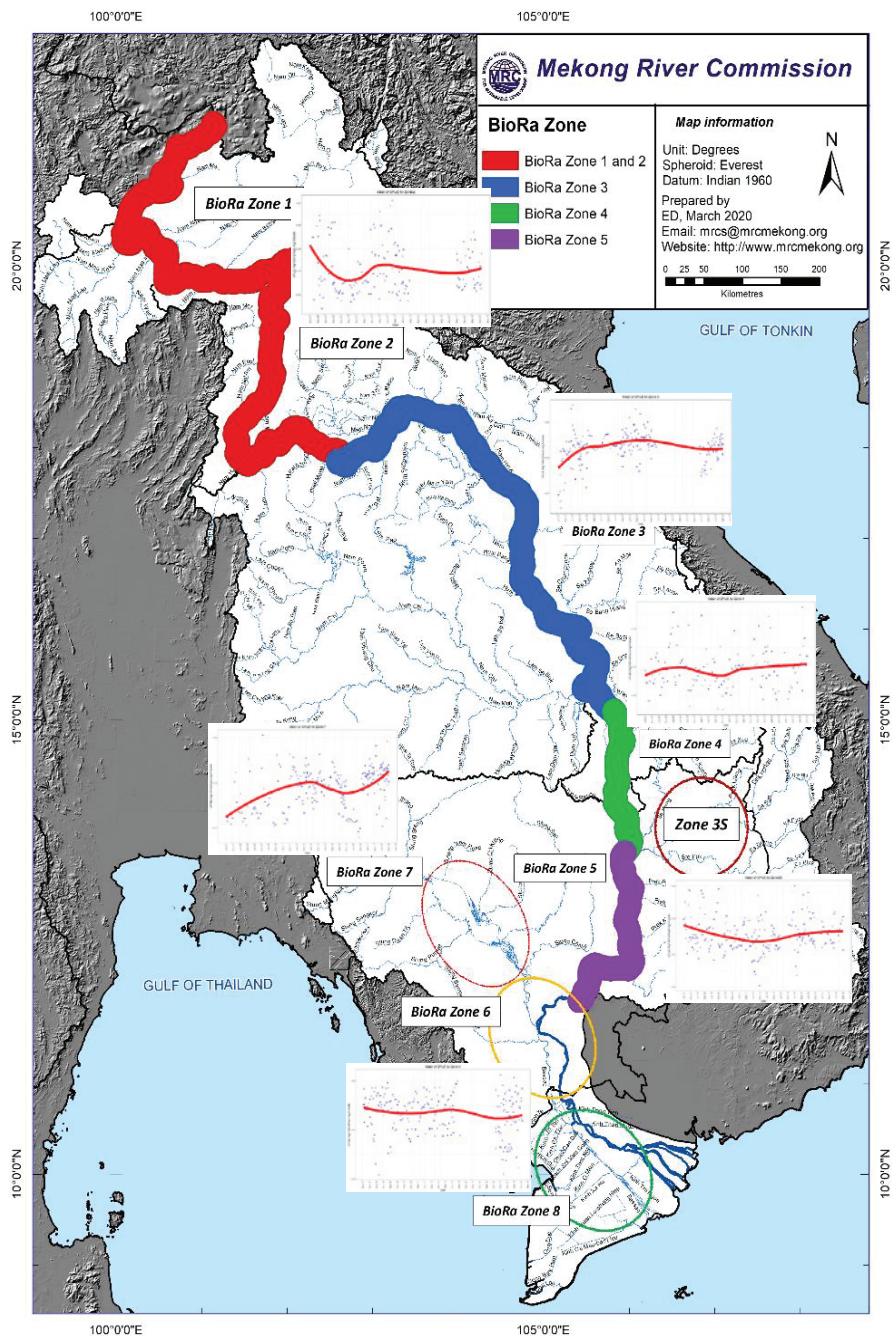


Figure 3.12 Mean catch per unit effort for each BioRa zone

3.3 SPATIAL AND TEMPORAL PATTERNS OF FISH ABUNDANCE AND DIVERSITY IN THE LMB

3.1.3 Spatial Patterns of fish richness and abundance

LMB species richness

Figure 3.13 shows the yearly cumulative fish species caught at each station clustered by BioRA zones during the monitoring period (2007–2018). Zone 3S, Zone 4 and Zone 7 had the highest richness in the LMB. At the station level, the highest richness was observed at CSK, CKT, CSS, and CPT, corresponding to the regional connectivity between 3S-Mekong with the Tonle Sap Lake, with more than 250 species caught each year at each station. The lowest richness stations were at the upper part of the Mekong River in Lao PDR and Thailand (i.e. LVT, TKR, LPB, LBX, TCK) and the delta of the LMB.

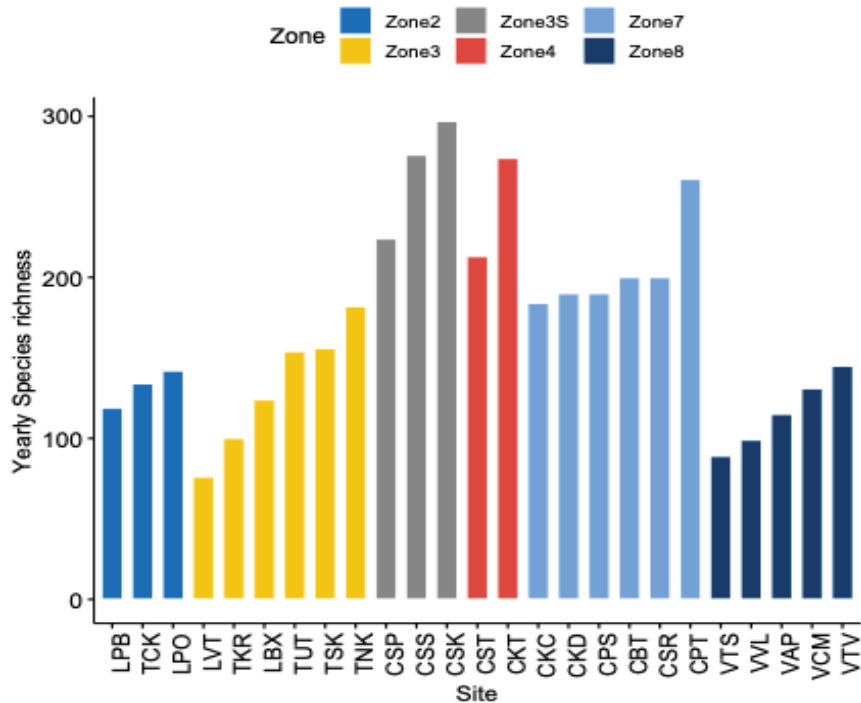


Figure 3.13 Cumulative annual fish species caught at each monitoring station, sorted for each BioRA zone

The Annual Species Accumulation Curve (Figure 3.14) showed that the majority of stations did not reach asymptote, meaning that a number of additional species may be discovered with further sampling efforts. Only certain stations showed a species accumulation curve close to asymptote; for example, TNK, TCK, LPO, LBX, LPB, TKR and LVT located upstream of the LMB in Lao PDR and Thailand. Four stations – two in 3S (CSK and CSS), one in the upper part of Cambodia’s Mekong River (CKT) and one in Tonle Sap Lake (CPT) – had the highest richness in the LMB. In contrast, the stations in the Viet Nam Mekong Delta (VTS and VVL), in Lao PDR (LVT) and in Thailand (TNK) had relatively low levels of richness.

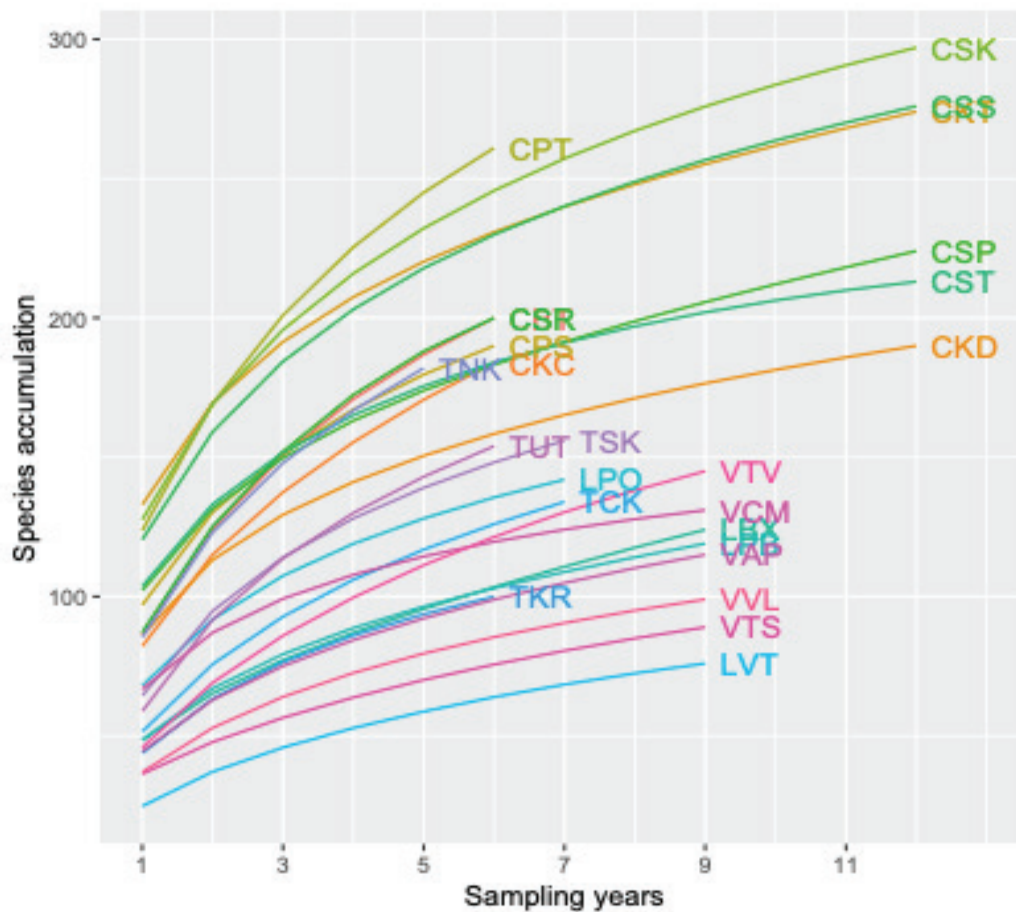


Figure 3.14 Annual species accumulation curves of the 25 FADM stations

Species richness and abundance by BioRA zones

Figure 3.15 shows the average species richness at each BioRA zone of the LMB. It clearly shows that the highest richness was found in Zone 4 and Zone 3S with a range of richness from 50 to around 200 species, with an average of around 115 species. Zone 7 (Tonle Sap) also had high average species richness but with a large distribution from almost 40 to 200 species due to the flood-pulse ecosystem in this area. The upper part of the LMB (Zone 2 & Zone 3) and the Mekong Delta (Zone 8) had lower richness and around 50 species on average.

The non-parametric ANOVA (Kruskal-Wallis test) showed a highly significant difference of richness among BioRA zones ($p < 0.01$). The pair-wise comparison using the Mann-Whitney test showed significant differences for all pairs, except between Zone 2 and Zone 3; between Zone 8 and Zone 2 and Zone 3; and between Zone 3S and Zone 4 (Table 3.1).

Table 3.1 Results of pair-wise comparison using the Mann-Whitney test showing the probability of pairs of richness between BioRA zones in the LMB

	Zone 2	Zone 3	Zone 3S	Zone 4	Zone 7
Zone 3	0.295	-	-	-	-
Zone 3S	2.6e-09	2.0e-10	-	-	-
Zone 4	1.5e-07	2.4e-08	1.000	-	-
Zone 7	5.7e-06	1.4e-07	0.00045	0.00284	-
Zone 8	0.052	1.000	3.1e-13	2.5e-10	2.4e-11

Note:

The p-values lower than 0.05 mean significant differences between the pairs of zones

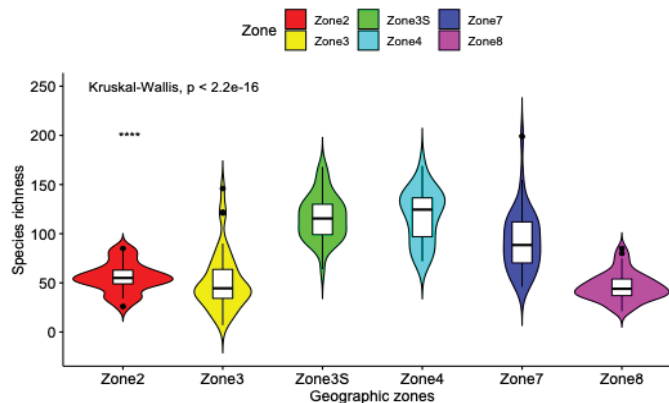


Figure 3.15 Violin plot and boxplot showing the distribution of Species Richness (SR) for different BioRA zones in the LMB

Note:

The non-parametric ANOVA (Kruskal-Wallis) test gave highly significant p-values (<0.01) for the differences in richness between zones

The highest relative fish abundance in the LMB was detected in Zone7 (Tonle Sap), followed by the Mekong delta (Zone 8). The other zones had quite similar and constant fish abundance over the monitoring period, except for Zone 3, which had a relatively large range of abundance (Figure 3.16).

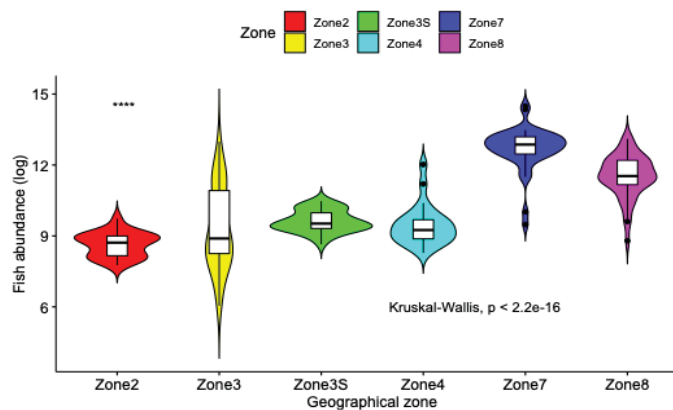


Figure 3.16 Violin plot and boxplot of fish abundance (log) for different BioRA zones of the LMB

Note:

The non-parametric ANOVA (Kruskal-Wallis) test gave highly significant p-values (<0.01) for the differences in richness between zones

The non-parametric ANOVA test (Kruskal-Wallis) showed an overall significant difference of relative fish abundance between LMB zones ($p < 0.001$). The pair-wise comparison using the Mann-Whitney test showed a significant difference for all pairs, except for Zone 2 and Zone 3. Zone 3 was not significantly different from Zones 3S and 4 as well as Zones 4 and 3S (Table 3.2).

Table 3.2 Results of pair-wise comparison using the Mann-Whitney test showing the probability of pairs of fish abundance difference between BioRA zones in the LMB

	Zone2	Zone3	Zone3S	Zone4	Zone7
Zone3	0.383	-	-	-	-
Zone3S	2.3e-09	0.2515	-	-	-
Zone4	0.0012	0.3833	0.2482	-	-
Zone7	2.5e-16	6.2e-16	< 2e-16	3.9e-14	-
Zone8	1.0e-14	7.0e-09	5.5e-15	1.8e-10	1.4e-09

Note:

The p-values lower than 0.05 mean significant differences between the pair of zones

Relationship between species richness and abundance in the LMB

The scatterplot between species richness and fish abundance for each zone is presented in Figure 3.17. The ellipse shows the one standard deviation confidence limit for each zone. It can be seen clearly that Zone 7 has the highest richness and abundance. A strong overlap between Zone 4 and Zone 3S indicates their similarity of high richness, but with a lower abundance than Zone 7. Zone 2 had the lowest richness and abundance, whereas Zone 8 had high abundance with a similar richness as Zone 2. Zone 3 also had low richness and abundance, but high variability since the ellipsoid overlaps with several other zones. Finally, Zone 7 had the highest richness and abundance in the LMB.

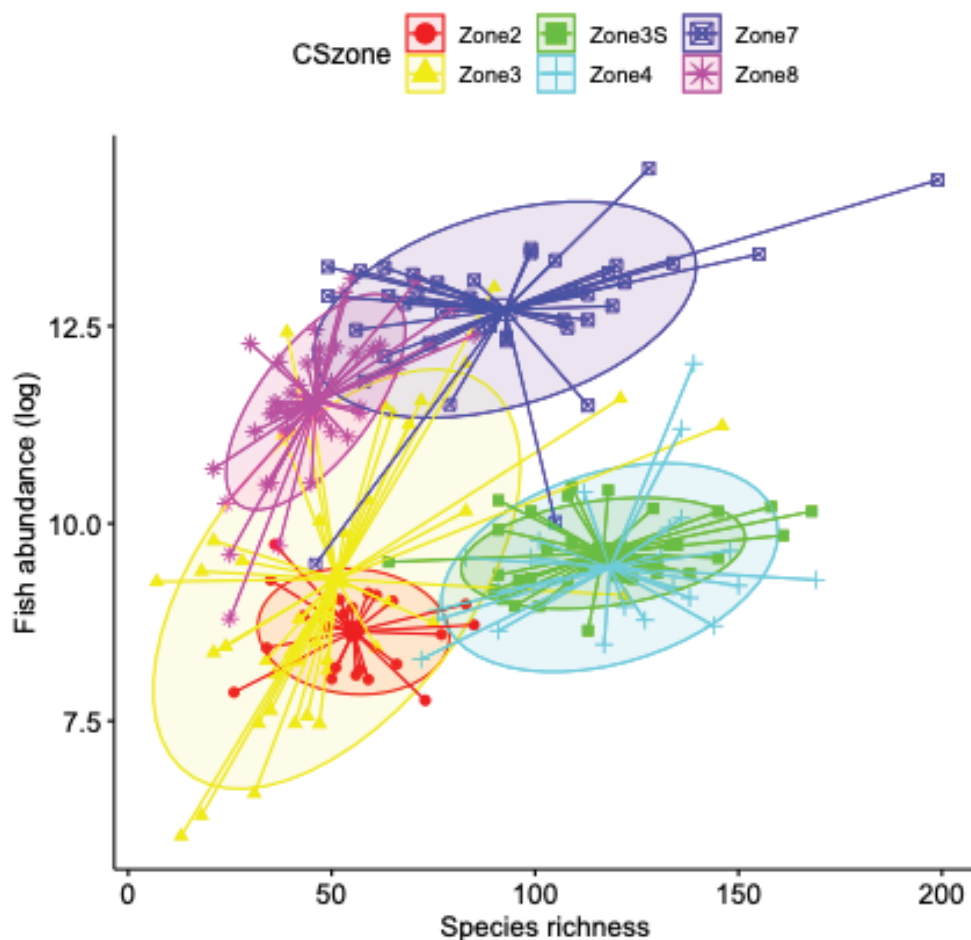


Figure 3.17 Scatterplot of the relationship between species richness and fish abundance (log) pooled by BioRA zones

Note:

The size of the ellipse relates to the 1-SD confidence of samples in each zone according to their values of fish richness and abundance (log-scale)

3.3.2 Temporal patterns of fish species richness and abundance in the LMB

Yearly species richness was plotted against the time period to show the trend of temporal changes by fitting with the linear model for each BioRA zone. It can be seen clearly that Zone 4 and Zone 8 decreased in richness over time, but in Zone 2, Zone 3 and Zone 7 richness increased slightly. The richness of Zone 3S appeared to be stable during the survey period (Figure 3.18).

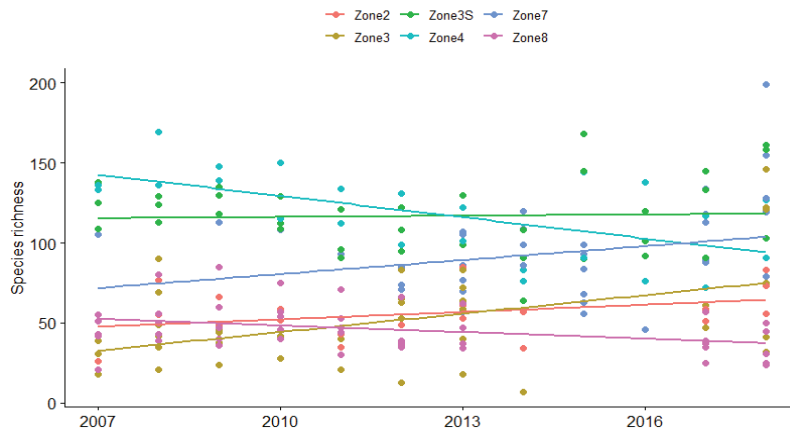


Figure 3.18 Scatterplot of monthly species richness from 2007 to 2018, fitted by linear models for each BioRA zone

The temporal trend of relative fish abundance caught in the LMB showed different results compared to species richness. In fact, only Zone 7 (Tonle Sap Lake) saw an increase in relative abundance during the survey period, while Zone 2, Zone 4 and Zone 8 decreased in relative abundance. The remaining zones had a stable trend during the same period (Figure 3.19).

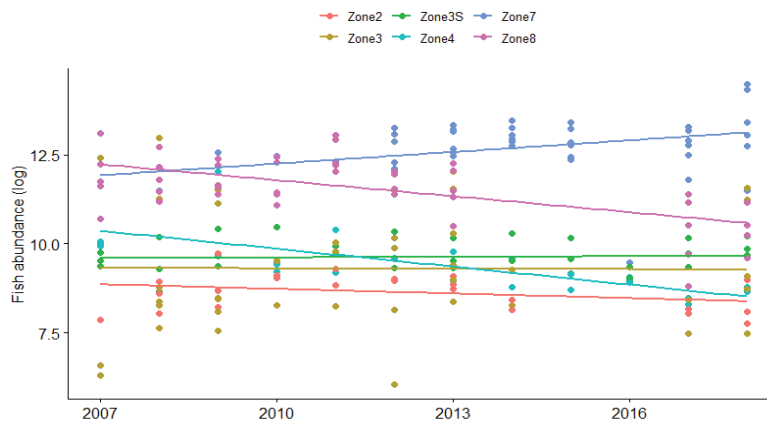


Figure 3.19 Scatterplot of monthly fish abundance (in log transform) from 2007 to 2018, fitted by linear models for each BioRA zone

Spatial and temporal patterns of fish species diversity

The diversity of a fish community needs (in most instances) to take into account both species richness and the abundance with which individuals are distributed among species.

There are two major forms of these indices: dominance indices and information indices. While more than 60 indices have been described, the three most widely used in the ecological literature have been considered for this study: Simpson's, Shannon-Weiner, and Equitability (or Evenness).

The ***Simpson's Index (D)*** is considered as a dominance index because it weights towards the abundance of the most common species. For this reason, in this report the ratio $1/D$ was used, known as the Inverse-Simpson index where a high value reveals high diversity.

The ***Shannon-Weiner Index (sh)*** (also incorrectly known as Shannon-Weaver) belongs to a subset of indices that maintain that diversity can be measured much like the information contained in each species. The function was originally to determine the amount of information in a code or signal and is defined as the proportion of individuals in the i^{th} species using the natural logarithm.

The ***Equitability or Evenness Index (E)*** is a measure of biodiversity that quantifies how equal the community is numerically. The value is constrained between 0 and 1.0 with 1 assuming that all species are represented within the sample site. The Evenness values close to 0 testify the disequilibrium in an ecosystem with 1 or 2 dominant species in the sample.

In the LMB (Figure 3.20), Zone 3S has the highest diversity according to the Simpson Index (D) and Shannon Index (sh). Furthermore, both indices show that Zone 8 in the Mekong Delta had the lowest diversity in the LMB. The high values of the Evenness Index (median values > 0.5 for all zones) reveal that all species are well represented in all BioRA zones.

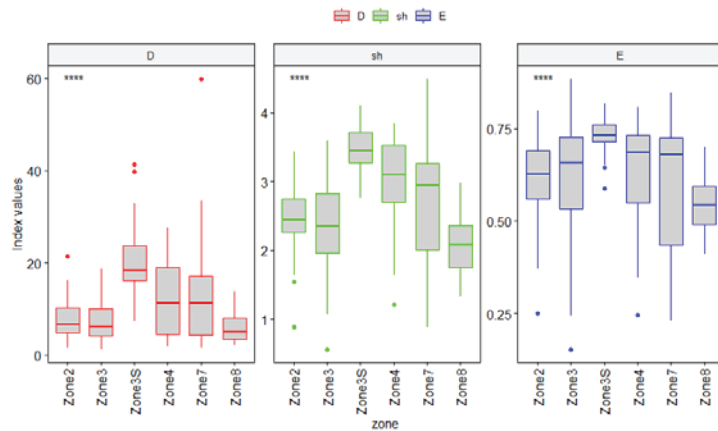


Figure 3.20 Diversity indices of fish in each BioRA zone: The inverse Simpson Index (D), the Shannon-Wiener Index (sh) and the Evenness Index (E)

Note:

Stars in the top-left corner show the significant level of difference (kruskal-Wallis test)

Temporally, over the past 12 years of the FADM period in the LMB, some temporal variations for the diversity indices – Simpson, Shannon and Evenness (Figure 3.21) – with significant differences were revealed by the non-parametric ANOVA (Kruskal-Wallis test, $p < 0.5$). The high Evenness index of around 0.7 during the FADM survey period testify that the LMB is a mature equilibrium system without dominant species. The high values of the Inverse Simpson index (between 10 and 20) and the Shannon diversity index (globally 2.5 to 3) indicate the high diversity of the LMB. All 3 indices have slightly increased during recent years probably due to increased fishing effort during these last 5 years.

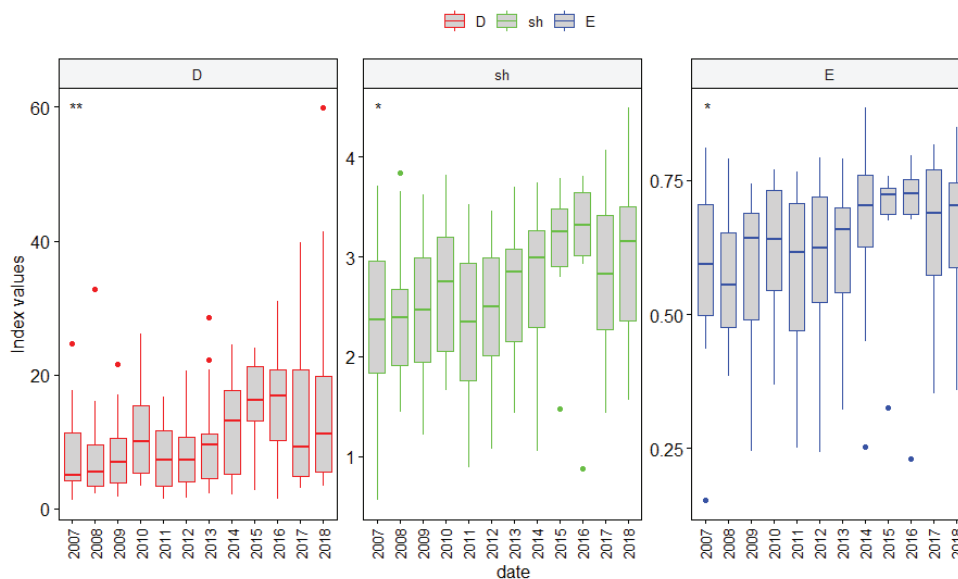


Figure 3.21 Diversity indices of fish in the LMB from 2007 to 2018: The inverse Simpson index (D), the Shannon-Wiener index (sh) and the Evenness index (E)

Note:

Stars in the top-left corner show the significant level of difference

Spatio-temporal patterns of beta diversity in the LMB

To identify the spatio-temporal changes of the fish community, Local Contribution for Beta Diversity (LCBD) was used. In the LMB, the yearly data from the FADM stations with the SS_{total} of 167.01 and the BD_{total} of 0.7357 showed that species substitution is quite high. Figure 3.22 shows the distribution of LCBD values for each station. The two stations in the Mekong Delta (VVL and VTV) had the highest LCBD values, meaning that a high turnover of species occurred in these stations during the FADM period. Several stations in the upstream part of Thailand and Lao PDR also had high LCBD values. Stations in Tonle Sap Lake and 3S areas had the lowest LCBD values, meaning that fish species' compositions were quite stable during the FADM period.

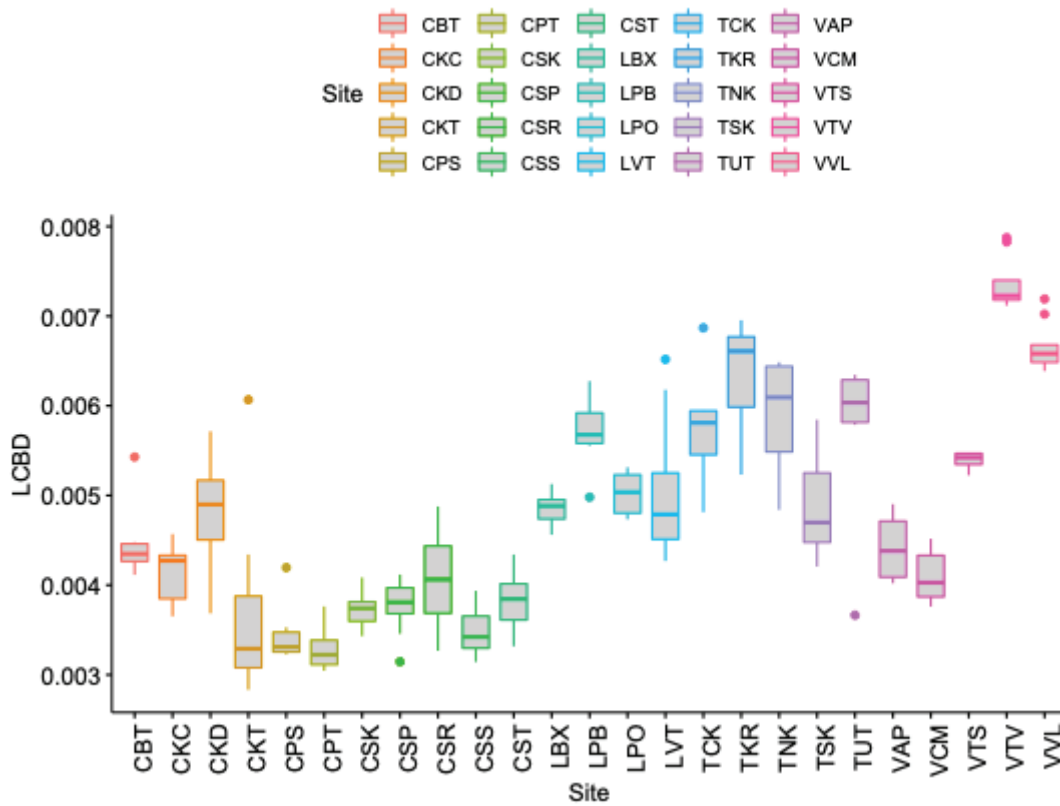


Figure 3.22 Distribution of LCBD in the FADM stations

Note:

Low values mean stable fish communities from one year to the next; high values mean a high turnover of fish species in the community

The Species Contribution for Beta Diversity (SCBD) showed that among 571 species recorded in the LMB, only a few species contributed greatly to the changes in beta diversity. The first group of five species (*Henicorhynchus lobatus*, *H. siamensis*, *Anabas testudineus*, *Sikukia gudgeri*, and *Coilia lindmani*) with SCBD higher than 0.03 (Figure 3.23) contribute strongly to the changes in beta diversity in the LMB. Among these five species, only one was a black fish (*Anabas testudineus*) with the rest white fish. The second group of six other species with SCBD values between 0.02 and 0.03 (*Pangasius macronema*, *Mystus mysticetus*, *Pangasius conchophilus*, *Hypsibarbus malcolmi*, *Puntioplites falcifer*, *Trichogaster trichopterus*) are also very important to the changes in LCBD values, but less so than the first group.

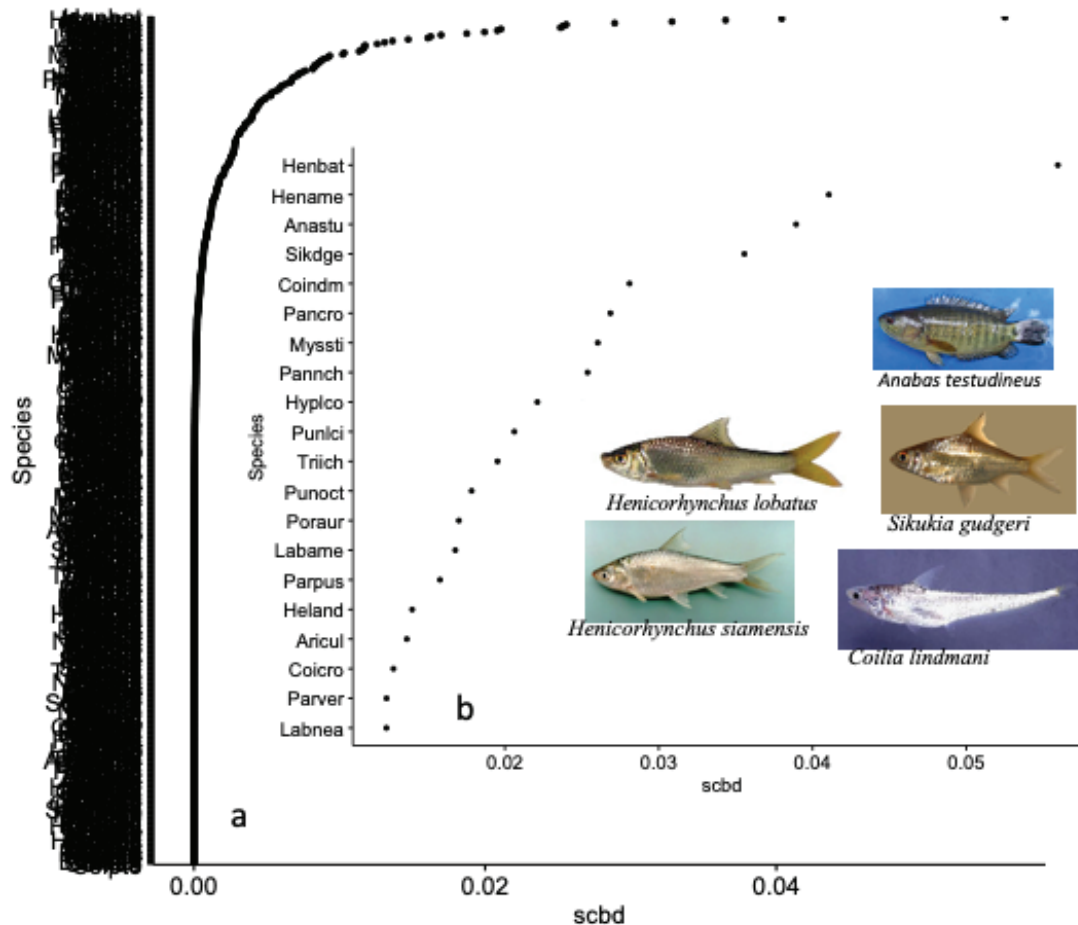


Figure 3.23 Species Contribution to Beta Diversity (SCBD) in the LMB

Note:

The profile of all 571 species in the LMB, zooming in on 20 species with SCBD > 0.01 and detail of the 5 highest SCBD values

3.4 FISH COMMUNITY PATTERNS AND THEIR RELATIONSHIP WITH ENVIRONMENTAL FACTORS

3.4.1 Patterns of fish communities in the Lower Mekong River (LMR)

The FADM from 25 monitoring stations recorded 571 fish species from 2007 to 2018, yet rare species occupied a larger proportion of fish species. To avoid noise in the analysis and to ensure

better graphic visualisation, species with less than 5% occurrence during the 2007–2018 period were removed from the fish assemblage study. This means only 247 species and over 228 yearly-site samples were selected for this study.

Hierarchical clustering using the Brey-Curtis Dissymmetric Distance and Ward Agglomerative Methods were used to construct a dendrogram. According to the dendrogram structure in Figure 3.24, four main groups are defined. Table 3.3 summarizes the correspondence between clustering groups and BioRA zones. It clearly shows that the majority of samples from Zone 2 and Zone 3 belonged to Cluster 1 giving evidence of similar fish composition for samples from these zones. Similarly, most samples from Zone 3S and Zone 4 were grouped under Cluster 3. For Zone 7 (Tonle Sap), almost all the samples belonged to Cluster 2, while almost half of Zone 8 belonged to Cluster 2 with the other half under Cluster 4. This is probably because CKD was assigned to Zone 8 instead of Zone 7.

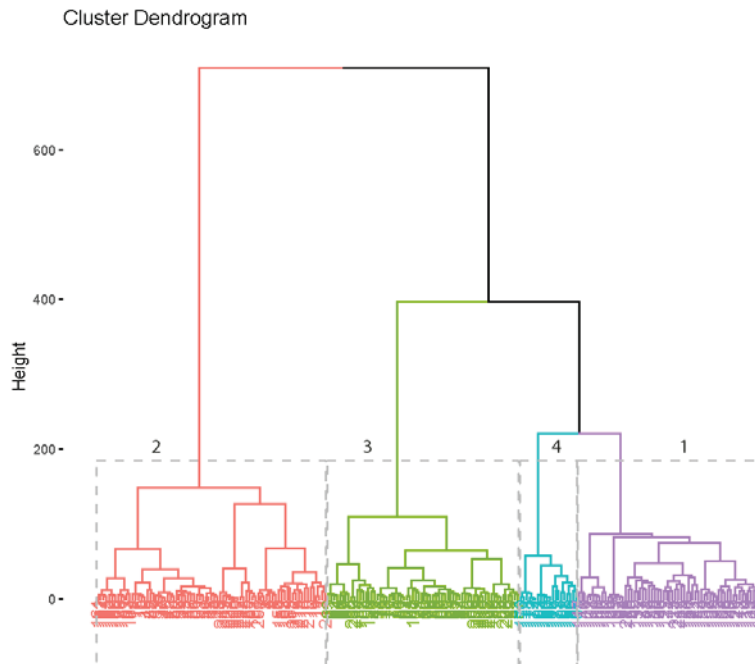


Figure 3.24 Dendrogram of hierarchical clustering of yearly site fish species in the LMB showing the 4 clusters of samples according to the degree of dissimilarity

Table 3.3 Correspondence between BioRA zones of the LMB and results of hierarchical clustering based on yearly fish composition in the LMB during the FADM survey period

BioRA Zones	Hierarchical Clustering Class			
	1	2	3	4
Zone2	23	0	0	0
Zone3	34	11	3	0
Zone3S	0	0	36	0
Zone4	1	1	22	0
Zone7	2	42	3	0
Zone8	3	25	2	20

The indicator species under each group were identified using the “multipatt” function from the “indicpecies” package in R (De Cáceres et al., 2010; De Cáceres & Legendre, 2009; Dufrêne & Legendre, 1997). Group 1, with a total of 63 samples, included samples mostly from Thailand and Lao PDR in the upstream of the LMB, but also a few samples from Cambodia and Vietnam. The Indicator Species value (IndVal) gave six indicator species of this group categorized into three guilds: grey fish (G4), black fish (G6), and estuarine resident (G7) (Table 3.4).

Group 2 accounted for 79 samples: 42 from the Tonle Sap area and the rest from Thailand and Vietnam (**Annex 5**). Fourteen (14) fish species were indicative of this group (Table 3.4) and those species were categorized into five guilds including: rhithron resident (G1), long-distance white fish (G2); short-distance white fish (G3); grey fish (G4); and exotic species (G11). Among these five guilds, G3 was the dominant guild (six species) followed by G11 (four species).

Group 3 consisted of 66 samples, of which 36 were from Zone 3S, and 22 samples from Kratie and Stung Treng (in the upper part of the Cambodia Mekong River). The rest were from the middle part of Lao PDR and Thailand, and the Vietnam Mekong Delta (**Annex 5**). This group had the largest number of indicator species with 57 species (Table 3.4) classified into eight guilds. The dominant guilds were the short-distance white fish (G3) and grey fish (G4) containing 16 and 15 species, respectively.

Finally, group 4 was the smallest with only 20 samples. All samples were mainly taken from VTV and VVL in the Mekong Delta. Nineteen fish species were ecologically characterized in this group (Table 3.4) and classified into five guilds, including a long-distance white fish (G2), estuarine resident (G7), anadromous fish (G8), marine visitor (G10), and exotic species (G11). The dominant guild was G7 (ten species) followed by G10 (five species).

Table 3.4 Indicator species with indicative statistical values and associated probability. See sample membership of each group in Annex 5

Group	Order	Family	Scientific Name	Short Name	Statistical Value	P.value	Guild	IUCN Category
1	Tetraodontiformes	Tetraodontidae	<i>Monotrete leiurus</i>	Moniur	0.348	0.017 *	G7	NA
	Siluriformes	Bagridae	<i>Mystus mysticetus</i>	Myssti	0.88	0.001 ***	G4	LC
	Siluriformes	Siluridae	<i>Ompok hypophthalmus</i>	Ompop	0.494	0.002 **	G4	NA
	Cypriniformes	Cyprinidae	<i>Parachela maculicauda</i>	Parcul	0.458	0.001 ***	G4	LC
	Cypriniformes	Cyprinidae	<i>Puntius brevis</i>	Punevi	0.578	0.001 ***	G6	LC
	Perciformes	Osphronemidae	<i>Trichogaster pectoralis</i>	Tricto	0.587	0.001 ***	G6	LC
2	Siluriformes	Sisoridae	<i>Bagarius</i>	<i>Baggar</i>	0.808	0.001 ***	G1	NT
	Siluriformes	Siluridae	<i>Belodontichthys dinema</i>	<i>Belnem</i>	0.707	0.001 ***	G11	NA
	Cypriniformes	Cyprinidae	<i>Cirrhinus prosemon</i>	<i>Cirose</i>	0.354	0.015 *	G3	NA
	Cypriniformes	Cyprinidae	<i>Cirrhinus cirrhosis</i>	<i>Cirrh</i>	0.467	0.018 *	G11	NA
	Cypriniformes	Cyprinidae	<i>Cyprinus carpio</i>	<i>Cyprpi</i>	0.814	0.001 ***	G11	NA
	Siluriformes	Pangasiidae	<i>Helicophagus leptorhynchus</i>	<i>Helpto</i>	0.493	0.001 ***	G3	DD
	Siluriformes	Bagridae	<i>Hemibagrus nemurus</i>	<i>Hemmur</i>	0.466	0.003 **	G3	LC
	Cypriniformes	Cyprinidae	<i>Hypsibarbus vernayi</i>	<i>Hyprna</i>	0.531	0.001 ***	G3	LC
	Siluriformes	Siluridae	<i>Kryptopterus limpok</i>	<i>Krympo</i>	0.331	0.023 *	G3	NA
	Cypriniformes	Cyprinidae	<i>Labeo erythropterus</i>	<i>Labyth</i>	0.567	0.001 ***	G11	NA
	Siluriformes	Bagridae	<i>Mystus nemurus</i>	<i>Mysmur</i>	0.623	0.001 ***	G3	NA
	Siluriformes	Pangasiidae	<i>Pangasianodon gigas</i>	<i>Pangas</i>	0.453	0.006 **	G2	CR
	Cypriniformes	Cyprinidae	<i>Poropuntius deauratus</i>	<i>Poraur</i>	0.555	0.001 ***	G1	EN
Cypriniformes	Cyprinidae	<i>Sikukia gudgeri</i>	<i>Sikdge</i>	0.679	0.001 ***	G4	DD	
3	Cypriniformes	Cobitidae	<i>Acanthopsis sp.1</i>	<i>Aca.1</i>	0.389	0.044 *	G3	NA
	Cypriniformes	Cobitidae	<i>Acanthopsis sp.5</i>	<i>Aca.5</i>	0.386	0.013 *	G3	NA

Group	Order	Family	Scientific Name	Short Name	Statistical Value	P.value	Guild	IUCN Category
	Pleuronectiformes	<i>Soleidae</i>	<i>Achiroides melanorhynchus</i>	<i>Achlan</i>	0.536	0.001 ***	G7	NA
	Siluriformes	<i>Sisoridae</i>	<i>Bagarius suchus</i>	<i>Bagchu</i>	0.834	0.001 ***	G1	NT
	Siluriformes	<i>Bagridae</i>	<i>Bagrichthys macracanthus</i>	<i>Bagcra</i>	0.922	0.001 ***	G3	NA
	Siluriformes	<i>Bagridae</i>	<i>Bagrichthys obscurus</i>	<i>Bagscu</i>	0.915	0.001 ***	G3	LC
	Cypriniformes	<i>Cyprinidae</i>	<i>Barbonymus schwanenfeldii</i>	<i>Barhwa</i>	0.874	0.001 ***	G4	LC
	Siluriformes	<i>Siluridae</i>	<i>Belodontichthys truncatus</i>	<i>Belunc</i>	0.76	0.001 ***	G3	LC
	Siluriformes	<i>Siluridae</i>	<i>Botia sp. c.f. lecontei</i>	<i>Botcont</i>	0.43	0.005 **	G3	NA
	Perciformes	<i>Channidae</i>	<i>Channa grandinosa</i>	<i>Chaand</i>	0.341	0.029 *	G6	NA
	Perciformes	<i>Channidae</i>	<i>Channa marulioides</i>	<i>Charul</i>	0.619	0.001 ***	G6	NA
	Osteoglossiformes	<i>Notopteridae</i>	<i>Chitala blanci</i>	<i>Chianc</i>	0.88	0.001 ***	G1	NT
	Osteoglossiformes	<i>Notopteridae</i>	<i>Chitala lopis</i>	<i>Chipis</i>	0.654	0.001 ***	G3	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Cirrhinus jullieni</i>	<i>Cirlli</i>	0.885	0.001 ***	G3	DD
	<i>Siluriformes</i>	<i>Clariidae</i>	<i>Clarias meladerma</i>	<i>Clalad</i>	0.472	0.002 **	G6	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Crossocheilus reticulatus</i>	<i>Crotic</i>	0.409	0.009 **	G5	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Cyclocheilichthys lagleri</i>	<i>Cycgle</i>	0.846	0.001 ***	G4	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Cyclocheilichthys apogon</i>	<i>Cycogo</i>	0.771	0.001 ***	G4	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Cyclocheilichthys tapiensis</i>	<i>Cycpie</i>	0.754	0.001 ***	G4	NA

Group	Order	Family	Scientific Name	Short Name	Statistical Value	P.value	Guild	IUCN Category
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Discherodontus ashmeadi</i>	<i>Dishme</i>	0.48	0.005 **	G1	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Hampala dispar</i>	<i>Hamspa</i>	0.849	0.001 ***	G5	LC
	<i>Siluriformes</i>	<i>Bagridae</i>	<i>Hemibagrus sp.</i>	<i>Hemisp</i>	0.353	0.011 *	G3	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Henicorhynchus ornatipinnis</i>	<i>Hennat</i>	0.368	0.020 *	G5	NA
	<i>Siluriformes</i>	<i>Heteropneustidae</i>	<i>Heteropneustes kemratensis</i>	<i>Hetmra</i>	0.377	0.010 **	G6	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Hypsibarbus pierrei</i>	<i>Hyperr</i>	0.925	0.001 ***	G3	DD
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Hypsibarbus suvattii</i>	<i>Hypvat</i>	0.913	0.001 ***	G3	NA
	<i>Siluriformes</i>	<i>Siluridae</i>	<i>Kryptopterus bicirrhis</i>	<i>Krycir</i>	0.433	0.003 **	G3	LC
	<i>Siluriformes</i>	<i>Siluridae</i>	<i>Kryptopterus kryptopterus</i>	<i>Kryypt</i>	0.632	0.001 ***	G3	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Labeo dyocheilus</i>	<i>Laboch</i>	0.706	0.001 ***	G11	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Lobocheilos melanotaenia</i>	<i>Loblan</i>	0.698	0.001 ***	G1	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Luciosoma bleekeri</i>	<i>Luceek</i>	0.786	0.001 ***	G3	LC
	<i>Synbranchiformes</i>	<i>Mastacembelidae</i>	<i>Macrogathus taeniagaster</i>	<i>Maceni</i>	0.478	0.002 **	G6	NA
	<i>Synbranchiformes</i>	<i>Mastacembelidae</i>	<i>Macrogathus semiocellatus</i>	<i>Macmio</i>	0.469	0.003 **	G6	LC
	<i>Cypriniformes</i>	<i>Cobitidae</i>	<i>Misgurnus anguillicaudatus</i>	<i>Misgui</i>	0.413	0.003 **	G11	NA
	<i>Tetraodontiformes</i>	<i>Tetraodontidae</i>	<i>Monotrete cambodgiensis</i>	<i>Monmbo</i>	0.359	0.020 *	G4	LC
	<i>Tetraodontiformes</i>	<i>Tetraodontidae</i>	<i>Monotrete barbatus</i>	<i>Monrba</i>	0.589	0.001 ***	G7	NA

Group	Order	Family	Scientific Name	Short Name	Statistical Value	P.value	Guild	IUCN Category
	<i>Siluriformes</i>	<i>Bagridae</i>	<i>Mystus wolffii</i>	<i>Myslff</i>	0.631	0.001 ***	G4	NA
	<i>Siluriformes</i>	<i>Bagridae</i>	<i>Mystus gulio</i>	<i>Mysljo</i>	0.483	0.002 **	G4	LC
	<i>Siluriformes</i>	<i>Bagridae</i>	<i>Mystus multiradiatus</i>	<i>Myslti</i>	0.58	0.001 ***	G4	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Onychostoma gerlachi</i>	<i>Onyrla</i>	0.423	0.002 **	G1	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Onychostoma fusiforme</i>	<i>Onysif</i>	0.439	0.002 **	G1	LC
	<i>Perciformes</i>	<i>Osphronemidae</i>	<i>Osphronemus exodon</i>	<i>Ospodo</i>	0.583	0.003 **	G1	VU
	<i>Perciformes</i>	<i>Osphronemidae</i>	<i>Osphronemus goramy</i>	<i>Ospram</i>	0.921	0.001 ***	G1	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Osteochilus waandersii</i>	<i>Ostand</i>	0.577	0.001 ***	G1	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Osteochilus microcephalus</i>	<i>Ostcro</i>	0.675	0.001 ***	G5	LC
	<i>Siluriformes</i>	<i>Pangasiidae</i>	<i>Pangasius</i>	<i>Pannga</i>	0.374	0.039 *	G11	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Paralaubuca barroni</i>	<i>Parrro</i>	0.619	0.001 ***	G4	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Probarbus labeaminor</i>	<i>Probean</i>	0.799	0.001 ***	G2	NT
	<i>Siluriformes</i>	<i>Bagridae</i>	<i>Pseudomystus siamensis</i>	<i>Pseame</i>	0.921	0.001 ***	G3	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Puntioplites bulu</i>	<i>Punlu</i>	0.747	0.001 ***	G3	DD
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Puntius binotatus</i>	<i>Punnot</i>	0.445	0.001 ***	G4	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Puntius rhombeus</i>	<i>Punomb</i>	0.48	0.003 **	G4	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Rasbora hobelmani</i>	<i>Rasbel</i>	0.465	0.001 ***	G4	NA
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Rasbora myersi</i>	<i>Rasers</i>	0.559	0.001 ***	G4	NA

Group	Order	Family	Scientific Name	Short Name	Statistical Value	P.value	Guild	IUCN Category
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Rasbora trilineata</i>	<i>Rasili</i>	0.412	0.013 *	G4	LC
	<i>Cypriniformes</i>	<i>Cyprinidae</i>	<i>Rasbora aurotaenia</i>	<i>Rasrot</i>	0.371	0.017 *	G4	LC
	<i>Siluriformes</i>	<i>Siluridae</i>	<i>Wallago leerii</i>	<i>Waleri</i>	0.608	0.001 ***	G11	NA
4	<i>Siluriformes</i>	<i>Ariidae</i>	<i>Arius maculatus</i>	<i>Aricul</i>	0.982	0.001 ***	G7	NA
	<i>Siluriformes</i>	<i>Ariidae</i>	<i>Arius malacanthus</i>	<i>Arilac</i>	0.341	0.019 *	G2	NA
	<i>Batrachoidiformes</i>	<i>Batrachoididae</i>	<i>Batrachomoeus trispinosus</i>	<i>Batisp</i>	0.816	0.001 ***	G7	NA
	<i>Clupeiformes</i>	<i>Engraulidae</i>	<i>Coilia macrognathos</i>	<i>Coicro</i>	0.853	0.001 ***	G10	NA
	<i>Clupeiformes</i>	<i>Engraulidae</i>	<i>Coilia lindmani</i>	<i>Coindm</i>	0.92	0.001 ***	G7	LC
	<i>Characiformes</i>	<i>Characidae</i>	<i>Colossoma macropomum</i>	<i>Colcro</i>	0.819	0.001 ***	G11	NA
	<i>Pleuronectiformes</i>	<i>Cynoglossidae</i>	<i>Cynoglossus microlepis</i>	<i>Cyncro</i>	0.819	0.001 ***	G10	LC
	<i>Perciformes</i>	<i>Polynemidae</i>	<i>Eleutheronema tetradactylum</i>	<i>Eletra</i>	0.703	0.001 ***	G7	NA
	<i>Perciformes</i>	<i>Gobiidae</i>	<i>Glossogobius aureus</i>	<i>Gloreu</i>	0.656	0.001 ***	G7	LC
	<i>Siluriformes</i>	<i>Ariidae</i>	<i>Hemarius stormii</i>	<i>Hemorm</i>	0.833	0.001 ***	G7	NA
	<i>Perciformes</i>	<i>Centropomidae</i>	<i>Lates calcarifer</i>	<i>Latlca</i>	0.634	0.001 ***	G10	NA
	<i>Mugiliformes</i>	<i>Mugilidae</i>	<i>Mugil cephalus</i>	<i>Mugpha</i>	0.662	0.001 ***	G10	NA
	<i>Siluriformes</i>	<i>Ariidae</i>	<i>Netuma thalassinus</i>	<i>Netala</i>	0.737	0.001 ***	G7	NA
	<i>Perciformes</i>	<i>Sciaenidae</i>	<i>Nibea soldado</i>	<i>Niblda</i>	0.913	0.001 ***	G10	NA

Group	Order	Family	Scientific Name	Short Name	Statistical Value	P.value	Guild	IUCN Category
	<i>Siluriformes</i>	<i>Ariidae</i>	<i>Osteogeneiosus militaris</i>	<i>Ostlit</i>	0.999	0.001 ***	G7	NA
	<i>Siluriformes</i>	<i>Pangasiidae</i>	<i>Pangasius krempfi</i>	<i>Panemp</i>	0.833	0.001 ***	G8	VU
	<i>Siluriformes</i>	<i>Pangasiidae</i>	<i>Pangasius polyuranodon</i>	<i>Panlyu</i>	0.782	0.001 ***	G11	LC
	<i>Siluriformes</i>	<i>Plotosidae</i>	<i>Plotosus canius</i>	<i>Ploniu</i>	0.94	0.001 ***	G7	NA
	<i>Perciformes</i>	<i>Polynemidae</i>	<i>Polynemus longipectoralis</i>	<i>Polngi</i>	0.843	0.001 ***	G7	NA

Note:

See sample membership of each group in Annexe 5.

The PCA conducted with a species matrix (Hellinger transformed) of the 247 species over 228 year-site samples is shown in Figure 3.25. It clearly shows the overlap between Zone 3S and Zone 4 (strong overlap of ellipsoids) in the positive coordinate of axis 1. This zone was characterized by very rich characteristic species (red arrows). Among them, the most dominant were *Hemibagrus spilopterus*, *Bagrichthys*, *Hampala dispar*, *Bagrichthys obscurus*, *Scaphognathops stejneri*, *Osphronemus goramy*, *Channa striata*, *Cirrhinus jullieni*, *Cyclocheilichthys lagleri*, *Chitala blanci* and *Pseudomystus siamensis*.

In contrast to this group, Zone 8 (Mekong Delta) is in the negative coordinate of axis 1 (Figure 3.25) with no species contributing significantly to this group; this is in contrast to the species in red text affirming the absence or scarcity of these species in the Delta.

Zone 2 and part of Zone 3 belong to the negative coordinate of axis 2 (Figure 3.25). This group is characterized by species with green arrows. The main species are: *Hemibagrus wyckioides*, *Cyprinus carpio*, *Belodontichthys dinema*, *Bagarius yarrell*, *Hypsibarbus wetmorei*, *Bagarius* and *Mekongina erythrospila*.

Tonle Sap stations (Zone 7) were linked to the positive coordinate of axis 2, characterized by two main fish species, *Trichogaster trichopterus* and *Osteochilus hasselti* (Figure 3.25).

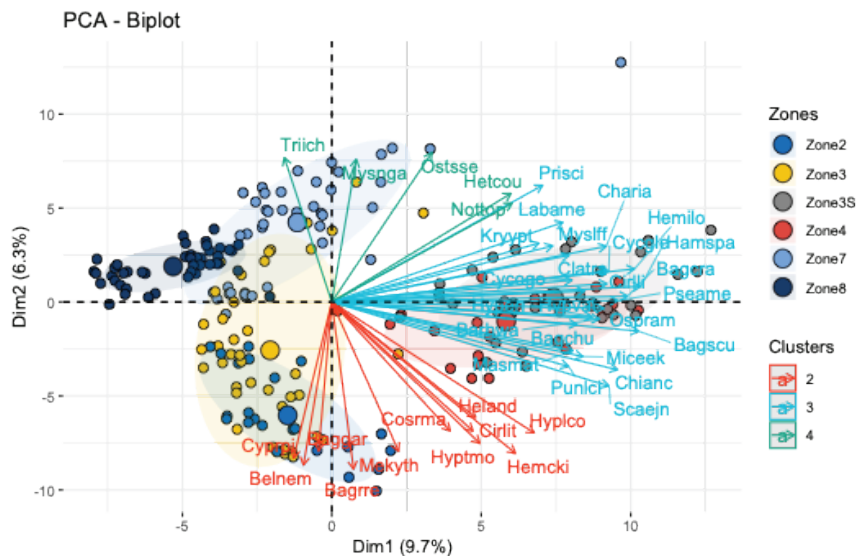


Figure 3.25 PCA on fish community results showing samples by zones (different colours)

Note:

The big dot represents the centroid of each BioRA zone. The ellipsoid (same colour as

the centroid) corresponds to the 1SD of distribution limit for samples in each zone. Only the 40 species that contributed most are shown (the 207 other species were ignored to ensure visibility of the figure). The colours correspond to the k-means clustering of the species in 3 groups. For the names of the species, refer to **Annex 4**

Last, the PCA revealed that Zone 3 samples were widely distributed since this zone composes of floodplain, mainstream and tributary habitats/stations at the upper and middle parts of the river. Obviously, it overlaps with Tonle Sap (Zone 7) and the upper part of the river (Zone 2).

3.4.2 Relationship between fish diversity and abundance with key environmental factors in the LMB

Water Level

The responses of fish species richness and diversity to water level fluctuation in the LMB are shown in Figure 3.26. The Loess regression fitting shows that richness, diversity indices and evenness increased with water level increases. However, the total relative abundance of fishes in the LMB had an inverse trend; i.e. decreasing relative abundance for high water levels. This was likely due to low fish densities, since fish were widely distributed by seasonal floods to floodplains and inundated forests, which makes them difficult to capture (Ngor, Grenouillet, et al., 2018).

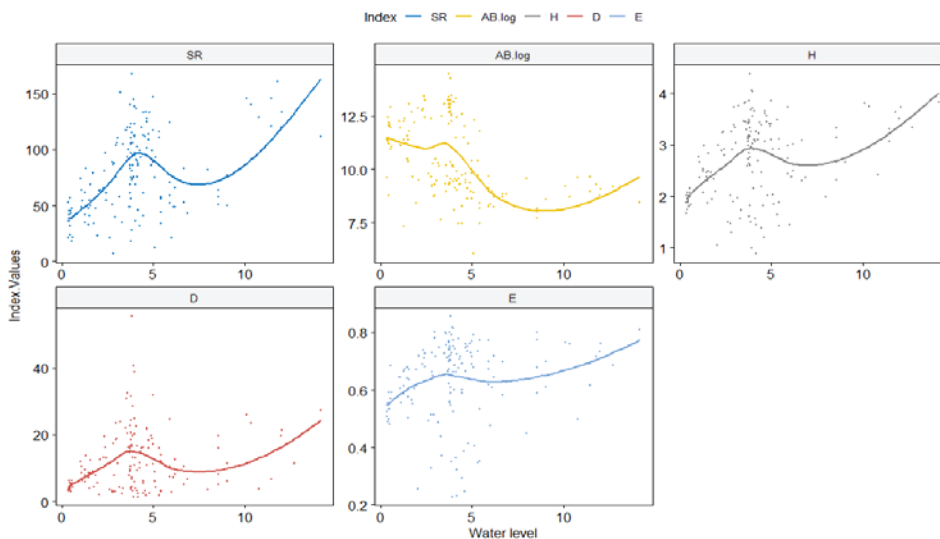


Figure 3.26 Relationship between water level and fish richness, diversity and abundance fitted by Loess curves

Note:

SR: Species richness, AB.log: log of Abundance, H: Shannon-Wiener index, D: Inverse Simpson index, E: Equitability (Evenness)

Water temperature

Figure 3.27 shows similar trends for the positive response of fish richness, diversity and evenness to water temperature; i.e. increasing response with increasing water temperatures. Since water temperature has a negative correlation with water level (Figure 3.30), at the low water levels (which have high temperatures), fish were likely not widely dispersed which made them easy to capture (Ngor, Grenouillet, et al., 2018).

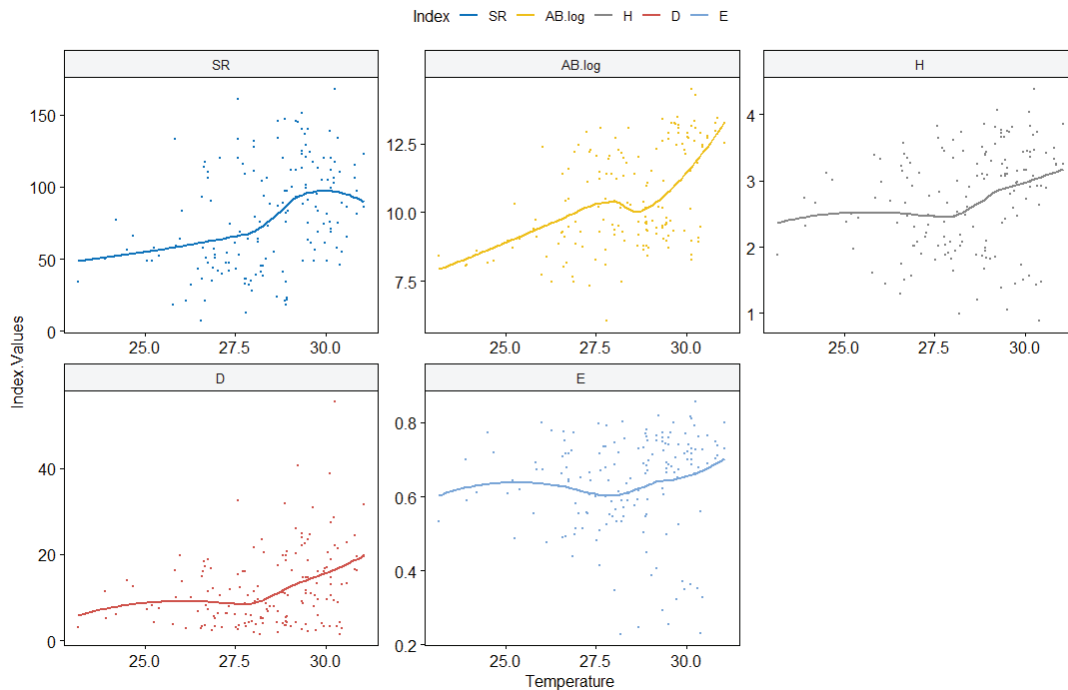


Figure 3.27 Relationship between water temperature and fish richness, abundance and diversity indices fitted by Loess curves

Note:

SR: Species richness, AB.log: log of Abundance, H: Shannon-Wiener index, D: Inverse Simpson index, E: Equitability (Evenness)

Dissolved oxygen

In relation to Dissolved Oxygen (DO), Figure 3.28 clearly shows a decreasing trend of fish abundance for the high level of DO, whereas the other indices show an increasing trend. The correlation coefficients for Species Richness and Shannon Wiener indices were stronger than the Simpson and Evenness indices. Since DO has a positive correlation with WL (Figure 3.30), a downward trend of fish abundance during high DO is because fish are difficult to capture when water levels are high (Ngor, Grenouillet, et al., 2018).

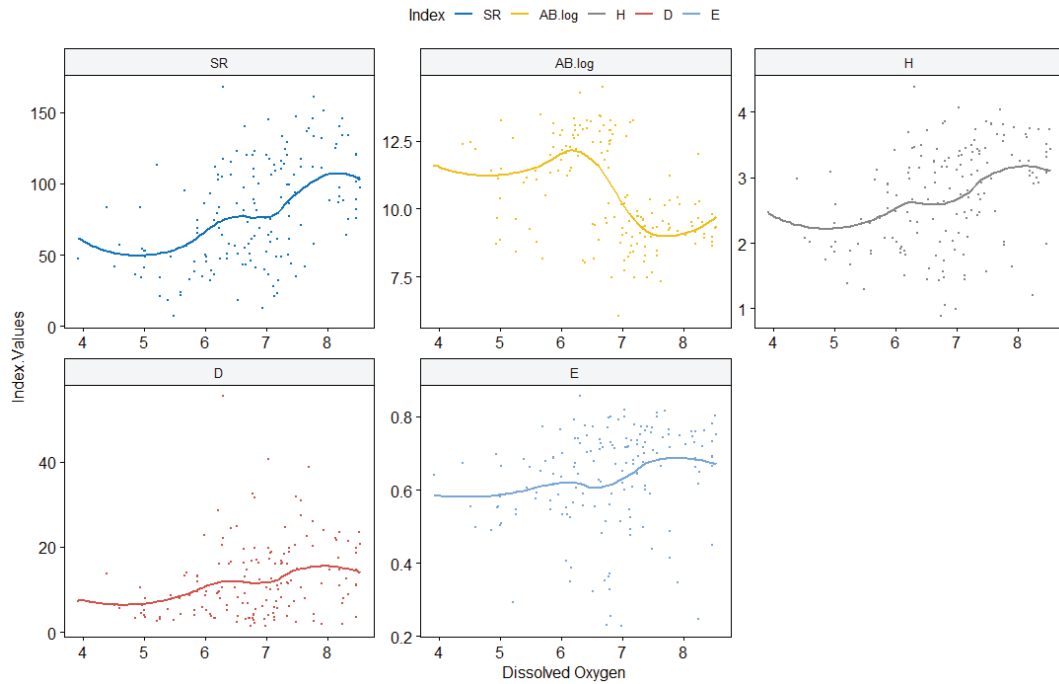


Figure 3.28 Relationship between dissolved oxygen and fish richness, abundance and diversity indices fitted by Loess curves. SR: Species richness, AB.log: log of Abundance, H: Shannon-Wiener index, D: Inverse Simpson index, E: Equitability (Evenness)

pH

The neutral pH environment (around 7.0) gave the highest richness and abundance for both diversity indices (Shannon Wiener and Simpson). However, equitability evenness seemed independent regarding the pH level (Figure 3.29).

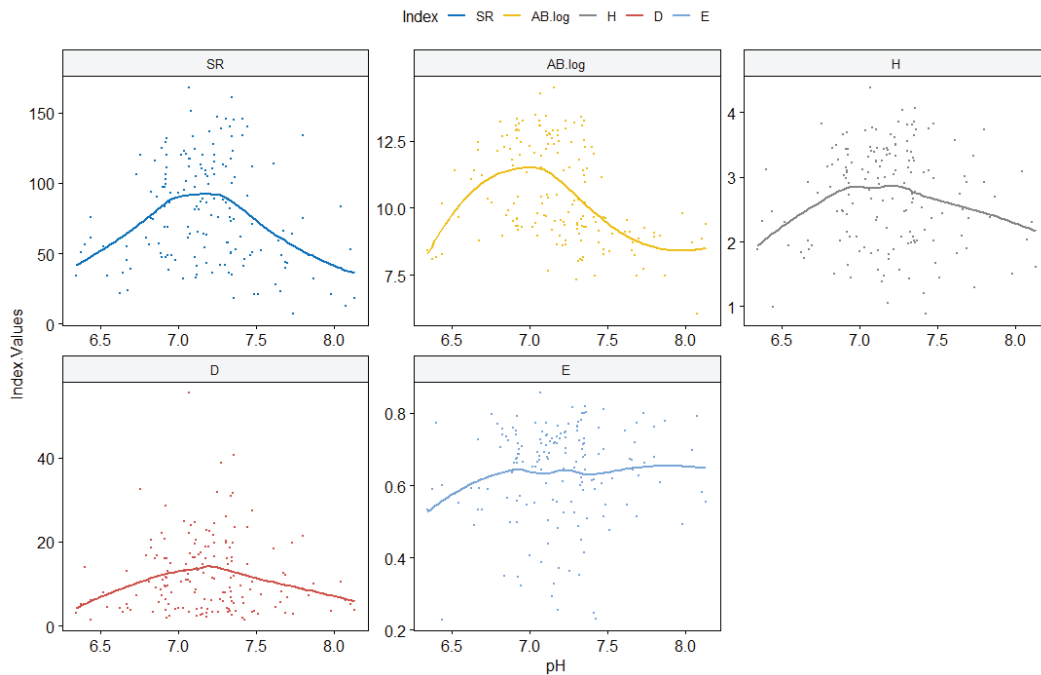


Figure 3.29 Relationship between pH and fish richness, abundance and diversity indices fitted by Loess curves. SR: Species richness, AB.log: log of Abundance, H: Shannon-Wiener index, D: Inverse Simpson index, E: Equitability (Evenness)

The relationship between both environmental factors and fish composition as well as the correspondence with the samples from different stations and sampling periods are shown in Figure 3.30. Dissolved Oxygen (DO) is positively correlated with Water Level (WL) and are more or less independent from the water temperature (orthogonal position). The highest DO and WL are in the upper part of Cambodia (Zone 4 and Zone 3S). The most abundant species linked to these 2 parameters are *Hypsibarbus malcolmi*, *Bagarius yarrelli*, *Hemibarbus wyckioides*, *Helicophagus waandersii* and *Puntioplites falcifer*. In contrast, the samples with low DO and WL are located in Viet Nam (Zone 8) and the most abundant species are *Coilia lindmani*, *Arius maculatus*, *Mystus mysticetus*, *Puntioplites proctozysron* and *Labiobarbus lineata*. Tonle Sap Lake stations (Zone7) had the highest temperature and the most important species are *Osteochilus hasselti*, *Labiobarbus siamensis*, *Paralabuca typus*, and *Henicorhynchus lobatus*. Zone2 and Zone3 from Lao PDR and Thailand had lower temperature. The most abundant species are *Bagarius yarrelli*, *Poropuntius deauratus*, *Cyprinus carpio*, *Hypsibarbus vernayi*, *Pangasius macronema*, and *Mystus nemurus*. The pH, represented by a short arrow in the figure, contributed weakly to the Redundancy Analysis (RDA) and therefore made interpretation impossible.

4

DISCUSSIONS

4.1 FISH DIVERSITY IN THE LMB

Fish species richness in the Mekong River is ranked as one of the world's highest (Chea et al., 2016; Guégan et al., 1998; Kong et al., 2017; Ngor, Oberdorff, et al., 2018; Winemiller et al., 2016). The LMB accounts for a very low rate of exotic species; 99% of its fish species are indigenous with most enjoying a 'least concerned' conservation status. Endangered species make up around 2%, threatened species about 10%, and vulnerable species around 3%. The LMB is considered a healthy ecosystem compared to other rivers (Chea et al., 2017; Valbo-Jorgensen et al., 2009). Among the 571 fish species caught by the MRC FADM programme over the past twelve years, the generalist fishes (G5) were dominant in terms of fish abundance followed by the floodplain spawners or grey fishes (G4) and the floodplain residents or black fishes (G6). However, for the relative biomass, it was observed that the main-channel spawners or short-distance white fishes (G3) were the dominant guild followed by generalist fishes (G5).

It is very well known that the number of fish species increases along an upstream-downstream gradient in terms of richness and fish assemblage composition (Chea et al., 2017; Grenouillet et al., 2004; Nuon et al., 2020). In the LMB, around 50 species were recorded in the upstream in Lao PDR (Zone 2) with the number increasing to more than 100 species around the Khone falls area (Zone 4). Zone 3S had very high richness, with 300 species, while the Tonle Sap Lake (Zone 7) and the Mekong Delta (Zone 8) had very high abundance due to the flood-pulse system. Zone 3S also had the highest diversity and evenness indices. *Henicorhynchus siamensis* and *Henicorhynchus lobatus* were the most abundant species, while *Henicorhynchus siamensis* and *Puntioplites proctozysron* had the highest biomass or catch in the LMB.

The high diversity and abundance of fish species found in the Tonle Sap area (Zone 7) is due to the river-lake flood-pulse system, which is in agreement with results obtained in most other tropical riverine ecosystems (Chan et al., 2017; Connell, 1978; Kong et al., 2017; Nuon et al., 2020); for example, the high biodiversity of riverine fishes in Lake Malawi. Similarly, most of the fish species caught in the Kisian and Awach Seme rivers also constitute the ichthyofauna community of Lake Victoria (e.g. 22 species) suggesting a close link between the rivers and the lake (Adaka et al., 2014). Campbell, Say, and Beardall (2009) classify Tonle Sap as the heart of the Mekong river system supporting the highest level of fisheries activities (Hortle, 2009; Kong et al., 2017). The low diversity and evenness in the Mekong Delta (Zone 8) can be explained by the strong impact on this zone from high population density, extensive agricultural activities (e.g. rice culture), and intensive aquaculture production (Campbell, 2012; Chan et al., 2017; Chea et al., 2016).

Temporally, both richness and abundance increased during the survey period from 2007 to 2018 in Tonle Sap (Zone 7) and in the Mekong upstream in Southern Lao PDR and Thailand (Zone 3), leading to the high diversity of these areas, which corresponded to an increase in sampling effort. This reflects the fact that Tonle Sap is one of the world's most diverse and productive fisheries (~400,000 tons annually), providing food security and livelihoods for millions of people in the region (Baran et al., 2014; Campbell et al., 2009; Chan et al., 2017; Kong et al., 2017; Ngor, Grenouillet, et al., 2018; Ngor, McCann, et al., 2018; Ngor, Oberdorff, et al., 2018).

However, richness and abundance decreased in Zone 8 (Mekong Delta) and Zone 4 (Mekong at the 3S confluence) due to high human impacts in these areas; for example, intensive agriculture and aquaculture in the Mekong Delta (Campbell, 2012) and hydropower dams in the upstream 3S and Mekong mainstream (Stone, 2016).

The Local Contribution for Beta Diversity (LCBD) showed the spatio-temporal changes of diversity in the LMB, which were higher in the Mekong Delta (Zone 8) and the upper part of the Mekong River in Lao PDR and Thailand (Zone 2 and Zone 3). Lower values of LCBD in the lowlands of the LMB below the Khone Falls and Tonle Sap confirmed that fish communities in these areas were quite stable during the FADM survey period. Five species contribute strongly to the change in diversity during this period (highest SCBD values): one black fish (*Anabas testudineus*) and four white fish (*Henicorhynchus siamensis*, *Henicorhynchus lobatus*, *Coilia lindmani*, and *Sikukia gudgeri*).

4.2 STATUS OF FISH CATCHES IN THE LMB

Most of the LMB zones are more or less under stress (negative values of W), except Zone 3S with positive values of W (0.025) testifying that this area was not under stress during the FADM period of 2007–2018. This might be because the Sekong and Srepok rivers flow through large protected areas (e.g. Lumphat, Mondulkiri and Yok Don protected areas) (MRC, 2011) which allows fish to grow to their natural size and biomass without disturbance from fishing. This finding is consistent with prior studies conducted in the Philippines and Bangladesh (Ali et al., 2009; Anticamara et al., 2010). However, this situation can change in the near future due to the number of dams

operating in the upstream of these 3 river systems (Ngor, Legendre, et al., 2018).

Overall, the fish community of the LMB (in terms of abundance and biomass) was moderately disturbed ($W=-0.03$). This might stem from numerous anthropogenic pressures such as hydropower dam, agriculture activities, illegal fishing and sand mining. The quarterly interviews between the national fisheries researchers and the participating fishers during the logbook collection provided information about the anthropogenic pressures on fish catches. For example, in Lao PDR, participating fishers acknowledged that it is very difficult to catch fish and they have to spend more time and effort than before. They perceived that some fishing grounds have also changed due to climate change, the cumulative impacts from development projects, and agriculture farming, all of which affect water levels and discharge. The fishers stated that the changing water levels in the dry season at the north monitoring stations (LHT, LDK, LPN, LOX, LPB, LPO, LXB and LNS) in Bokeo, Udomxay, Luangprabang and Xayaburi provinces are partly due to dam development. Also, water from the wet season is very low compared to previous years. This change has allowed fishers to catch more brood stock inhabiting shallow water; however, the fish population may decline in the future.

Another threat to fish catches is the use of illegal fishing gear such as electro fishing and poison, which are still widely used in the northern monitoring stations. If compared to the stations in Vientiane (LVT), illegal activities are fewer since the station is located along the Mekong River near the village. Likewise, the participating fishers in LBX station of Borikhamxay province also reported that illegal fishing occurred not only in the mainstream but also in tributaries, rice fields and wetlands. Although such fishing gear is prohibited by law, it is still used due to a lack of capacity and funding to educate fishers and enforce the law. Moreover, sand mining has been practiced in the downstream Thamuang monitoring station (LVT) in Vientiane. However, the adverse impacts on fish communities, fish catches or fish production are unclear since there have not been any studies on this issue in the region. The participating fishers in Vientiane always refer to an increase in the number of fishers, the use of advance fishing gear and climate change when asked about the factors that influence their catch.

Similar to Lao fishers, the fishers in Thailand from all monitoring stations mentioned that they find it relatively difficult to catch fish and have to spend more time and effort than before. They inferred that it might be an impact from the operation of Xayaburi dam because of the changed condition in certain fishing grounds; for example, very clear water, lots of algae and extreme water shortages. Fishers at TCK, TUT and TKR in Loei, Nakhonphanom, and Ubon Ratchathani provinces noticed changing water levels in the dry season as well as a relatively short flood season, which are partly due to development projects on the Mekong River. Fishers in TUT station stated that sand mining in both Thailand and Lao PDR have negative effects on fish catches and fish production, and also cause erosion and landslides. In addition to the abovementioned threats, fishers reported that illegal fishing has occurred in TKR, TNK and TSK. Also, an increase in the use of insecticide and fertilizer in TSK at the Songkhram River has caused an adverse effect on water quality (algae bloom) and in turn aquatic animals.

The participating fishers in Cambodia similarly reported that their fish catch has decreased and that the size of fish that they catch reduced. They surmised that the change in fish catch and composition may be a result of development projects, illegal fishing and sand mining. The fishers at all monitoring stations in Cambodia reported that the water level fluctuation is not the same as before (natural pattern). They also stated that illegal fishing has occurred in their fishing grounds. The fishers in CPS, CSK, CSP and CSS affirmed that sand mining has been conducted in a channel/tributary of Tonle Sap Lake as well as in Sekong, Srepok and Sesan rivers. Many researchers have shown that sand mining can destroy the aquatic plants and benthic animals that are food for many fishes (Boyd et al., 2005; Duan et al., 2008; Pitchaiah, 2017) and also impact on eggs and larvae (Wenger et al., 2017).

In Vietnam, most participating fishers (90%) reported that their catches have declined over recent years. They also reported that fish size has decreased and fish species composition has changed. Fishers perceived that there are a number of threats (e.g. climate change, population growth, pollution, overfishing, sluice gates and hydropower dams) leading to a decline in fish catches, but the key drivers are (i) the change in flood regime which plays an important role in sustaining fish populations. It has been noticed that water levels in the upstream stations (VAP, VTS and VCM) in An Giang province in the Mekong Delta is very low in comparison with previous years. The fishers found that the onset of flood season is later and the flood period relatively short. Consequently, the fishers at the downstream stations (VTV, VLT and VVL) in Vinh Long and Tra Vinh provinces observed high seawater intrusion due to lower freshwater levels; and (ii) population growth is posing a major threat to fishery resources since the demand for fish has also increased. That is why fishers intend to use modern fishing gear.

4.3 FISH ASSEMBLAGE AND THE INFLUENCE OF ENVIRONMENTAL FACTORS

The similarity of the fish communities in the LMB enables 4 clusters to be defined: i) the LMB upstream community from the China-Lao PDR border to Khone Falls (Zone 2 and Zone 3), with 12 indicator species; ii) the cluster downstream of Khone Falls with the complex 3S rivers (Zone 4 and Zone 3S), with 7 indicator species; iii) the cluster of the Tonle Sap system (Zone 7) and some samples from the Mekong Delta (Zone 8), with 52 indicator species; and iv) the specific cluster of the Mekong Delta, with 18 indicator species mostly from estuarine species. Classification in the LMB clearly showed zonation from up to downstream according to fish community composition similar to temperate rivers (Lasne et al., 2007). However, the LMB is characterized by an impressive number of fish species in each zone linked to the high diversity of the Mekong ecosystems compared to other tropical rivers (Englmaier et al., 2020).

The correspondence between fish distribution and environmental factors has been documented by several researchers (Chan et al., 2017; Chea et al., 2017; Ngor, Grenouillet, et al., 2018; Pool et al., 2019) and they confirmed longitudinal changes of fish assemblages along an upriver-downriver gradient (Lasne et al., 2007; Poff & Allan, 1995). In the LMB, fish richness and diversity

increase with water levels, but maximal abundance occurs during the low water-level period. Abundance becomes lower during the very high-water level period due probably to the higher dispersion of fishes and a decrease in catch efficiency (Ngor et al., 2018). Poff and Allan (1995) state that fish assemblage is strongly linked to hydrological variability.

All diversity and abundant indices respond positively to increases in water temperature. It is well known that temperature is an important factor controlling fish diversity in streams (Chu et al., 2008). Leuven et al. (2011) stresses that rising water temperature increases fish richness in European rivers, but mostly benefits exotic species due to their high tolerance for temperature variation compared to native species. In South America, Cussac and colleagues mentioned that river and marine fish diversity is driven by temperature. In the LMB, temperature correlated positively and significantly with all diversity indices, with a higher correlation for species richness and abundance compared to other indices.

Dissolved oxygen is an important parameter controlling fish communities. Howell and Simpson (1994) show that both abundance and diversity decreased markedly with bottom DO dramatically declining to lower than 2 mg/l. Of the 18 species examined, 15 were found to occur at the sites with DO > 3 mg/l compared to sites with < 2 mg/l. In West-Africa, Kouamélan, Teugels, N'Douba, Gooré Bi, & Koné (2003) showed a significant correlation between species distribution and environmental factors with oxygen an important variable influencing fish distribution. Several research papers showed the important role of DO on freshwater fish abundance and diversity (Justus et al., 2014; Lima-Junior et al., 2006; Rocha et al., 2009). In the LMB, richness and diversity increased with high DO (which has a positive correlation with water levels), but abundance decreased because fish were widely dispersed and difficult to capture (Ngor et al., 2018).

It is well known that the acidity and alkalinity of the water is an important factor for freshwater fish development (detailed in the European Inland Fisheries Advisory Commission Working Party on Water Quality Criteria for European Freshwater Fish, 1969). The pH range which is not directly lethal to fish ranges from 5–9. The pH values lower than 5 and higher than 10 are considered lethal for fish although some species may be acclimated outside of this range. The changes of pH induce disruption of the chemosensory abilities of fish populations and modify the association preference in fish communities (Kleinhappel et al., 2019). Several researchers have shown the important role of pH for fish development (Mount, 1973; Rask, 1984). In the LMB, pH values ranged in the lethal scale for fish development from 6 to 8.5. The maximal richness, abundance and diversity in the LMB appears linked to the neutral pH values, at around pH 7.

The distribution and abundance of fish communities are governed by various environmental factors (Kwon et al., 2012, Sá-Oliveira et al., 2016). In the LMB, Redundancy Analysis (RDA) showed the correlation between Dissolved Oxygen (DO) and Water Level (WL) especially in the lower part of the LMB (except for the Mekong Delta). The associated species were white species (*Hypsibarbus malcolmi*, *Bagarius yarrelli*, *Hemibagrus wyckioides*, *Helicophagus waandersi*, and *Puntioplites falcifer*). In contrast, the low DO and lower WL at the Mekong Delta were good habitats for black or grey fish species, e.g. *Coilia lindmani*, *Arius maculatus*, *Mystus mysticetus*, *Puntioplites proctozysron*, and *Labiobarbus lineata*. In the LMB, the temperature was independent

of DO and WL. The higher temperature area in the LMB includes the Tonle Sap stations and some parts of the lower reaches of the Basin (VAP and VCM), while the lowest temperature area is at the upstream stations in Lao PDR and Thailand (Zone 2 and Zone 3). The fish community characterized by the higher temperatures were *Labiobarbus siamensis*, *Osteochilus hasselti*, and by lower temperatures *Poropuntius deauratus* and *Bagarius yarrelli*. Canonical analysis (RDA) showed that pH did not contribute to the LMB's fish community assemblage.



5

CONCLUSIONS

This study is the first ever large scale study that considers both spatial and temporal variations of fish abundance and diversity in the LMB using the MRC's long-term fisheries monitoring data. In this section, we conclude our findings in relation to the specific objectives of the study as follows:

- 1. Contribution of fish species and guilds to the fisheries of the LMB:** The MRC-FADM programme in the LMB from 2007 to 2018 found 617 fish species¹ belonging to 21 orders and 80 families. Cypriniformes and Cyprinidae were the dominant order and family, respectively. Over the monitoring period, the catch (i.e. number of individuals or relative abundance and relative biomass) was driven by small-sized or short-lived fish species, such as *Henicorhynchus* (*H. siamensis* and *H. lobatus*). Moreover, the LMB was dominated by the generalist fishes (G5), the main-channel spawners or short-distance white fishes (G3), the floodplain spawners or grey fishes (G4) and the floodplain residents or black fishes (G6). Regarding conservation status, most fish caught were under the 'least concerned' status. The LMB accounted for a very low rate of exotic species (<1% of abundance or about 1.5% of biomass).
- 2. The status and trends of fish catches in the LMB:** At the country level, Cambodia had an upward trend for fish catch rates at most of the FADM stations (eight out of 11 stations). In Lao PDR, the catch rate appeared to have dropped slightly since the fish catch rate showed a decreasing trend at two of four stations. Unlike Lao PDR, the catch rate in Thailand increased slightly as four out of five stations showed increasing and stable trends. For Viet Nam, the trend decreased as three of the five stations showed the downward trends. In regard to the BioRa zones, the trend for the catch rates decreased at Zone 2, Zone 8 and Zone 3S, with the rest showing an increasing trend. Regarding the status of the fish community, all zones appeared to be stressed or disturbed, except Zone 3S. Moreover, the study

1 Note that 617 species is the number derived from the records of all 38 monitoring stations from 2007 to 2018 and 571 species derived from the 25 stations in the monitoring period.

suggests that the ABC curves of the fish community in the LMB were moderately disturbed.

- 3. *Spatial and temporal changes in fish diversity and abundance:*** It is evident that the lower part of Viet Nam (Mekong Delta) had high species turnover across the survey period. This was the same for certain stations in the upstream parts of the river in Thailand and Lao PDR. Yet, the fish species composition at Tonle Sap and 3S were quite stable. Spatially, the study confirms that the upper and lower parts of the LMB (Zone 2 and Zone 8) had the lowest species richness, while the north-eastern part of Cambodia (Zone 4) had the highest. Regarding relative fish abundance, the Tonle Sap Lake and River (Zone 7) had the highest fish abundance, while the upper part of the LMB (Zone 2) showed the lowest abundance. Temporally, trends of species richness and abundance in areas near confluences with Xe Bang Fei and Nam Kam as well as the Tonle Sap area (Zone 3 and Zone 7) moved upwards, but those of the north-eastern part of Cambodia and the Viet Nam Mekong Delta (Zone 4 and Zone 8) moved downwards. In relation to spatial changes in species diversity indexes, 3S was found to be the highest zone for the three indexes used. The lowest zone was the Viet Nam Mekong Delta (Zone 8). The temporal variation of these three indexes occurred, but with no significant differences.
- 4. *Fish community patterns and their relationship with key environmental factors:*** Fish communities in the LMB were classified into four groups based on their similarity. Cluster 1 mostly contained fish species at the upstream of the LMB, where most parts of the river border Lao PDR and Thailand. Also, six indicator species found in this cluster belonged to three guilds: grey fish (G4), black fish (G6) and estuarine resident (G7). Cluster 2 was mostly made up by the floodplain, tributary and canal fish communities at Tonle Sap Lake, the middle section of the LMB, and Viet Nam's Mekong Delta. This cluster was also home to 14 indicator species with five guilds, with the dominant one a short-distance white fish (G3). Cluster 3 mostly comprised fish communities at the north-eastern part of Cambodia with 57 indicator species and two dominant guilds: the short-distance white fish (G3) and grey fish (G4). The last cluster mainly consisted of fish communities at the stations adjacent to the sea with 19 indicator species, divided into five guilds. Estuarine resident (G7) and marine visitor (G10) were the dominant guilds in this cluster. In the LMB, fish diversity and richness had a significant link to temperature, Dissolved Oxygen (DO) and a neutral pH of around 7. This study indicated that fish communities in Zones 4 and 3S at the upper part of Cambodia are associated with high DO and WL, in contrast to that of Zone 8 in the Viet Nam Mekong Delta. Moreover, fish communities in Zone 7 at Tonle Sap Lake and some parts of Zone 8 had a strong relationship with high temperatures in contrast to those of Zone 2 and Zone 3 in Lao PDR and Thailand with lower temperatures and higher pH levels.

6

RECOMMENDATIONS

- Fish diversity and abundance needs to be preserved to sustain food supplies for millions of people living in the LMB.
- A number of hydropower projects have been built and proposed in the mainstream. Also, fisheries monitoring stations are not located close to the project sites, which makes it difficult to develop a baseline before the hydropower projects are operational. Thus, it is critical to set up more monitoring stations close to dam sites. This will enable hydropower projects in the Mekong mainstream to be assessed in terms of their impact. MRC's Joint Environmental Monitoring Guideline should be consulted when selecting monitoring stations close to dam sites.
- As mentioned earlier, data has been collected by participating fishers who use multiple types of gear to catch fish. Thus, it is suggested that standardized gear, for example multiple panel gillnets, be used in the FADM programme to strengthen results.
- The results of ABC curves showed that fish communities in almost all zones were disturbed, so it is crucial that the governments of the four MCs jointly enforce fisheries laws and restore key habitats and connectivity within and between zones. Importantly, integrated river management plans should consider new threats resulting from hydropower development.
- Transboundary Fish Protected Areas (PAs) or transboundary Fish Conservation Zones should be set up to maintain biodiversity in the LMB, especially during spawning, egg and larvae development periods.
- As the current study mainly focuses on the current climate regardless of climate change, a study on the impact of climate change on fish abundance and diversity in the LMB should be conducted.
- A study on the impact of sand mining on fish populations and fisheries in the LMB should be carried out to assist policy makers in formulating policy to minimize the impact of sand mining.

GLOSSARY

Abundance	is a measure of how many fish are in a population or a fishing zone.
Alien species	A species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities (also known as an exotic or introduced species).
Analysis of covariance (ANCOVA)	is a general linear model which blends ANOVA and regression. ANCOVA evaluates whether the means of a dependent variable are equal across levels of a categorical independent variable often called a treatment, while statistically controlling for the effects of other continuous variables that are not of primary interest, known as covariates or nuisance variables.
Analysis of variance (ANOVA)	A statistical procedure for analysing experimental data. It is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyse the differences among group means in a sample. ANOVA provides a statistical test of whether two or more population means are equal, and therefore generalizes the t-test beyond two means.
Aquaculture	the farming of freshwater and saltwater organisms including molluscs, crustaceans and aquatic plants.
Average	An ambiguous term. It often denotes the arithmetic mean, but it can also denote the median, the mode, the geometric mean, and weighted means, among other things. Beware if something reports "the average" without making it clear which average.
Biodiversity	is the variation of life forms within an area. In the context of fisheries the number and variety of organisms found within a fishery.
Biodiversity indices	are measures of species diversity expressed as ratios between numbers of species and — importance values (numbers, biomass, productivity and so on) of individuals. The term may also refer to genetic diversity and diversity of habitats or communities
Biomass	the total weight of a fish species in a given area. Can be measured as the total weight in tons of a stock in a fishery, or can be measured per square metre or square kilometre.
Brackish water	water that has more salinity than fresh water, but not as much as seawater. It may result from mixing seawater with fresh water, as in delta or estuaries.
Canonical Correlation Analysis or CCA	The purpose of CCA is to explain or summarize the relationship between two sets of variables by finding a linear combinations of each set of variables that yields the highest possible correlation between the composite variable for set A and B

Chi-square Statistic.	The chi-square statistic is used to measure the agreement between categorical data and a multinomial model that predicts the relative frequency of outcomes in each possible category.
Classification:	the process of simplifying complex, and sometimes continuous, data and information and converting it into practical categories to make it more usable. Through classification, attributes can be classified into categories, independent of one another, enabling synthesis of the parts (components) and processes of different ecosystems
Climate change	variation in the Earth's global climate or in regional climates over time. Climate change involves changes in the variability or average state of the atmosphere over time periods ranging from decades to millions of years. These changes can be caused by natural processes on Earth, external factors including variations in sunlight intensity, and more recently by human activities.
Cluster analysis	A general approach to multivariate problems in which the aim is to see whether the individuals into groups or clusters. There are several methods of procedure; most depend on setting up a metric to define the "closeness" of individuals. Generally used when the number and nature of the groups are not known.
Coefficient of determination	The percentage of variation in a variable explained by one or more of the others. In a simple linear regression setup, this is square of the correlation coefficient. In a multiple linear regression setup, this is square of the multiple correlation coefficient. In some other setups, this is explained sum of squares as proportion of total sum of squares.
Coefficient of variation (CV)	The standard deviation of a random variable divided by the mean. Result expressed frequently as percentage.
Community of species	A community of species is an assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interfacing with one another
Confidence Interval	A confidence interval for a parameter is a random interval constructed from data in such a way that the probability that the interval contains the true value of the parameter can be specified before the data are collected.
Confidence interval	A confidence interval is an interval which has a known and controlled probability (generally 95% or 99%) to contain the true value.
Correlation	In its most general sense correlation denoted the interdependence between quantitative or qualitative data. In this sense it would include the association of dichotomised attributes and the contingency of multiply-classified attributes. The concept is quite general and may be extended to more than two variates. The word is most frequently used in a somewhat narrower sense to denote the relationship between measurable variates or ranks.
Correlation coefficient	The correlation coefficient r is a measure of how nearly a scatterplot falls on a straight line. The correlation coefficient is always between -1 and $+1$.

Correlation coefficient	A correlation coefficient is a measure of the degree to which two variables tend to move together. The coefficient has a value between plus and minus 1, which indicates the strength and direction of association
Correlation	A measure of linear association between two (ordered) lists. Two variables can be strongly correlated without having any causal relationship, and two variables can have a causal relationship and yet be uncorrelated.
Correspondence analysis (CA) or Correspondence Factor Analysis	is an approach to representing categorical data in a Euclidean space, suitable for visual analysis. CA is often used where the data (in the form of a two-way contingency table) have many rows and/or columns and are not easy to interpret by visual inspection. The map obtained by CA helps reveal relationships within the table. CA is used in ecology, market research, and other areas.
Dendrogram	is a graphical representation of the results of hierarchical cluster analysis. This is a tree-like plot where each step of hierarchical clustering is represented as a fusion of two branches of the tree into a single one. The branches represent clusters obtained on each step of hierarchical clustering.
Dependent variable	A variable that is sought to be explained by one or more of the other variables. The dependent variable “y” is generally the outcome of interest whereas independent variables (x1 ...xn) are the antecedents.
Ecoregion Ecozone	is a homogeneous area of one or more ecosystems that interact with relatively self-contained human activities
Endangered species	An endangered species is a population of an organism which is at risk of becoming extinct. The IUCN has calculated the percentage of endangered species as 40 percent of all organisms based on the sample of species that have been evaluated through to 2006.
Endangered species	are taxa in danger of extinction and whose survival is unlikely if causal factors continue operating.
Endemic	native to a certain ecological region, often a fairly small local area.
Estuary	a semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea. Healthy estuaries can have high rates of biological productivity.
Eutrophication	an increase in chemical nutrients – typically compounds containing nitrogen or phosphorus – in an ecosystem. Eutrophication in water often results in an increase in algae growth and decay, which can lead to decreased levels of oxygen and fish populations.
Explanatory Variable	Explanatory variable is a synonym for independent variable.
Fish assemblage	is a group of associated animals living in the same geographical environment.
Fish community	is a group or association of populations of two or more different species occupying the same geographical area at the same time. Community ecology also takes into account abiotic factors e.g. temperature, oxygen, pH...

Fisherman or Fisher	someone who captures fish and other animals from a body of water.
Fishery	the activities leading to and resulting in the harvesting of fish. A fishery is characterised by the species caught, the fishing gear used, and the area of operation.
Fishing	the activity of trying to catch fish
General Linear Model - GLM	General (or generalized) linear models (GLM), in contrast to linear models, allow you to describe both additive and non-additive relationship between a dependent variable and N independent variables. The independent variables in GLM may be continuous as well as discrete. (The dependent variable is often named "response", independent variables - "factors" and "covariates", depending on whether they are controlled or not).
Gillnet	fishing nets constructed so that fish are entangled or enmeshed, usually in the gills, by the netting. According to their design, ballasting and buoyancy, these nets can be used to fish on the surface, in midwater or on the bottom.
Hierarchical cluster analysis (or hierarchical clustering)	is a general approach to cluster analysis, in which the object is to group together objects or records that are "close" to one another. A key component of the analysis is repeated calculation of distance measures between objects, and between clusters once objects begin to be grouped into clusters. The outcome is represented graphically as a dendrogram.
Histogram	A diagram showing the number or percentage of subjects with values in different intervals by means of contiguous bars: used only for quantitative variables.
Independent variable	This term is regularly used in contradistinction to “dependent variable” in regression analysis. When a variate y is expressed as a function of variables x, plus a stochastic term the x's are known as “independent variables”.
Indicator species or Indicative species	<p>A species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem. Such species are described as playing a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community.</p> <p>Indicator species are indicative of particular groups of sites. Good indicator species should be found mostly in a single group of a typology and be present at most of the sites belonging to that group.</p>
Invasive species	Invasive species are those that are introduced—intentionally or unintentionally—to an ecosystem in which they do not naturally appear and which threaten habitats, ecosystems, or native species. These species become invasive due to their high reproduction rates and by competing with and displacing native species, that naturally appear in that ecosystem. Unintentional introduction can be the result of accidents (e.g. when species escape from a zoo), transport (e.g. in the ballast water of a ship); intentional introduction can be the result of e.g. importing animals or plants or the genetic modification of organisms.

IUCN	the International Union for the Conservation of Nature and Natural Resources is the world's main authority on the conservation status of species. Their system divides threatened species into three categories: critically endangered (CR), endangered (EN), and vulnerable (VU). They also list extinctions that have occurred since 1500 AD and taxa that are extinct in the wild.
IUCN Red List	the IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List), created in 1963, is the world's most comprehensive inventory of the global conservation status of plant and animal species.
k-means clustering	The k-means clustering method is used in non-hierarchical cluster analysis. The goal is to divide the whole set of objects into a predefined number (k) of clusters. The criteria for such subdivision is normally the minimal dispersion inside clusters - e.g. the minimal sum of squares of the distances from the mean vector (centroid) of the cluster. A direct rigorous solution to this problem requires testing of an impractically large number of data subdivisions. The k-means clustering is a fast heuristic method that provides a reasonably good solution, although not optimal.
Kruskal - Wallis Test	The Kruskal-Wallis test is a nonparametric test for finding if three or more independent samples come from populations having the same distribution. It is a nonparametric version of ANOVA.
Linear correlation	An obsolete expression once used to denote either (a) the product moment correlation in cases where the corresponding regressions were linear or (b) a coefficient of correlation constructed from linear functions of the observations. The expression is best avoided altogether.
Linear Regression	Linear regression is aimed at finding the "best-fit" linear relationship between the dependent variable and independent variable(s). See also: Regression analysis, Simple linear regression, Multiple regression
Log-Normal Distribution	A random variable X has a log-normal distribution if $\ln(X)$ is normally distributed.
Mann-Whitney test	A nonparametric test for comparing central tendency in two groups: analogous to t-test for Gaussian data. Gives exactly same result as Wilcoxon test for paired samples.
Mean, Arithmetic mean	The sum of a list of numbers, divided by the number of elements in the list. See also average.
Median	"Middle value" of a list. The smallest number such that at least half the numbers in the list are no greater than it. If the list has an odd number of entries, the median is the middle entry in the list after sorting the list into increasing order. If the list has an even number of entries, the median is the smaller of the two middle numbers after sorting. The median can be estimated from a histogram by finding the smallest number such that the area under the histogram to the left of that number is 50%.
Multiple (linear) regression	is a regression technique aimed at finding a linear relationship between the dependent variable and multiple independent variables.

Native species	Flora and fauna species that occur naturally in a given area or region. Also referred to as indigenous species.
Nonparametric Tests	In statistical inference procedures (hypothesis tests and confidence intervals), nonparametric procedures are those that are relatively free of assumptions about population parameters.
Parametric Tests	In statistical inference procedures (hypothesis tests and confidence intervals), parametric procedures are those that incorporate assumptions about population parameters.
Predictor Variable	Predictor variable is a synonym for independent variable. See also: dependent and independent variables.
Principal Component Analysis (PCA)	The purpose of principal component analysis is to derive a small number of linear combinations (principal components) of a set of variables that retain as much of the information in the original variables as possible.
Red List	The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on taxa that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction, and the main purpose of the IUCN Red List is to catalogue and highlight those taxa that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). The IUCN Red List also includes information on taxa that are categorized as Extinct or Extinct in the Wild; on taxa that cannot be evaluated because of insufficient information (i.e. are Data Deficient); and on taxa that are either close to meeting the threatened thresholds or that would be threatened were it not for an ongoing taxon-specific conservation programme (i.e. are Near Threatened).
Redundancy analysis (RDA)	is a method to extract and summarise the variation in a set of response variables that can be explained by a set of explanatory variables. More accurately, RDA is a direct gradient analysis technique which summarises linear relationships between components of response variables that are "redundant" with (i.e. "explained" by) a set of explanatory variables. To do this, RDA extends multiple linear regression (MLR) by allowing regression of multiple response variables on multiple explanatory variables. A matrix of the fitted values of all response variables generated through MLR is then subject to principal components analysis (PCA). Detailed discussion is available in Legendre and Legendre (1998).
Regression, Linear Regression	Linear regression fits a line to a scatterplot in such a way as to minimize the sum of the squares of the residuals. The resulting regression line, together with the standard deviations of the two variables or their correlation coefficient, can be a reasonable summary of a scatterplot if the scatterplot is roughly football-shaped.
Residuals	Residuals are differences between the observed values and the values predicted by some model. Analysis of residuals allows you to estimate the adequacy of a model for particular data; it is widely used in regression analysis.
Scatter diagram or Scatter plot	A diagram displaying values of one quantitative variable for different values of the other variable by plotting points. This is also called the (x, y) plot.

Scatterplot	A scatterplot is a way to visualize bivariate data. A scatterplot is a plot of pairs of measurements on a collection of "individuals". For example, suppose we record the lengths and weights of a group of 100 fish. The scatterplot of those data would be 100 points. Each point represents one fish's length and weight. In a scatterplot of weight against length, the x-coordinate of each point would be length of one fish, the y-coordinate of that point would be the weight of the same fish. In a scatterplot of length against weight, the x-coordinates would be the weights and the y-coordinates would be the lengths.
Significance, Significance level, Statistical significance	The significance level of a hypothesis test is the chance that the test erroneously rejects the null hypothesis when the null hypothesis is true.
Simpson index	Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species.
Species richness	is the number of different species represented in an ecological community, landscape or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions. Species richness is sometime considered synonymous with species diversity, but the formal metric Species diversity takes into account both species richness and species evenness.
Species richness or Richness	is the number of different species represented in an ecological community, landscape, or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions.
Standard Deviation (SD)	The standard deviation of a set of numbers is the rms of the set of deviations between each element of the set and the mean of the set.
Standard Error (SE)	The Standard Error of a random variable is a measure of how far it is likely to be from its expected value; that is, its scatter in repeated experiments.
t-test	A hypothesis test based on approximating the probability histogram of the test statistic by Student's t curve. t-tests usually are used to test hypotheses about the mean of a population when the sample size is intermediate and the distribution of the population is known to be nearly normal.
t-test or Student t-test	A statistical procedure to test hypothesis of equality of two means, and for certain other hypotheses relating to parameters such as regression coefficient

Threatened species

A technical classification referring to a species that is likely to become endangered within the foreseeable future, throughout all or a significant portion of its range. 12,259 species are known by IUCN, the World Conservation Union, to be threatened with extinction. IUCN keeps the world's inventory of the conservation status of animals and plants, compiling data from thousands of scientists and conservationists worldwide. However, the 12,259 threatened species are only the tip of the iceberg. Nobody knows how many species there are on Earth, let alone how they are doing. The total number of recorded living species is around 1.75 million. But more than two thirds are insects and other invertebrates, which are extremely difficult to monitor. An estimate of the real number of species on Earth is 14 million. For its 2003 "Red List of Threatened Species", IUCN was able to evaluate the conservation status of 2% of 1.53 million species for which it has descriptions. The only two well-monitored groups are birds and mammals, so IUCN was able to evaluate 100% of birds and 99% of mammals for threatened status.



REFERENCES

- Adaka, G. S., Udoh, J. P., & Onyeukwu, D. C. (2014). Freshwater fish diversity of a tropical rainforest river in Southeast Nigeria. *Advances in Life Science and Technology*, 23(January 2014).
- Ali, L., Hossain, M. A. R., & Ahmed, M. (2009). *Impact of sanctuary on fish production and biodiversity in Bangladesh* (Issue August).
- Anticamara, J. A., Zeller, D., & Vincent, A. C. J. (2010). Spatial and temporal variation of abundance, biomass and diversity within marine reserves in the Philippines. *Diversity and Distributions*, 16(4), 529–536. <https://doi.org/10.1111/j.1472-4642.2010.00661.x>
- Arias, M. E., Cochrane, T. A., & Elliott, V. (2014). Modelling future changes of habitat and fauna in the Tonle Sap wetland of the Mekong. *Environmental Conservation*, 41(2), 165–175. <https://doi.org/10.1017/S0376892913000283>
- Arias, M. E., Cochrane, T. A., Piman, T., Kummu, M., Caruso, B. S., & Killeen, T. J. (2012). Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin. *Journal of Environmental Management*, 112, 53–66. <https://doi.org/10.1016/j.jenvman.2012.07.003>
- Baran, E., Jantunen, T., & Kieok, C. C. (2014). *Values of Inland Fisheries in the Mekong River Basin* (Issue January). WorldFish Center.
- Beisner, B. E., McCauley, E., & Wrona, F. J. (1997). Predator-prey instability: Individual-level mechanisms for population-level results. *Functional Ecology*, 11(1), 112–120. <https://doi.org/10.1046/j.1365-2435.1997.00062.x>
- Boyd, S. E., Limpenny, D. S., Rees, H. L., & Cooper, K. M. (2005). The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). *ICES Journal of Marine Science*, 62(2), 145–162. <https://doi.org/10.1016/j.icesjms.2004.11.014>
- Campbell, I. C. (2009). Introduction. In I. C. Campbell (Ed.), *The mekong biophysical environment of an international river basin* (First). Elsevier Academic Press.
- Campbell, I. C. (2012). Biodiversity of the Mekong Delta. In F. G. Renaud & C. Künzer (Eds.), *The Mekong Delta System* (pp. 293–313). Springer. https://doi.org/10.1007/978-94-007-3962-8_11
- Campbell, I. C., Say, S., & Beardall, J. (2009). Tonle Sap Lake, the heart of the Lower Mekong. In I. C. Campbell (Ed.), *The Mekong, Biophysical environment of an international river basin* (pp. 251–272). Elsevier Academic Press.

- Chan, B., Ngor, P. B., So, N., & Lek, S. (2017). Spatial and temporal changes in fish yields and fish communities in the largest tropical floodplain lake in Asia. *Annales de Limnologie*, 53, 485–493. <https://doi.org/10.1051/limn/2017027>
- Chea, R., Guo, C., Grenouillet, G., & Lek, S. (2016). Toward an ecological understanding of a flood-pulse system lake in a tropical ecosystem: Food web structure and ecosystem health. *Ecological Modelling*, 323, 1–11. <https://doi.org/10.1016/j.ecolmodel.2015.11.014>
- Chea, R., Lek, S., Ngor, P., & Grenouillet, G. (2017). Large-scale patterns of fish diversity and assemblage structure in the longest tropical river in Asia. *Ecology of Freshwater Fish*, 26(4), 575–585. <https://doi.org/10.1111/eff.12301>
- Chu, C., Jones, N. E., Mandrak, N. E., Piggott, A. R., & Minns, C. K. (2008). The influence of air temperature, groundwater discharge, and climate change on the thermal diversity of stream fishes in southern Ontario watersheds. *Canadian Journal of Fisheries and Aquatic Sciences*, 65(2), 297–308. <https://doi.org/10.1139/f08-007>
- Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. *Science*, 199(4335), 1302–1310. <https://doi.org/10.1126/science.199.4335.1302>
- Cowx, I. ., Nuon, V., & So, N. (2019). *Standard sampling guidelines for fish abundance and diversity monitoring in the Lower Mekong Basin*. Mekong River Commission Secretariat.
- Cussac, V. E., Fernández, D. A., Gómez, S. E., & López, H. L. (2009). Fishes of southern South America: A story driven by temperature. *Fish Physiology and Biochemistry*, 35(1), 29–42. <https://doi.org/10.1007/s10695-008-9217-2>
- De Cáceres, M., & Legendre, P. (2009). Associations between species and groups of sites: Indices and statistical inference. *Ecology*, 90(12), 3566–3574. <https://doi.org/10.1890/08-1823.1>
- De Cáceres, M., Legendre, P., & Moretti, M. (2010). Improving indicator species analysis by combining groups of sites. *Oikos*, 119(10), 1674–1684. <https://doi.org/10.1111/j.1600-0706.2010.18334.x>
- Duan, X., Wang, Z., & Tian, S. (2008). Effect of streambed substrate on macroinvertebrate biodiversity. *Frontiers of Environmental Science and Engineering in China*, 2(1), 122–128. <https://doi.org/10.1007/s11783-008-0023-y>
- Dufrêne, M., & Legendre, P. (1997). Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs*, 67(3), 345–366. <https://doi.org/10.2307/2963459>
- Englmaier, G. K., Hayes, D. S., Meulenbroek, P., Terefe, Y., Lakew, A., Tesfaye, G., Waidbacher, H., Malicky, H., Wubie, A., Leitner, P., & Graf, W. (2020). Longitudinal river zonation in the tropics: Examples of fish and caddisflies from the endorheic Awash River, Ethiopia. *Hydrobiologia*, 847(19), 4063–4090. <https://doi.org/10.1007/s10750-020-04400-0>

- Fridley, J. D. (2003). Diversity effects on production in different light and fertility environments: An experiment with communities of annual plants. *Journal of Ecology*, 91(3), 396–406. <https://doi.org/10.1046/j.1365-2745.2003.00775.x>
- Grenouillet, G., Pont, D., & Hérissé, C. (2004). Within-basin fish assemblage structure: The relative influence of habitat versus stream spatial position on local species richness. *Canadian Journal of Fisheries and Aquatic Sciences*, 61(1), 93–102. <https://doi.org/10.1139/f03-145>
- Guégan, J. F., Lek, S., & Oberdorff, T. (1998). Energy availability and habitat heterogeneity predict global riverine fish diversity. *Nature*, 391(6665), 382–384. <https://doi.org/10.1038/34899>
- He, J.-S., Bazzaz, F. A., & Schmid, B. (2002). Interactive effects of diversity, nutrients and elevated CO₂ on experimental plant communities. *Oikos*, 97(3), 337–348. <https://doi.org/10.1034/j.1600-0706.2002.970304.x>
- Hortle, K. G. (2009). Fisheries of the Mekong River Basin. In I. C. Campbell (Ed.), *The Mekong, biophysical environment of an international river basin* (pp. 197–249). Aquatic Ecology ed.
- Hortle, K. G., & Bamrungrach, P. (2015). *Fisheries habitat and yield in the Lower Mekong Basin*. Mekong River Commission Secretariat.
- Howell, P., & Simpson, D. (1994). Abundance of marine resources in relation to dissolved oxygen in Long Island Sound. *Estuaries*, 17(2), 394. <https://doi.org/10.2307/1352672>
- Jongman, R. H. G., Braak, C. J. F. Ter, & Tongeren, O. F. R. van. (1995). *Data analysis in community and landscape ecology*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511525575>
- Justus, B. G., Mize, S. V., Wallace, J., & Kroes, D. (2014). Invertebrate and fish assemblage relations to dissolved oxygen minima in lowland streams of southwestern Louisiana. *River Research and Applications*, 30(1), 11–28. <https://doi.org/10.1002/rra.2623>
- Kleinhappel, T. K., Burman, O. H. P., John, E. A., Wilkinson, A., & Pike, T. W. (2019). The impact of water pH on association preferences in fish. *Ethology*, 125(4), 195–202. <https://doi.org/10.1111/eth.12843>
- Kong, H., Chevalier, M., Laffaille, P., & Lek, S. (2017). Spatio-temporal variation of fish taxonomic composition in a South-East Asian flood-pulse system. *PLOS ONE*, 12(3), e0174582. <https://doi.org/10.1371/journal.pone.0174582>
- Kouamélan, E. P., Teugels, G. G., N'Douba, V., Gooré Bi, G., & Koné, T. (2003). Fish diversity and its relationships with environmental variables in a West African basin. *Hydrobiologia*, 505(1–3), 139–146. <https://doi.org/10.1023/B:HYDR.0000007302.74296.84>
- Lambshhead, P. J. D., Platt, H. M., & Shaw, K. M. (1983). The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *Journal of Natural History*, 17(6), 859–874. <https://doi.org/10.1080/00222938300770671>

- Lasne, E., Bergerot, B., Lek, S., & Laffaille, P. (2007). Fish zonation and indicator species for the evaluation of the ecological status of rivers: Example of the Loire basin (France). *River Research and Applications*, 23(8), 877–890. <https://doi.org/10.1002/rra.1030>
- Legendre, P., & De Cáceres, M. (2013). Beta diversity as the variance of community data: Dissimilarity coefficients and partitioning. *Ecology Letters*, 16(8), 951–963. <https://doi.org/10.1111/ele.12141>
- Legendre, P., & Legendre, L. (2012). *Numerical Ecology* (3rd ed.). Elsevier BV.
- Legendre, P., & Salvat, B. (2015). Thirty-year recovery of mollusc communities after nuclear experimentations on Fangataufa atoll (Tuamotu, French Polynesia). *Proceedings of the Royal Society B: Biological Sciences*, 282(1810). <https://doi.org/10.1098/rspb.2015.0750>
- Leuven, R. S. E. W., Hendriks, A. J., Huijbregts, M. A. J., Lenders, H. J. R., Matthews, J., & Velde, G. Van Der. (2011). Differences in sensitivity of native and exotic fish species to changes in river temperature. *Current Zoology*, 57(6), 852–862. <https://doi.org/10.1093/czoolo/57.6.852>
- Lima-Junior, S. E., Cardone, I. B., & Goitein, R. (2006). Fish assemblage structure and aquatic pollution in a Brazilian stream: Some limitations of diversity indices and models for environmental impact studies. *Ecology of Freshwater Fish*, 15(3), 284–290. <https://doi.org/10.1111/j.1600-0633.2006.00156.x>
- Magurran, A. (2004). Measuring biological diversity. In *Blackwell Publishing*. Blackwell Science Ltd.
- Mekong River Commission. (2011). Planning atlas of the Lower Mekong River Basin. In *Mekong River Commission*. Mekong River Commission Secretariat. <http://www.mrcmekong.org/assets/Publications/basin-reports/BDP-Atlas-Final-2011.pdf>
- Mekong River Commission. (2013). *Integrated analysis of data from MRC fisheries monitoring programmes in the Lower Mekong Basin*. Mekong River Commission Secretariat.
- Mekong River Commission. (2015). *Climate change impacts on hydrology of the Lower Mekong Basin—Volume 1: Water level, flow and salinity*. Mekong River Commission Secretariat.
- Mekong River Commission. (2017). *The Council study: The study on sustainable management and development of the Mekong River, including impacts of mainstream hydropower projects. biological resource assessment final technical report series. Volume 1: Specialists' report* (Vol. 1, Issue September). Mekong River Commission Secretariat.
- Mekong River Commission. (2018a). *MRC's updated database offers comprehensive information on Mekong fish species*. <http://www.mrcmekong.org/news-and-events/events/mrc-updated-database-offers-comprehensive-information-on-mekong-fish-species/>
- Mekong River Commission. (2018b). State of the basin report 2018. In *Mekong River Commission*. Mekong River Commission Secretariat. <https://doi.org/ISSN 1728:3248>

- Mount, D. I. (1973). Chronic effect of low pH on fathead minnow survival, growth and reproduction. *Water Research*, 7(7), 987–993. [https://doi.org/10.1016/0043-1354\(73\)90180-2](https://doi.org/10.1016/0043-1354(73)90180-2)
- Ngor, P. B., Grenouillet, G., Phem, S., So, N., & Lek, S. (2018). Spatial and temporal variation in fish community structure and diversity in the largest tropical flood-pulse system of South-East Asia. *Ecology of Freshwater Fish*, 27, 1087–1100. <https://doi.org/10.1111/eff.12417>
- Ngor, P. B., Legendre, P., Oberdorff, T., & Lek, S. (2018). Flow alterations by dams shaped fish assemblage dynamics in the complex Mekong-3S river system. *Ecological Indicators*, 88(July 2017), 103–114. <https://doi.org/10.1016/j.ecolind.2018.01.023>
- Ngor, P. B., McCann, K. S., Grenouillet, G., So, N., McMeans, B. C., Fraser, E., & Lek, S. (2018). Evidence of indiscriminate fishing effects in one of the world's largest inland fisheries. *Scientific Reports*, 8(1), 1–12. <https://doi.org/10.1038/s41598-018-27340-1>
- Ngor, P. B., Oberdorff, T., Phen, C., Baehr, C., Grenouillet, G., & Lek, S. (2018). Fish assemblage responses to flow seasonality and predictability in a tropical flood pulse system. *Ecosphere*, 9(11), e02366. <https://doi.org/10.1002/ecs2.2366>
- Nuon, V., Lek, S., Ngor, P. B., So, N., & Grenouillet, G. (2020). Fish community responses to human-induced stresses in the Lower Mekong Basin. *Water (Switzerland)*, 12(12), 1–21. <https://doi.org/10.3390/w12123522>
- Parmesan, C., & Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, 421(6918), 37–42. <https://doi.org/10.1038/nature01286>
- Pitchaiah, P. S. (2017). Impacts of Sand Mining on Environment—A Review. *International Journal of Geoinformatics and Geological Science*, 4(1), 1–6. <https://doi.org/10.14445/23939206/ijggs-v4i1p101>
- Poff, N. L., & Allan, J. D. (1995). Functional organization of stream fish assemblages in relation to hydrological variability. *Ecology*, 76(2), 606–627. <https://doi.org/10.2307/1941217>
- Pool, T., Elliott, V., Holtgrieve, G., Arias, M., Altman, I., Kaufman, L., McCann, K., Fraser, E. D. G., Tudesque, L., Chevalier, M., Grenouillet, G., Chea, R., Lek, S., McMeans, B., Cooperman, M., Phen, C., Hannah, L., Miller, B., Guo, C., & Nam, S. (2019). Fish assemblage composition within the floodplain habitat mosaic of a tropical lake (Tonle Sap, Cambodia). *Freshwater Biology*, 64(11), 2026–2036. <https://doi.org/10.1111/fwb.13391>
- Rask, M. (1984). The effect of low pH on perch, *Perca fluviatilis* L. II. The effect of acid stress on different development stages of perch. In *Annales Zoologici Fennici* (Vol. 21, Issue 1, pp. 9–13).
- Rocha, R., Thomaz, S., Carvalho, P., & Gomes, L. (2009). Modeling chlorophyll-a and dissolved oxygen concentration in tropical floodplain lakes (Paraná River, Brazil). *Brazilian Journal of Biology*, 69(2 suppl), 491–500. <https://doi.org/10.1590/S1519-69842009000300005>

- Shaw, K., Lamshead, P., & Piatt, H. (1983). Detection of pollution-induced disturbance in marine benthic assemblages with special reference to nematodes. *Marine Ecology Progress Series*, 11, 195–202. <https://doi.org/10.3354/meps011195>
- So, N., Phommakone, S., Ly, V., Samphawamana, T., Nguyen, H. S., Khumsri, M., Ngor, P. B., Kong, S., Degen, P., & Starr, P. (2015). Lower Mekong fisheries estimated to be worth around \$17 billion a year. *Catch and Culture*, 21(3), 4–7. <http://www.mrcmekong.org/assets/Publications/Catch-and-Culture/CatchCultureVol-21.3.pdf>
- Stone, R. (2016). Dam-building threatens Mekong fisheries. *Science*, 354(6316), 1084–1085. <https://doi.org/10.1126/science.354.6316.1084>
- Sutherst, R. W. (2000). Climate change and invasive species: A conceptual framework. In H. Mooney & R. J. Hobbs (Eds.), *Invasive species in a changing world* (p. 384). Island Press.
- Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F. N., de Siqueira, M. F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A. S., Midgley, G. F., Miles, L., Ortega-Huerta, M. A., Townsend Peterson, A., Phillips, O. L., & Williams, S. E. (2004). Extinction risk from climate change. *Nature*, 427(6970), 145–148. <https://doi.org/10.1038/nature02121>
- Valbo-Jorgensen, J., Coates, D., & Hortle, K. G. (2009). Fish diversity in the Mekong River Basin. In C. I. Cambel (Ed.), *The Mekong biophysical environment of an international river basin* (pp. 162–185). Elsevier Academic Press.
- Warwick, R. M. (1986). A new method for detecting pollution effects on marine macrobenthic communities. *Marine Biology*, 92(4), 557–562. <https://doi.org/10.1007/BF00392515>
- Wenger, A. S., Harvey, E., Wilson, S., Rawson, C., Newman, S. J., Clarke, D., Saunders, B. J., Browne, N., Travers, M. J., Mcilwain, J. L., Erftemeijer, P. L. A., Hobbs, J. P. A., Mclean, D., Depczynski, M., & Evans, R. D. (2017). A critical analysis of the direct effects of dredging on fish. *Fish and Fisheries*, 18(5), 967–985. <https://doi.org/10.1111/faf.12218>
- Whittaker, R. H. (1965). Dominance and diversity in land plant communities: Numerical relations of species express the importance of competition in community function and evolution. *Science*, 147(3655), 250–260. <https://doi.org/10.1126/science.147.3655.250>
- Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny, M. L. J., Silvano, R. A. M., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M., ... Sáenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science*, 351(6269), 128–129. <https://doi.org/10.1126/science.aac7082>
- WWF. (2013). *Ecosystems in the Greater Mekong: Past trends, current trends, possible futures*. WWF-Great Mekong.

Annex 1: Sampling Station Characteristics

No.	Country	Province	District	Village	Site Code	Used for this study	Habitats	BioRA Zone	Station Characteristics
1	Cambodia	Battambang	Ek Phnom	Prek Torl	CBT	X	Tonle Sap Floodplain	Zone 7	This station is located in the northwest of Tonle Sap Great Lake and near Prek Toal biospheres. In the dry season between December to May, fishers can catch more fish. The main fishing habitats in this station are Tonle Sap Great Lake, flooded forest, and Sangke River.
2	Cambodia	Kompong Chhnang	Boribo	Chhnouk Trou	CKC	X	Tonle Sap Floodplain	Zone 7	This station is located in a lowland floodplain in the central part of Tonle Sap with lots of tributaries. The water flows in and out of the Tonle Sap Lake so the fishers have difficulty using fishing nets. The main fishing habitats are Tonle Sap River and flooded forest.
3	Cambodia	Kompong Thom	Kompong Svay	Neang Sav; Pheam Bang; Pich Chikreng	CPT	X	Tonle Sap Floodplain	Zone 7	This station is located between Tonle Sap Lake and the Tonle Chhmar Ramsar site. This station is rich in flooded forest and water hyacinth from the Staung River. The main habitats are Tonle Sap lake, flooded forest, and Staung River.
4	Cambodia	Pursat	Kro Kor	Ti 1, 3,4	CPS	X	Tonle Sap Floodplain	Zone 7	This station is located in Kompong Loung Commune near two fisheries conservation areas. There are lots of fishing grounds. The main habitats are Tonle Sap Lake and flooded forest.
5	Cambodia	Siem Reap	Siem Reap	Ti 3,4,5	CSR	X	Tonle Sap Floodplain	Zone 7	This station is located in Kompong Phluk Commune. It is a good habitat for fish because it is rich in flooded forest. The main habitats are Tonle Sap Great lake and flooded forest.
6	Cambodia	Kra Tie	Sambo	Koh Khne	CKT	X	Mekong mainstream	Zone 4	This station is located in the Mekong mainstream and is surrounded by many islands. It has a lot of deep pools and areas of rapids. It is home to many fish species in the dry season. The fishing habitats are the Mekong River and Canal.
7	Cambodia	Kandal	Ponhea Leu	Sang Var	CKD	X	Tributaries	Zone 7	This station is located on the Tonle Sap River and is different from other stations. The main fishing habitat is the Tonle Sap River.

No.	Country	Province	District	Village	Site Code	Used for this study	Habitats	BioRA Zone	Station Characteristics
8	Cambodia	Ratanakiri	Veounsai	Fang	CSS	X	Tributaries	Zone 3S	This station is located in the Sesan River and experiences a lot of impacts from dam construction. The water level in this area does not change according to the seasons. The riverbed has a lot of sand brought by strong currents from the dam and has become shallow. In the dry season, people can walk across the river. There are five main fishing habitats in this station: the Sesan River, canal, lake, pond, and rice fields.
9	Cambodia	Ratanakiri	Lum Phat	Day Lo	CSP	X	Tributaries	Zone 3S	This station is located in the Srepok River. There are many impacts from dam construction in the upper part of the stream causing water in the river to change every day. This station has small pools and an area of rapids. The fishing habitats are the Srepok River and canal.
10	Cambodia	Stung Treng	Siem Pang	Pres Bang	CSK	X	Tributaries	Zone 3S	This station is located in the Sekong River in Siem Pang district. The river connects to the Mekong River at Stung Treng town. There are a lot of pools, areas of rapids, and it has one spawning habitat of <i>Probabus</i> sp. on Koh Tachan island. The fishing habitats in this area are the Sekong River, canal, flooded area, pond, and rice fields.
11	Cambodia	Stung Treng	Thalaborivat	Ou Run	CST	X	Mekong mainstream	Zone 4	This station has a lot of flooded forests, deep pools, and areas of rapids. It is home to many fish species in the dry season, especially the large-sized fish. The fishing habitats are the Mekong River and canal.
12	Lao PDR	Attapeu	Samakhixay	Saphaonthong	LAP		Tributaries	N/A	The fishing ground is located in the Xekong River. The area is near a deep pool with an average depth 7–10 m during the dry season. Water flow is slow and the bottom of river consists of rocks and sand. There are gardens and houses along the riverbank.
13	Lao PDR	Borikhamxay	Pak sanh	Sinhxay	LBX	X	Mekong mainstream	Zone 3	The fishing ground is about 500 m from the village, at the confluence of the Ngip River with the Mekong River. The water flow is slow and the bottom is sandy with muddy with a depth is 12 m. The riverbanks are surrounded by gardens and houses.

No.	Country	Province	District	Village	Site Code	Used for this study	Habitats	BioRA Zone	Station Characteristics
14	Lao PDR	Borkeo	Huay xai	Huay tap	LHT		Mekong mainstream	Zone 1	This fishing ground is around 25 km from the village, and has a water flow that is fast with a bottom of sand and rocks. The water depth is 15–20 m. There is a deep pool near the fishing areas with a depth of 40 m.
15	Lao PDR	Borkeo	Huay xai	Donekoun	LDK		Tributaries	Zone 1	The fishing area is about 3 km from the village. The water flow is moderate and the bottom consists of sand and rocks. The water depth is 8–10 m, and the riverbank is surrounded by forest and gardens.
16	Lao PDR	Champasak	Khong	Hangsadam	LSD		Mekong mainstream	Zone 4	The fishing areas is about 300 m from the village. The water flow is slow and the bottom consists of sand and rocks. The water depth is 15 m and the riverbank is surrounded by forest.
17	Lao PDR	Champasak	Khong	Hat	LCS		Mekong mainstream	Zone 4	The fishing areas is 800 m from the village and the water flow is moderate. The water depth is about 18 m and the bottom consists of sand and rocks. This is known as a fish migration corridor for cyprinid species in the dry season during Chinese New Year.
18	Lao PDR	Champasak	Phonthong	Hatsalao	LSL		Mekong mainstream	Zone 4	This fishing areas is closed to the village and the riverbank is surrounded by banana gardens. The water depth is about 25–30 m. The water flow is moderate with mud and sand on the river bottom. There are 25 fishers working in this area.
19	Lao PDR	Luangphrabang	Luangphrabang	Pha O	LPB	X	Mekong mainstream	Zone 2	The fishing areas is located in the mainstream and about 1 km from the village. The water depth is 15 m and the bottom consists of sand and rocks. The water flow is moderate. About 15 fishers work in this area.
20	Lao PDR	Luangphrabang	Pak Ou	Hadgna	LPO	X	Tributaries	Zone 2	This fishing areas is located in the Ou River about 2–4 km from the village. The water depth is about 9 m and the bottom consists of sand and rocks. The water flow is moderate and the riverbank is surrounded by gardens and houses. The area is located about 10 km downstream of the Nam Ou dam. Ten fishers are working in this area.

No.	Country	Province	District	Village	Site Code	Used for this study	Habitats	BioRA Zone	Station Characteristics
21	Lao PDR	Oudomxay	Pak beng	Pak ngery	LPN		Mekong mainstream	Zone 1	This fishing areas is located in the mainstream about 1km from the village. The water depth is 60 m, the river bottom is rocky, and it has a moderate flow. The river bank is surrounded by forest.
22	Lao PDR	Oudomxay	Pak beng	Pakbeng	LOX		Tributaries	Zone 1	The fishing areas are about 3 km from the village. The water depth is about 4 m. The river bottom is mixed with rock and mud, and it has a moderate water flow. The riverbank is surrounded by forest and gardens. It is located about 2 km from Pak Beng dam.
23	Lao PDR	Vientiane Capital	Hatxayfong	Thamuang	LVT	X	Mekong mainstream	Zone 3	This fishing area is about 500 m from the village. The water depth is 12 m and the bottom consists of sand and rocks. The water flow is fast. The riverbank is surrounded by houses. About 20 fishers are fishing in this area.
24	Lao PDR	Xayaboury	Xayaboury	Thadeua	LXB		Mekong mainstream	Zone 2	This fishing area is about 3 km from the village. The water depth is 30 m and the river bottom is rocky and muddy. It has a moderate flow. The riverbank is surrounded by forest. About 15–20 fishers are fishing in this area. This area is located downstream of the Xayaboury dam.
25	Lao PDR	Xayaboury	Xayaboury	Na xam	LNS		Tributaries	Zone 2	This fishing area is located in Nam Houg about 2 km from the village. The water depth is 6 m, it has a fast flow, and the bottom consists of sand and rocks. The riverbank is surrounded by forest and gardens. About 10 fishers are fishing in this area.
26	Lao PDR	Xekong	Lamam	Navasaen	LXK		Tributaries	N/A	This fishing area is located in Xekong River about 500 m from the village. The water depth is 15 m and the bottom consists of sand and rocks. The water flow is slow and the riverbank is surrounded by gardens.
27	Thailand	Loei	Chiangkhan	Ban Noy	TCK	X	Mekong mainstream	Zone 2	This station is narrower than the other stations and there is a rocky barrier in the middle of the mainstream, so the water current is quite strong. There are 40–50 fishers working along the river in this area.

No.	Country	Province	District	Village	Site Code	Used for this study	Habitats	BioRA Zone	Station Characteristics
28	Thailand	Nakhon Phanom	Si Songkhram	Ban Tha Bho	TSK	X	Floodplain	Zone 3	The station has many floodplain areas and many swamps around it. There are many tributaries and its water flows to the Songkhram mainstream, such as Huai Hee, Nam Mao, and Nam Yam etc. There are also a lot of fishing grounds in the Lower Songkhram Basin.
29	Thailand	Nakhonphanom	Tha Uthen	Ban Tha Dok Kaeo	TUT	X	Mekong mainstream	Zone 3	It is wider than the others areas. The water current is slow. There are about 15 fishers fishing in this village.
30	Thailand	Nong Khai	Tha Bo	Thadaeng	TNK	X	Tributaries	Zone 2	This station is located at a tributary and has a development project for irrigation and flood protection. There is a weir at the mouth of the Huai Mong River near the Mekong River, and there are 9 pumping stations and irrigation canals. After construction of the weir, the flood area in Huai Mong decreased and became rice fields and an agricultural area.
31	Thailand	Ubon Ratchathani	Khemarat	Ladjalean	TKR	X	Mekong mainstream	Zone 3	There are two deep pools in this station where fishers catch fish, one is Wern Kan Yang and the other is Wern Mae Kai Fuk. Wern Kan Yang has the strongest water current and deepest water level. There are 17–20 fishers catching fish in this area.
32	Viet Nam	An Giang	An Phu	Ap 2	VAP	X	Canal	Zone 8	This station is a branch of the Bassac River near a natural reservoir. it is used for aquaculture and tourism. The strong current is on a downward tidal regime. There are about 30 fishers in this area.
33	Viet Nam	An Giang	Cho Moi	My Thuan	VCM	X	Mekong mainstream	Zone 8	This station is a big canal connecting the Mekong and Bassac rivers. It is about 7km long and 500 m wide. The main shipway is used as an international trade shipway. There is one deep pool at the corner about 50m deep. The strong current is on a downward tidal regime. There are about 50 fishers in this area.
34	Viet Nam	An Giang	Thoai Son	Tay Son	VTS	X	Floodplain/ swamp	Zone 8	This station is in a flood land area but fishers catch fish in the tributary/canal because there are rice field dykes for irrigation. The current is not strong in the upward or downward tidal regime. There are 15–20 fishers in this area.

No.	Country	Province	District	Village	Site Code	Used for this study	Habitats	BioRA Zone	Station Characteristics
35	Viet Nam	Can Tho	Phong Dien	My Thuan	VCT		Floodplain/swamp	Zone 8	This station is in a flooded area, but fishers catch fish in the tributary/canal of the Bassac River. The water current is not strong in the upward or downward tidal regime. There are 10–15 fishers in this area.
36	Viet Nam	Tra Vinh	Tieu Can	Khom 3	VTV	X	Estuarine	Zone 8	This station is located on the Bassac mainstream, near the estuary. It sees 3 months of freshwater (in the flood season) and 9 months of salt water. The water current depends on the tidal regime; it isn't strong when the tide comes in but is strong when the tide goes out. There are 15–20 fishers in this area.
37	Viet Nam	Tra Vinh	TP Tra Vinh	Long Tri	VLT		Estuarine	Zone 8	This station is located on the Mekong mainstream, near the estuary. It sees 3 months of freshwater (in the flood season) and 9 months of salt water. The water current depends on the tidal regime; it isn't strong when the tide comes in but is strong when the tide goes out. There are 15–20 fishers in this area.
38	Viet Nam	Vinh Long	Vung Liem	Lang	VVL	X	Mekong mainstream	Zone 8	This station is located on the Mekong mainstream with some islands around it. In the river, there are some sand mining activities. So, the water is not transparent and the current depends on the tidal regime; it isn't so strong when the tide comes in but is strong when the tide goes out. There are 12–15 fishers catching fish in this area.



LHT, Mainstream at Borkeo province



LDK, Tributary at Borkeo province



LPN, Mainstream at Oudomxay province



LOX, Tributary at Oudomxay province



LPB, Mainstream at Luangphrabang province



LPO, Tributary at Luangphrabang province



LXB, Mainstream at Xayaboury province



LNS, Tributary at Xayaboury province



LVT, Mainstream at Vientiane Capital



LBX, Mean stream at Borikhamxay province



LSL, Mean stream at Champasak province



LCS, Mainstream at Champasak province



LSD, Mainstream at Champasak province



LXK, Tributary at Xekong province



LAP, Tributary at Attapeu province



TCK, Mainstream at Loei province



TNK, Tributary at Nong Khai province



TSK, Floodplain at Nakhon Phanom province



TUT, Mainstream at Nakhon Phanom province



TKR, Mainstream at Ubon Ratchathani province



CSK, Sekong at Stung Treng province



CSS, Sesan at Ratanakiri province



CSP, Srepok at Ratanakiri province



CST, Mainstream at Stung Treng province



CKT, Mainstream at Kratei province



CBT, Floodplain at Battambang province



CSR, Floodplain at Siem Reap province



CPT, Floodplain at Kompong Thom province



CPS, Floodplain at Pursat province



CKC, Floodplain at Kompong Chhang province



CKD, Tributary at Kandal province



VAP, Canal at An Giang province



VCM, Mainstream at An Giang province



VTS, Floodplain at An Giang province



VCT, Floodplain at Can Tho province



VTV, Estuarine at Tra Vinh province



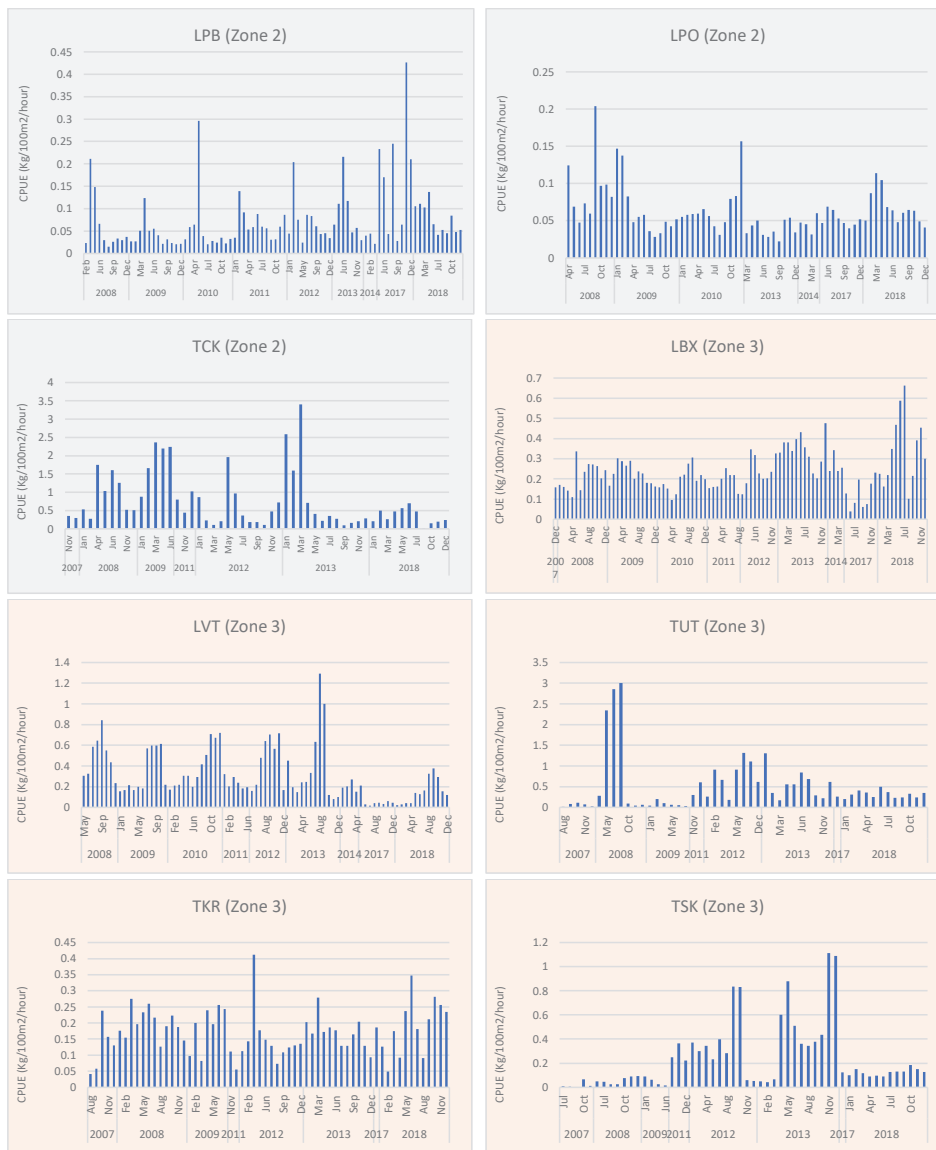
VVL, Estuarine at Vinh Long province

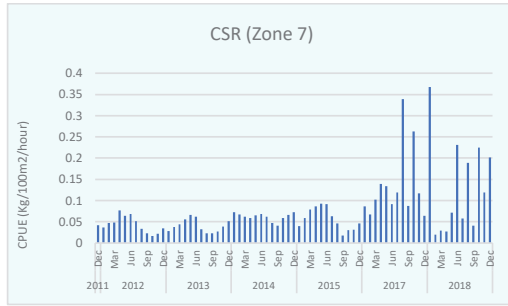
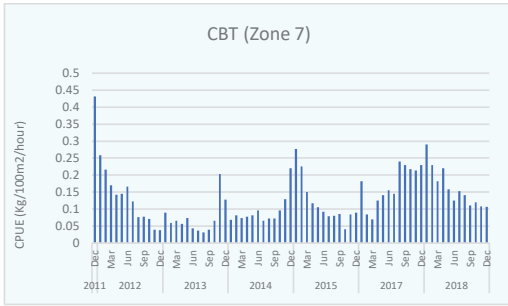
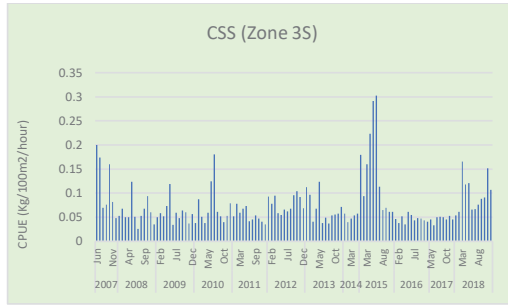
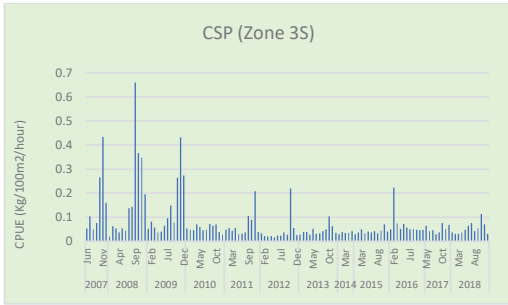
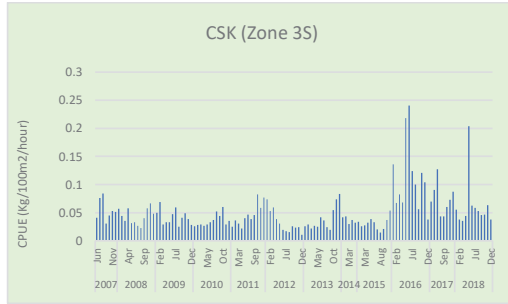
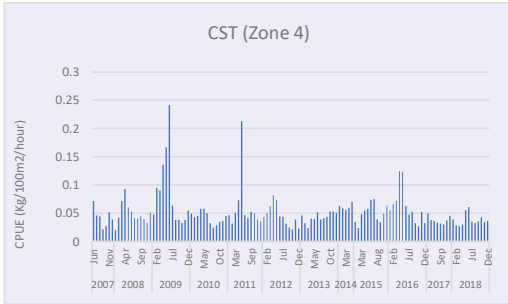
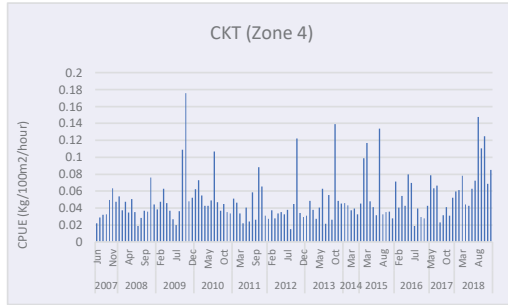
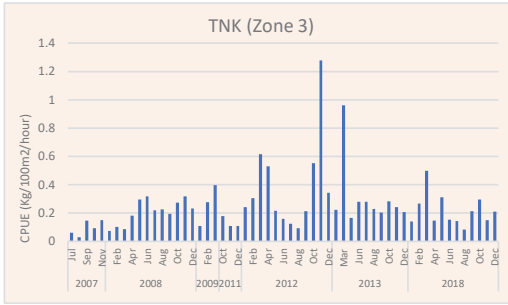


VLT, Estuarine at Tra Vinh province

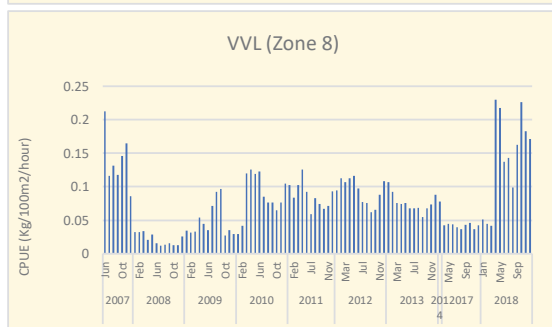
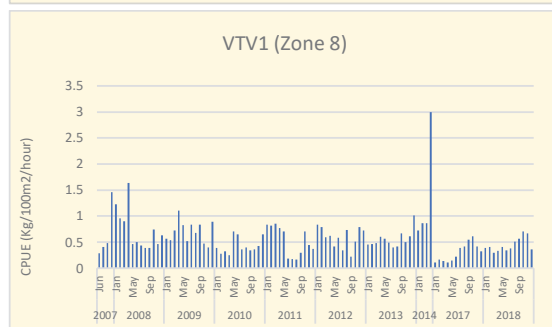
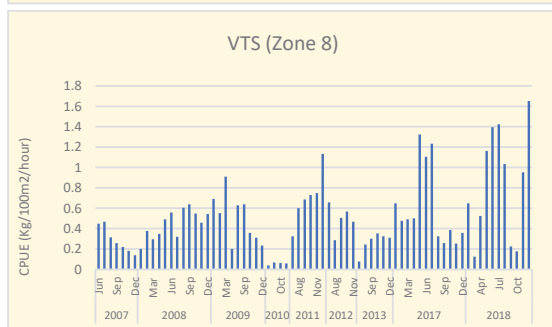
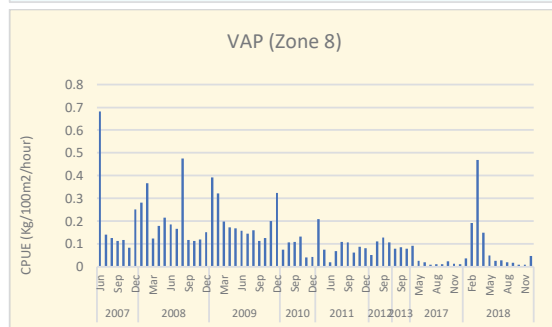
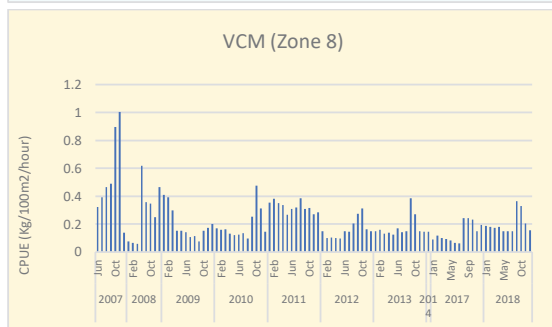
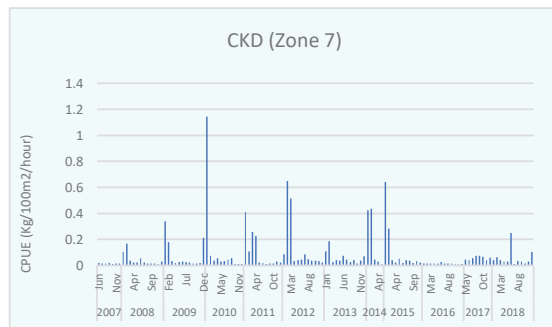
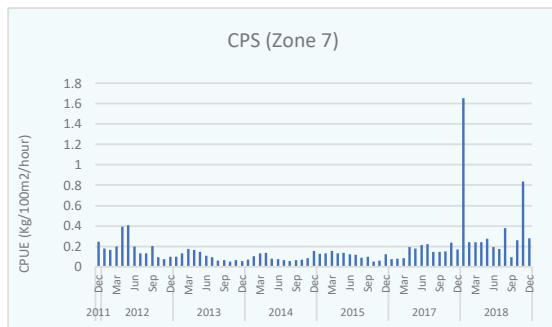


Annex 2: Catch per Unit Effort for All Stations Clustered by BioRA Zone

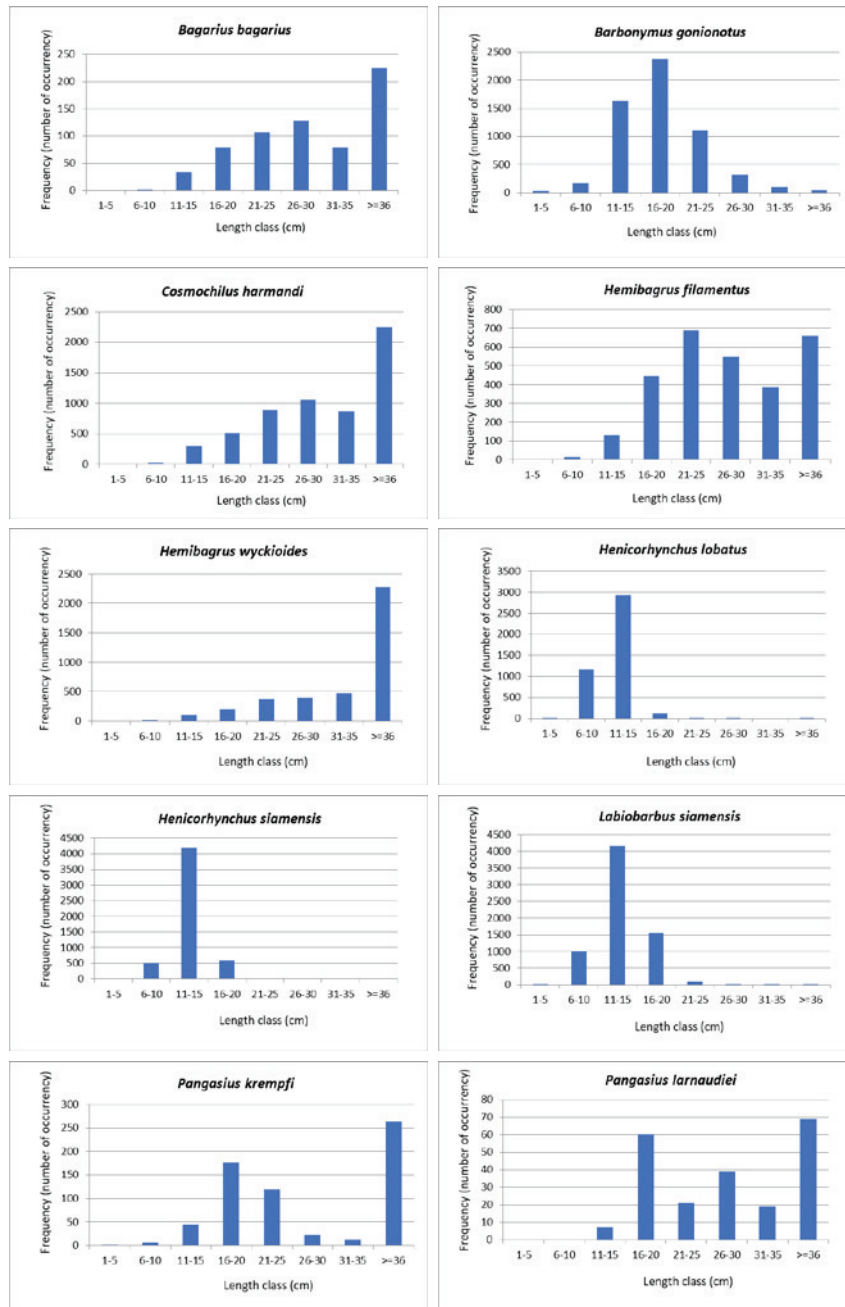




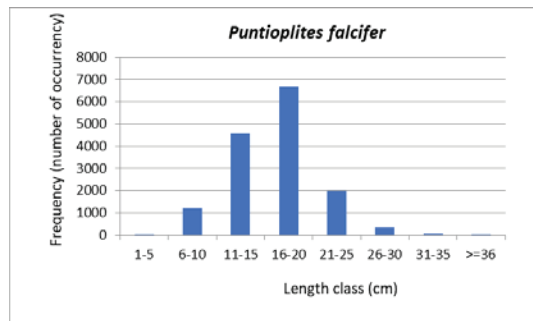
STATUS AND TRENDS OF FISH ABUNDANCE AND DIVERSITY IN THE LOWER MEKONG BASIN DURING 2007–2018



Annex 3: Distribution of Maximum Length for Important Species in 2018



STATUS AND TRENDS OF FISH ABUNDANCE AND DIVERSITY IN THE LOWER MEKONG BASIN DURING 2007–2018



Annex 4: LMB Fish Species List with Short Names, Invasion Status, Guild and Conservation Status

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	<i>Aaptosyax grypus</i>	Aapypu	Indigenous	G3	CR
Cypriniformes	Cyprinidae	<i>Abbottina rivularis</i>	Abbvul	Exotic	G11	NA
Cypriniformes	Cobitidae	<i>Acantopsis</i> sp.	Aca.	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsis</i> sp.1	Aca.1	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsis</i> sp.2	Aca.2	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsis</i> sp.5	Aca.5	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsoides gracilentus</i>	Acaaci	Indigenous	G3	LC
Cypriniformes	Cobitidae	<i>Acantopsis</i> sp "cheek spot"	Acaeek	Indigenous	G3	NA
Siluriformes	Siluridae	<i>Acanthocobitis</i> sp. cf. bilotorio	Acalot	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsoides delphax</i>	Acalph	Indigenous	G3	LC
Cypriniformes	Cobitidae	<i>Acantopsis</i> spp. Thai Catch/ Mkt	Acanspp	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsoides</i> spp. Thai Catch	Acanth	Indigenous	G3	NA
Cypriniformes	Cobitidae	<i>Acanthopsoides hapalias</i>	Acapal	Indigenous	G3	LC
Pleuronectiformes	Soleidae	<i>Achiroides melanorhynchus</i>	Achlan	Indigenous	G7	NA
Cypriniformes	Cyprinidae	<i>Acheilognathus barbatulus</i>	Achrba	Indigenous	G4	LC
Pleuronectiformes	Soleidae	<i>Achiroides leucorhynchus</i>	Achuco	Indigenous	G7	NA
Myliobatiformes	Myliobatidae	<i>Aetomylaeus nichofii</i>	Aetcho	Indigenous	G10	NA
Siluriformes	Akysidae	<i>Akysis brachybarbatus</i>	Akyach	Indigenous	G1	NA
Siluriformes	Akysidae	<i>Akysis inermis</i>	Akyerm	Indigenous	G3	NA
Siluriformes	Akysidae	<i>Akysis similis</i>	Akymil	Indigenous	G3	NA
Siluriformes	Akysidae	<i>akysis hendricksoni</i>	akyndr	NA	?	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Siluriformes	Akysidae	Akysis varius	Akyriu	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Albulichthys albuloides	Albbul	Indigenous	G3	LC
Batrachoidiformes	Batrachoididae	Allenbatrachus grunniens	Allunn	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Amblyrhynchichthys micracanthus	Ambcra	Indigenous	G3	LC
Siluriformes	Amblycipitidae	Amblyceps mucronatum	Ambcro	Indigenous	G1	NA
Perciformes	Gobiidae	Amblyotrypauchen arctocephalus	Ambcto	Indigenous	G7	NA
Perciformes	Chandidae	Ambassis gymnocephalus	Ambmno	Indigenous	G7	NA
Siluriformes	Amblycipitidae	Amblyceps foratum	Ambrat	Indigenous	G1	LC
Perciformes	Chandidae	Ambassis buruensis	Ambrue	Indigenous	G7	NA
Perciformes	Ambassidae	Ambassidae spA Thai Catch	AmbspA	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Amblyrhynchichthys truncatus	Ambunc	Indigenous	G3	NA
Perciformes	Anabantidae	Anabas testudineus	Anastu	Indigenous	G6	DD
Anguilliformes	Anguillidae	Anguilla bicolor	Angcol	Indigenous	G9	NA
Anguilliformes	Anguillidae	Anguilla marmorata	Angrmo	Indigenous	G9	NA
Clupeiformes	Clupeidae	Anodontostoma chacunda	Anoacu	Indigenous	G10	NA
Cyprinodontiformes	Aplocheilidae	Aplocheilus panchax	Aplnch	Indigenous	G7	LC
Perciformes	Gobiidae	Apocryptodon madurensis	Apodur	Indigenous	G7	NA
Siluriformes	Ariidae	Arius macracanthus	Aricra	Indigenous	?	NA
Siluriformes	Ariidae	Arius macronotacanthus	Aricro	Indigenous	G7	NA
Siluriformes	Ariidae	Arius maculatus	Aricul	Indigenous	G7	NA
Siluriformes	Ariidae	Arius caelatus	Ariela	Indigenous	G7	NA
Siluriformes	Ariidae	Arius sagor	Arigor	Indigenous	G7	NA
Siluriformes	Ariidae	Arius argyropleuron	Arigyr	Indigenous	G7	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Siluriformes	Ariidae	<i>Arius sciurus</i>	Ariiur	Indigenous	G7	NA
Siluriformes	Ariidae	<i>Arius malacanthus</i>	Arilac	Indigenous	G2	NA
Siluriformes	Ariidae	<i>Arius venosus</i>	Arinos	Indigenous	G7	NA
Siluriformes	Ariidae	<i>Arius crossocheilos</i>	Arioss	Indigenous	G7	NA
Siluriformes	Ariidae	<i>Arius leptonotacanthus</i>	Aripto	Indigenous	G7	NA
Siluriformes	Ariidae	<i>Arius truncatus</i>	Ariunc	Indigenous	G7	NA
Perciformes	Sciaenidae	<i>Aspericorvina jubata</i>	Aspbat	Indigenous	G10	NA
Perciformes	Carangidae	<i>Atule mat</i>	Atut	Indigenous	G10	NA
Tetraodontiformes	Tetraodontidae	<i>Auriglobus modestus</i>	Aurdes	Indigenous	G1	LC
Perciformes	Nandidae	<i>Badis ruber</i>	Badber	Indigenous	G4	LC
Siluriformes	Sisoridae	<i>Bagarius suchus</i>	Bagchu	Indigenous	G1	NT
Siluriformes	Bagridae	<i>Bagrichthys macracanthus</i>	Bagcra	Indigenous	G3	NA
Siluriformes	Sisoridae	<i>Bagarius bagarius</i>	Baggar	Indigenous	G1	NT
Siluriformes	Sisoridae	<i>Bagarius yarrelli</i>	Bagrre	Indigenous	G1	NT
Siluriformes	Bagridae	<i>Bagrichthys obscurus</i>	Bagscu	Indigenous	G3	LC
Perciformes	Sciaenidae	<i>Bahaba polykladiskos</i>	Bahlyk	Indigenous	G10	NA
Cypriniformes	Cyprinidae	<i>Balantiocheilos melanopterus</i>	Ballan	Indigenous	G3	NA
Cypriniformes	Cyprinidae	<i>Bangana elegans</i>	Banega	Indigenous	G3	NT
Cypriniformes	Cyprinidae	<i>Bangana behri</i>	Banhri	Indigenous	G3	VU
Cypriniformes	Cyprinidae	<i>Bangana lippus</i>	Banppu	Indigenous	G3	NA
Cypriniformes	Cyprinidae	<i>Bangana sp.</i>	Bansp	Indigenous	G3	NA
Cypriniformes	Cyprinidae	<i>Barbonymus schwanenfeldii</i>	Barhwa	Indigenous	G4	LC
Cypriniformes	Cyprinidae	<i>Barbonymus gonionotus</i>	Barnio	Indigenous	G5	LC
Cypriniformes	Cyprinidae	<i>Barbichthys nitidus</i>	Bartid	Indigenous	G3	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	Barbonymus altus	Bartus	Indigenous	G4	LC
Batrachoidiformes	Batrachoididae	Batrachomoeus trispinosus	Batisp	Indigenous	G7	NA
Siluriformes	Ariidae	Batrachocephalus mino	Batno	Indigenous	G7	NA
Batrachoidiformes	Batrachoididae	Batrichthys grunniens	Batunn	Indigenous	G7	NA
Siluriformes	Siluridae	Belodontichthys dinema	Belnem	Exotic	G11	NA
Siluriformes	Siluridae	Belodontichthys truncatus	Belunc	Indigenous	G3	LC
Perciformes	Osphronemidae	Betta smaragdina	Betara	Indigenous	G6	DD
Perciformes	Osphronemidae	Betta prima	Betima	Indigenous	G6	LC
Perciformes	Sciaenidae	Boesemania microlepis	Boecro	Indigenous	G4	NT
Cypriniformes	Cyprinidae	Boraras micros	Borcro	Indigenous	G6	LC
Cypriniformes	Cyprinidae	Boraras urophthalmoides	Boroph	Indigenous	G6	NT
Perciformes	Eleotridae	Bostrychus sinensis	Bosnen	Indigenous	G10	LC
Cypriniformes	Cobitidae	Botia beauforti	Botauf	Indigenous	G3	NA
Siluriformes	Siluridae	Botia sp. cf. beauforti	Botaufo	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia lecontei	Botcon	Indigenous	G3	NA
Siluriformes	Siluridae	Botia sp. cf. lecontei	Botcont	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia modesta	Botdes	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia sidthimunki	Botdth	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia eos	Boteos	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia nigrolineata	Botgro	Indigenous	G3	VU
Cypriniformes	Cobitidae	Botia splendida	Botlen	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia helodes	Botlod	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia longidorsalis	Botngi	Indigenous	G3	NA
Cypriniformes	Cobitidae	Botia morleti	Botrle	Indigenous	G3	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cobitidae	Botia caudipunctata	Botudi	Indigenous	G3	NA
Pleuronectiformes	Soleidae	Brachirus orientalis	Braien	Indigenous	G10	NA
Pleuronectiformes	Soleidae	Brachirus panoides	Branoi	Indigenous	G7	LC
Pleuronectiformes	Soleidae	Brachirus harmandi	Brarma	Indigenous	G5	LC
Perciformes	Eleotridae	Butis amboinensis	Butboi	Indigenous	G7	NA
Perciformes	Eleotridae	Butis koilomatodon	Butilo	Indigenous	G7	NA
Perciformes	Eleotridae	Butis butis	Buttis	Indigenous	G7	LC
Perciformes	Carangidae	Carangoides armatus	Carmat	Indigenous	G10	NA
Carcharhiniformes	Carcharhinidae	Carcharhinus limbatus	Carmba	Indigenous	G10	NA
Tetraodontiformes	Tetraodontidae	Carinotetraodon lorteti	Carrte	Indigenous	G7	LC
Carcharhiniformes	Carcharhinidae	Carcharhinus dussumieri	Carssu	Indigenous	G10	NA
Carcharhiniformes	Carcharhinidae	Carcharhinus leucas	Caruca	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Catlocarpio siamensis	Catame	Indigenous	G10	CR
Siluriformes	Siluridae	Ceratoglanis pachynema	Cerchy	Indigenous	G3	NA
Perciformes	Channidae	Channa grandinosa	Chaand	Indigenous	G6	NA
Perciformes	Channidae	Channa gachua	Chachu	Indigenous	G1	LC
Perciformes	Channidae	Channa lucius	Chaciu	Indigenous	G6	LC
Perciformes	Channidae	Channa micropeltes	Chacro	Indigenous	G6	LC
Perciformes	Channidae	Channa melasoma	Chalas	Indigenous	G6	NA
Perciformes	Channidae	Channa limbata	Chamba	Indigenous	G1	NA
Perciformes	Channidae	Channa striata	Charia	Indigenous	G6	LC
Perciformes	Channidae	Channa maruloides	Charul	Indigenous	G6	NA
Synbranchiformes	Chaudhuriidae	Chaudhuria fuspinnis	Chasip	Indigenous	G6	DD
Mugiliformes	Mugilidae	Chelon subviridis	Chebvi	Indigenous	G10	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	<i>Chela laubuca</i>	Cheubu	Indigenous	G4	NA
Osteoglossiformes	Notopteridae	<i>Chitala blanci</i>	Chianc	Indigenous	G1	NT
Osteoglossiformes	Notopteridae	<i>Chitala ornata</i>	Chinat	Indigenous	G5	LC
Osteoglossiformes	Notopteridae	<i>Chitala lopis</i>	Chipis	Indigenous	G3	LC
Scorpaeniformes	Scorpaenidae	<i>Choriodactylus multibarbus</i>	Cholti	Indigenous	G10	NA
Perciformes	Sciaenidae	<i>Chrysochir aureus</i>	Chrreu	Indigenous	G10	NA
Cypriniformes	Cyprinidae	<i>Cirrhinus microlepis</i>	Circro	Indigenous	G3	VU
Cypriniformes	Cyprinidae	<i>Cirrhinus spilopleura</i>	Cirilo	Indigenous	G3	NA
Cypriniformes	Cyprinidae	<i>Cirrhinus molitorella</i>	Cirlit	Indigenous	G3	NT
Cypriniformes	Cyprinidae	<i>Cirrhinus jullieni</i>	Cirlli	Indigenous	G3	DD
Cypriniformes	Cyprinidae	<i>Cirrhinus prosemion</i>	Cirose	Indigenous	G3	NA
Cypriniformes	Cyprinidae	<i>Cirrhinus cirrhosus</i>	Cirrrh	Exotic	G11	NA
Siluriformes	Clariidae	<i>Clarias macrocephalus</i>	Clacro	Indigenous	G6	NT
Siluriformes	Clariidae	<i>Clarias nieuhofi</i>	Claeuh	Indigenous	G6	NA
Siluriformes	Clariidae	<i>Clarias meladerma</i>	Clalad	Indigenous	G6	NA
Siluriformes	Clariidae	<i>Clarias gariepinus</i>	Clarie	Exotic	G11	NA
Siluriformes	Clariidae	<i>Clarias fuscus</i>	Clascu	Indigenous	G6	LC
Siluriformes	Clariidae	<i>Clarias sp.</i>	Clasp	Exotic	G6	NA
Siluriformes	Clariidae	<i>Clarias cataractus</i>	Clatar	Indigenous	G6	NA
Siluriformes	Clariidae	<i>Clarias batrachus</i>	Clatra	Indigenous	G6	LC
Siluriformes	Schilbeidae	<i>Clupisoma sinensis</i>	Clunen	Indigenous	G3	LC
Siluriformes	Schilbeidae	<i>Clupisoma longianalis</i>	Clungi	Indigenous	G3	NA
Clupeiformes	Clupeidae	<i>Clupeoides borneensis</i>	Clurne	Indigenous	G3	LC
Clupeiformes	Clupeidae	<i>Clupeichthys aesarnensis</i>	Clusar	Indigenous	G3	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Clupeiformes	Engraulidae	Coilia rebentischii	Coiben	Indigenous	G10	NA
Clupeiformes	Engraulidae	Coilia macrognathos	Coicro	Indigenous	G10	NA
Clupeiformes	Engraulidae	Coilia lindmani	Coindm	Indigenous	G7	LC
Characiformes	Characidae	Colossoma macropomum	Colcro	Exotic	G11	NA
Anguilliformes	Muraenesocidae	Congresox talabon	Conlab	Indigenous	G10	NA
Anguilliformes	Muraenesocidae	Congresox talabonoides	Conlabo	Indigenous	G10	NA
Clupeiformes	Clupeidae	Corica soborna	Corbor	Indigenous	G3	NA
Clupeiformes	Clupeidae	Corica laciniata	Corcin	Indigenous	G3	NA
Cypriniformes	Cyprinidae	Cosmochilus cardinalis	Cosrdi	Indigenous	G2	NA
Cypriniformes	Cyprinidae	Cosmochilus harmandi	Cosrma	Indigenous	G2	LC
Cypriniformes	Cyprinidae	Crossocheilus cobitis	Crobit	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Crossocheilus atrilimes	Croril	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Crossocheilus reticulatus	Crotic	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Ctenopharyngodon idella	Cteell	Exotic	G4	NA
Cypriniformes	Cyprinidae	Cyclocheilichthys lagleri	Cycgle	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Cyclocheilichthys mekongensis	Cyckon	Indigenous	G4	NA
Cypriniformes	Cyprinidae	Cyclocheilichthys armatus	Cycmat	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Cyclocheilichthys apogon	Cycogo	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Cyclocheilichthys enoplos	Cycopl	Indigenous	G2	LC
Cypriniformes	Cyprinidae	Cyclocheilichthys repasson	Cycpas	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Cyclocheilichthys tapiensis	Cycpie	Indigenous	G4	NA
Cypriniformes	Cyprinidae	Cyclocheilichthys furcatus	Cycrca	Indigenous	G2	LC
Cypriniformes	Cyprinidae	Cyclocheilichthys spA Thai Catch	CycspA	Indigenous	G4	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	Cyclocheilichthys heteronema	Cycter	Indigenous	G4	LC
Pleuronectiformes	Cynoglossidae	Cynoglossus microlepis	Cyncro	Indigenous	G10	LC
Pleuronectiformes	Cynoglossidae	Cynoglossus feldmanni	Cynldm	Indigenous	G10	LC
Pleuronectiformes	Cynoglossidae	Cynoglossus bilineatus	Cynlin	Indigenous	G10	NA
Pleuronectiformes	Cynoglossidae	Cynoglossus puncticeps	Cynnct	Indigenous	G10	NA
Pleuronectiformes	Cynoglossidae	Cynoglossus lingua	Cynngu	Indigenous	G10	NA
Pleuronectiformes	Cynoglossidae	Cynoglossus cynoglossus	Cynnog	Indigenous	G10	NA
Beloniformes	Exocoetidae	Cypselurus poecilopterus	Cypeci	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Cyprinus barbatus	Cyprba	Indigenous	G4	NA
Cypriniformes	Cyprinidae	Cyprinus carpio	Cyprpi	Exotic	G11	NA
Cypriniformes	Cyprinidae	Danio tweediei	Daneed	Indigenous	G6	NA
Cypriniformes	Cyprinidae	Danio roseus	Danseu	Indigenous	G6	LC
Myliobatiformes	Dasyatidae	Dasyatis zugei	Dasgei	Indigenous	G10	NA
Myliobatiformes	Dasyatidae	Dasyatis laosensis	Dasose	Indigenous	G3	EN
Perciformes	Datnioididae	Datnioides polota	Datadr	Indigenous	G7	LC
Perciformes	Datnioididae	Datnioides undecimradiatus	Datdec	Indigenous	G3	VU
Perciformes	Sciaenidae	Dendrophysa russellii	Densse	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Devario gibber	Devbbe	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Devario fangfangae	Devngf	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Devario leptos	Devpto	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Discherodontus ashmeadi	Dishme	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Discherodontus schroederi	Dishro	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Discherodontus parvus	Disrvu	Indigenous	G1	DD
Perciformes	Eleotridae	Eleotris acanthopomus	Eleant	Indigenous	G7	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Perciformes	Eleotridae	Eleotris fusca	Elesca	Indigenous	G7	LC
Perciformes	Polynemidae	Eleutheronema tetradactylum	Eletra	Indigenous	G7	NA
Mugiliformes	Mugilidae	Ellochelon vaigiensis	Elligi	Indigenous	G7	NA
Elopiformes	Elopidae	Elops hawaiiensis	Eloaie	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Epalzeorhynchus frenatum	Epaena	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Epalzeorhynchus munense	Epanen	Indigenous	G1	VU
Cypriniformes	Cyprinidae	Esomus longimana	Esongi	Indigenous	G6	NA
Cypriniformes	Cyprinidae	Esomus metallicus	Esotal	Indigenous	G6	LC
Perciformes	Gobiidae	Eugnathogobius microps	Eugcro	Indigenous	G7	NA
Perciformes	Polynemidae	Filimanus heptadactyla	Filpta	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Folifer brevifilis	Folevi	Indigenous	G3	DD
Cyprinodontiformes	Poeciliidae	Gambusia affinis	Gamfin	Exotic	G11	NA
Cypriniformes	Cyprinidae	Garra theunensis	Gareun	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Garra cambodgiensis	Garmbo	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Garra cyrano	Garran	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Garra fasciacauda	Garsci	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Gibelion catla	Gibtla	Exotic	G11	NA
Perciformes	Gobiidae	Glossogobius aureus	Gloreu	Indigenous	G7	LC
Perciformes	Gobiidae	Glossogobius giuris	Glouri	Indigenous	G7	LC
Siluriformes	Sisoridae	Glyptothorax macromaculatus	Glycro	Indigenous	G1	LC
Siluriformes	Sisoridae	Glyptothorax laosensis	Glyose	Indigenous	G1	LC
Siluriformes	Sisoridae	Glyptothorax horai	Glyrai	Indigenous	G1	LC
Siluriformes	Sisoridae	Glyptothorax fuscus	Glyscu	Indigenous	G1	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Perciformes	Gobiidae	Gobiopterus brachypterus	Gobach	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Gobiobotia yuanjianensis	Gobanj	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Gobiobotia longibarba	Gobngi	Indigenous	G1	NA
Anguilliformes	Muraenidae	Gymnothorax pictus	Gymctu	Indigenous	G10	NA
Anguilliformes	Muraenidae	Gymnothorax tile	Gymle	Indigenous	G10	NA
Cypriniformes	Gyrinocheilidae	Gyrinocheilus aymonieri	Gyrmon	Indigenous	G3	LC
Cypriniformes	Gyrinocheilidae	Gyrinocheilus pennocki	Gyrnno	Indigenous	G3	LC
Cypriniformes	Cyprinidae	Hampala macrolepidota	Hamcro	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Hampala dispar	Hamspa	Indigenous	G5	LC
Aulopiformes	Harpadontinae	Harpadon nehereus	Harher	Indigenous	G10	NA
Siluriformes	Pangasiidae	Helicophagus waandersii	Heland	Indigenous	G3	NA
Perciformes	Helostomatidae	Helostoma temminckii	Helmmi	Indigenous	G4	LC
Siluriformes	Pangasiidae	Helicophagus leptorhynchus	Helpto	Indigenous	G3	DD
Cypriniformes	Cyprinidae	Hemibarbus labeo	Hembeo	Exotic	G11	NA
Siluriformes	Bagridae	Hemibagrus wyckioides	Hemcki	Indigenous	G3	LC
Siluriformes	Bagridae	Hemibagrus wyckii	Hemckii	Indigenous	G3	LC
Beloniformes	Hemiramphidae	Hemirhamphodon pogonognathus	Hemgon	Indigenous	G10	NA
Cypriniformes	Balitoridae	Hemimyzon tchangi	Hemhan	Indigenous	G1	NA
Siluriformes	Bagridae	Hemibagrus spilopterus	Hemilo	Indigenous	G3	LC
Siluriformes	Bagridae	Hemibagrus sp.	Hemisp	Indigenous	G3	NA
Siluriformes	Siluridae	Hemisilurus mekongensis	Hemkon	Indigenous	G3	LC
Siluriformes	Bagridae	Hemibagrus filamentus	Hemlam	Indigenous	G3	DD
Siluriformes	Bagridae	Hemibagrus nemurus	Hemmur	Indigenous	G3	LC
Cypriniformes	Balitoridae	Hemimyzon confluens	Hemnfl	Indigenous	G1	VU

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Balitoridae	Hemimyzon pengi	Hemngi	Indigenous	G1	DD
Siluriformes	Ariidae	Hemiarius stormii	Hemorm	Indigenous	G7	NA
Cypriniformes	Balitoridae	Hemimyzon papilio	Hempil	Indigenous	G1	LC
Siluriformes	Ariidae	Hemipimelodus borneensis	Hemrne	Indigenous	G7	NA
Siluriformes	Ariidae	Hemiarius verrucosus	Hemrru	Indigenous	G7	NA
Siluriformes	Ariidae	Hemipimelodus intermedius	Hemter	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Henicorhynchus siamensis	Hename	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Henicorhynchus lobatus	Henbat	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Henicorhynchus ornatipinnis	Hennat	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Henicorhynchus lineatus	Hennea	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Henicorhynchus caudimaculatus	Henudi	Indigenous	G5	NA
Siluriformes	Bagridae	Heterobagrus bocourti	Hetcou	Indigenous	G4	NA
Siluriformes	Heteropneustidae	Heteropneustes kemratisensis	Hetmra	Indigenous	G6	NA
Myliobatiformes	Dasyatidae	Himantura imbricata	Himbri	Indigenous	G10	NA
Myliobatiformes	Dasyatidae	Himantura undulata	Himdul	Indigenous	G10	NA
Myliobatiformes	Dasyatidae	Himantura krempfi	Himemp	Indigenous	G3	NA
Myliobatiformes	Dasyatidae	Himantura signifer	Himgni	Indigenous	G10	EN
Myliobatiformes	Dasyatidae	Himantura uarnak	Himrna	Indigenous	G10	NA
Myliobatiformes	Dasyatidae	Himantura oxyrhynchus	Himyrh	Indigenous	G10	EN
Cypriniformes	Balitoridae	Homaloptera indochinensis	Homdoc	Indigenous	G1	NA
Cypriniformes	Balitoridae	Homaloptera vulgaris	Homlga	Indigenous	G1	NA
Cypriniformes	Balitoridae	Homaloptera zollingeri	Homlli	Indigenous	G1	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Balitoridae	Homaloptera yunnanensis	Homnna	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Hypophthalmichthys nobilis	Hypbil	Exotic	G11	NA
Siluriformes	Loricariidae	Hypostomus plecostomus	Hypeco	Exotic	G3	NA
Cypriniformes	Cyprinidae	Hypsibarbus pierrei	Hyperr	Indigenous	G3	DD
Cypriniformes	Cyprinidae	Hypsibarbus lagleri	Hypgle	Indigenous	G3	VU
Cypriniformes	Cyprinidae	Hypsibarbus malcolmi	Hypico	Indigenous	G3	LC
Cypriniformes	Cyprinidae	Hypophthalmichthys molitrix	Hypplit	Exotic	G11	NA
Beloniformes	Hemiramphidae	Hyporhamphus limbatus	Hypmba	Indigenous	G7	LC
Cypriniformes	Cyprinidae	Hypsibarbus vernayi	Hyprna	Indigenous	G3	LC
Beloniformes	Hemiramphidae	Hyporhamphus intermedius	Hyppter	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Hypsibarbus wetmorei	Hypmo	Indigenous	G3	LC
Cypriniformes	Cyprinidae	Hypsibarbus suvattii	Hypvat	Indigenous	G3	NA
Perciformes	Sciaenidae	Johnius trachycephalus	Johach	Indigenous	G10	NA
Perciformes	Sciaenidae	Johnius belangerii	Johlan	Indigenous	G10	NA
Perciformes	Sciaenidae	Johnius borneensis	Johrne	Indigenous	G10	NA
Perciformes	Sciaenidae	Johnius carouna	Johrou	Indigenous	G10	NA
Siluriformes	Siluridae	Kryptopterus bicirrhis	Krycir	Indigenous	G3	LC
Siluriformes	Siluridae	Kryptopterus micronema	Krycro	Indigenous	G3	NA
Siluriformes	Siluridae	Kryptopterus cheveyi	Kryeve	Indigenous	G3	NA
Siluriformes	Siluridae	Kryptopterus schilbeides	Kryhil	Indigenous	G3	NA
Siluriformes	Siluridae	Kryptopterus palembangensis	Krylem	Indigenous	G3	NA
Siluriformes	Siluridae	Kryptopterus geminus	Krymin	Indigenous	G3	LC
Siluriformes	Siluridae	Kryptopterus limpok	Krympo	Indigenous	G3	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Siluriformes	Siluridae	Kryptopterus sp.	Krypsp	Indigenous	G3	NA
Siluriformes	Siluridae	Kryptopterus dissitus	Kryssi	Indigenous	G3	DD
Siluriformes	Siluridae	Kryptopterus kryptopterus	Krypyt	Indigenous	G3	NA
Cypriniformes	Cyprinidae	Labiobarbus siamensis	Labame	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Labeo pierrei	Laberr	Indigenous	G3	VU
Cypriniformes	Cyprinidae	Labeo rohita	Labhit	Exotic	G11	NA
Cypriniformes	Cyprinidae	Labiobarbus lineata	Labnea	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Labeo dyocheilus	Laboch	Exotic	G11	LC
Cypriniformes	Cyprinidae	Labiobarbus kuhli	Labpto	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Labeo chrysophekadion	Labrys	Indigenous	G3	LC
Cypriniformes	Cyprinidae	Labiobarbus sp. cf. lineata	Labsp	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Labeo erythropterus	Labyth	Exotic	G11	NA
Tetraodontiformes	Tetraodontidae	Lagocephalus spadiceus	Lagadi	Indigenous	G10	NA
Siluriformes	Schilbeidae	Laides longibarbis	Laingi	Indigenous	G3	LC
Cypriniformes	Cyprinidae	Laocypris hispida	Laospi	Indigenous	G4	DD
Perciformes	Centropomidae	Lates calcarifer	Latlca	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Leptobarbus hoeveni	Lepeve	Exotic	G11	NA
Cypriniformes	Cobitidae	Lepidocephalichthys hasselti	Lepsse	Indigenous	G6	LC
Perciformes	Trichiuridae	Lepturacanthus savala	Lepval	Indigenous	?	NA
Cypriniformes	Cyprinidae	Lobocheilos rhabdoura	Lobabd	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Lobocheilos gracilis	Lobaci	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Lobocheilos melanotaenia	Loblan	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Lobocheilos davisii	Lobvis	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Longiculus siahii	Lonahi	Indigenous	No Data	DD

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	Luciosoma bleekeri	Luceek	Indigenous	G3	LC
Cypriniformes	Cyprinidae	Luciocyprinus striolatus	Lucrio	Indigenous	G3	EN
Cypriniformes	Cyprinidae	Luciosoma setigerum	Luctig	Indigenous	G3	DD
Perciformes	Lutjanidae	Lutjanus johnii	Luthni	Indigenous	G10	NA
Perciformes	Lutjanidae	Lutjanus malabaricus	Lutlab	Indigenous	G10	NA
Perciformes	Lutjanidae	Lutjanus russellii	Lutsse	Indigenous	G10	NA
Clupeiformes	Engraulidae	Lycothrissa crocodilus	Lycoco	Indigenous	G7	LC
Synbranchiformes	Mastacembelidae	Macrogathus siamensis	Macame	Indigenous	G6	LC
Cypriniformes	Cyprinidae	Macrochirichthys macrochirus	Maccro	Indigenous	G4	NT
Synbranchiformes	Mastacembelidae	Macrogathus maculatus	Maccul	Indigenous	G6	LC
Synbranchiformes	Mastacembelidae	Macrogathus taeniagaster	Maceni	Indigenous	G6	NA
Perciformes	Belontiidae	Macropodus opercularis	Macerc	Exotic	G11	LC
Synbranchiformes	Synbranchidae	Macrotrema caligans	Maclig	Indigenous	G7	NA
Synbranchiformes	Mastacembelidae	Macrogathus semiocellatus	Macmio	Indigenous	G6	LC
Synbranchiformes	Mastacembelidae	Macrogathus circumcinctus	Macrcu	Indigenous	G6	LC
Perciformes	Gobiidae	Mahidolia mystacina	Mahsta	Indigenous	G10	NA
Synbranchiformes	Mastacembelidae	Mastacembelus armatus	Masmat	Indigenous	G5	LC
Synbranchiformes	Mastacembelidae	Mastacembelus favus	Masvus	Indigenous	G5	LC
Synbranchiformes	Mastacembelidae	Mastacembelus erythrotaenia	Masyth	Indigenous	G5	LC
Elopiformes	Megalopidae	Megalops cyprinoides	Megpri	Indigenous	G10	DD
Cypriniformes	Cyprinidae	Mekongina erythrospila	Mekyth	Indigenous	G1	NT
Cypriniformes	Cyprinidae	Metzia lineata	Metnea	Indigenous	G1	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Siluriformes	Siluridae	Micronema bleekeri	Miceek	Indigenous	G3	NA
Siluriformes	Siluridae	Micronema cheveyi	Miceve	Indigenous	G3	DD
Siluriformes	Siluridae	Micronema apogon	Micogo	Indigenous	G3	NA
Siluriformes	Siluridae	Micronema hexapterus	Micxap	Indigenous	G3	NA
Cypriniformes	Cobitidae	Misgurnus anguillicaudatus	Misgui	Exotic	G11	NA
Synbranchiformes	Synbranchidae	Monopterus albus	Monbus	Indigenous	G6	LC
Tetraodontiformes	Tetraodontidae	Monotrete cochinchinensis	Monchi	Indigenous	G6	LC
Tetraodontiformes	Tetraodontidae	Monotrete abei	Monei	Indigenous	G3	NA
Perciformes	Monodactylidae	Monodactylus argenteus	Mongen	Indigenous	G10	NA
Tetraodontiformes	Tetraodontidae	Monotrete baileyi	Monile	Indigenous	G1	LC
Tetraodontiformes	Tetraodontidae	Monotrete leiurus	Moniur	Indigenous	G7	NA
Tetraodontiformes	Tetraodontidae	Monotrete cambodgiensis	Monmbo	Indigenous	G4	LC
Tetraodontiformes	Tetraodontidae	Monotrete fangi	Monngi	NA	G7	NA
Tetraodontiformes	Tetraodontidae	Monotrete barbatus	Monrba	Indigenous	G7	NA
Tetraodontiformes	Tetraodontidae	Monotrete turgidus	Monrgi	Indigenous	G1	LC
Tetraodontiformes	Tetraodontidae	Monotrete suvattii	Monvat	Indigenous	G4	LC
Mugiliformes	Mugilidae	Moolgarda pedaraki	Moodar	Indigenous	G10	NA
Mugiliformes	Mugilidae	Moolgarda seheli	Moohel	Indigenous	G10	NA
Mugiliformes	Mugilidae	Mugil cephalus	Mugpha	Indigenous	G10	NA
Perciformes	Gobiidae	Mugilogobius chulae	Mugula	Indigenous	G7	LC
Anguilliformes	Muraenesocidae	Muraenesox bagio	Murgio	Indigenous	G10	NA
Anguilliformes	Muraenesocidae	Muraenesox cinereus	Murner	Indigenous	G10	NA
Siluriformes	Bagridae	Mystus albolineatus	Mysbol	Indigenous	G4	LC
Siluriformes	Bagridae	Mystus micracanthus	Myscra	Indigenous	G4	NA

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Cypriniformes	Cyprinidae	Mystacoleucus greenwayi	Myseen	Indigenous	G1	LC
Siluriformes	Bagridae	Mystus rhegma	Mysegm	Indigenous	G4	DD
Cypriniformes	Cyprinidae	Mystacoleucus chlopterus	Mysilo	Indigenous	G1	LC
Siluriformes	Bagridae	Mystus wolffii	Myslff	Indigenous	G4	NA
Siluriformes	Bagridae	Mystus cf wolffi	Myslffi	Indigenous	G4	NA
Siluriformes	Bagridae	Mystus gulio	Mysllo	Indigenous	G4	LC
Siluriformes	Bagridae	Mystus multiradiatus	Mysliti	Indigenous	G4	LC
Siluriformes	Bagridae	Mystus nemurus	Mysmur	Indigenous	G3	NA
Siluriformes	Bagridae	Mystus singaringan	Mysnga	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Mystacoleucus lepturus	Mysptu	Indigenous	G1	VU
Cypriniformes	Cyprinidae	Mystacoleucus marginatus	Mysrgi	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Mystacoleucus atridorsalis	Mysrid	Indigenous	G1	LC
Siluriformes	Bagridae	Mystus atrifasciatus	Mysrif	Indigenous	G4	LC
Siluriformes	Bagridae	Mystus mysticetus	Myssti	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Mystacoleucus ectypus	Mystyp	Indigenous	G1	LC
Perciformes	Nandidae	Nandus nebulosus	Nanbul	Indigenous	G7	LC
Perciformes	Nandidae	Nandus oxyrhynchus	Nanyrh	Indigenous	G4	LC
Cypriniformes	Balitoridae	Nemacheilus pallidus	Nemlli	Indigenous	G1	LC
Cypriniformes	Balitoridae	Nemacheilus longistriatus	Nemngi	Indigenous	G1	LC
Clupeiformes	Clupeidae	Nematalosa nasus	Nemsus	Indigenous	G7	NA
Cypriniformes	Balitoridae	Nemacheilus masyae	Nemsya	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Neolissochilus blanci	Neoanc	Indigenous	G1	NT
Cypriniformes	Cyprinidae	Neobarynotus microlepis	Neocro	Exotic	G11	DD
Cypriniformes	Cyprinidae	Neolissochilus stracheyi	Neorac	Indigenous	G1	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	<i>Neolissochilus soroides</i>	Neoroi	Indigenous	G1	NA
Siluriformes	Ariidae	<i>Netuma thalassinus</i>	Netala	Indigenous	G7	NA
Siluriformes	Ariidae	<i>Netuma bilineatus</i>	Netlin	Indigenous	G7	NA
Perciformes	Sciaenidae	<i>Nibea soldado</i>	Niblda	Indigenous	G10	NA
Osteoglossiformes	Notopteridae	<i>Notopterus notopterus</i>	Nottop	Indigenous	G5	LC
Perciformes	Gobiidae	<i>Odontamblyopus tenuis</i>	Odonui	Indigenous	G10	NA
Perciformes	Odontobutidae	<i>Odontobutis aurarmus</i>	Odorar	Indigenous	G4	NA
Siluriformes	Siluridae	<i>Ompok siluroides</i>	Omplur	NA	G4	NA
Siluriformes	Siluridae	<i>Ompok hypophthalmus</i>	Omppop	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Onychostoma meridionale</i>	Onyrid	Indigenous	G1	LC
Cypriniformes	Cyprinidae	<i>Onychostoma gerlachi</i>	Onyrla	Indigenous	G1	NA
Cypriniformes	Cyprinidae	<i>Onychostoma fusiforme</i>	Onysif	Indigenous	G1	LC
Synbranchiformes	Synbranchidae	<i>Ophisternon bengalense</i>	Ophnga	Indigenous	G7	NA
Perciformes	Eleotridae	<i>Ophiocara porocephala</i>	Ophroc	Indigenous	G7	LC
Anguilliformes	Ophichthidae	<i>Ophichthus rutidoderma</i>	Ophtid	Indigenous	G10	NA
Clupeiformes	Clupeidae	<i>Opisthopterus tardoore</i>	Opirdo	Indigenous	G10	NA
Cypriniformes	Cyprinidae	<i>Opsarius pulchellus</i>	Opslch	Indigenous	G1	LC
Cypriniformes	Cyprinidae	<i>Opsarius koratensis</i>	Opsrat	Indigenous	G1	LC
Cypriniformes	Cyprinidae	<i>Opsarius caudicellatus</i>	Opsudi	Indigenous	G1	NA
Perciformes	Cichlidae	<i>Oreochromis niloticus</i>	Orelot	Exotic	G11	NA
Perciformes	Cichlidae	<i>Oreochromis aureus</i>	Orereu	Exotic	G11	NA
Cypriniformes	Cyprinidae	<i>Oreochromis parvus</i>	Orervu	Indigenous	G1	DD
Perciformes	Cichlidae	<i>Oreochromis mossambicus</i>	Oressa	Exotic	G11	NA
Beloniformes	Adrianichthyidae	<i>Oryzias pectoralis</i>	Orycto	Indigenous	G6	DD

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Beloniformes	Adrianichthyidae	Oryzias minutillus	Orynut	Indigenous	G6	LC
Aulopiformes	Synodontidae	Osmerus nelereus (Ca Khoai)	Osmere	NA	G10	NA
Perciformes	Osphronemidae	Osphronemus exodon	Ospodo	Indigenous	G1	VU
Perciformes	Osphronemidae	Osphronemus goramy	Ospram	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Osteochilus waandersii	Ostand	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Osteochilus microcephalus	Ostcro	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Osteochilus schlegeli	Osthle	Indigenous	G3	NA
Cypriniformes	Cyprinidae	Osteochilus melanopleura	Ostlan	Indigenous	G3	LC
Siluriformes	Ariidae	Osteogeneiosus militaris	Ostlit	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Osteochilus enneaporus	Ostnea	Indigenous	G5	NA
Cypriniformes	Cyprinidae	Osteochilus lini	Ostni	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Osteochilus hasselti	Ostsse	Indigenous	G5	NA
Perciformes	Sciaenidae	Otolithes ruber	Otober	NA	G10	NA
Perciformes	Sciaenidae	Otolithoides pama	Otoma	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Oxygaster pointoni	Oxyint	Indigenous	G3	VU
Perciformes	Eleotridae	Oxyeleotris marmorata	Oxyrmo	Indigenous	G5	LC
Siluriformes	Pangasiidae	Pangasius djambal	Panamb	Exotic	G11	NA
Siluriformes	Pangasiidae	Pangasius bocourti	Pancou	Indigenous	G2	LC
Siluriformes	Pangasiidae	Pangasius macronema	Pancro	Indigenous	G3	LC
Perciformes	Sciaenidae	Panna microdon	Pancrod	Indigenous	G10	NA
Siluriformes	Pangasiidae	Pangasius krempfi	Panemp	Indigenous	G8	VU
Cypriniformes	Cobitidae	Pangio myersi	Paners	Indigenous	G4	LC
Siluriformes	Pangasiidae	Pangasius pleurotaenia	Paneur	Indigenous	G3	NA
Siluriformes	Pangasiidae	Pangasianodon gigas	Pangas	Indigenous	G2	CR

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Siluriformes	Pangasiidae	Pangasius sp.	Pangsp	Indigenous	G3	NA
Cypriniformes	Cobitidae	Pangio anguillaris	Pangui	Indigenous	G4	NA
Siluriformes	Pangasiidae	Pangasius micronemus	Panicr	Indigenous	G3	NA
Siluriformes	Pangasiidae	Pangasius mekongensis	Pankon	Indigenous	G2	LC
Cypriniformes	Cobitidae	Pangio filinaris	Panlin	Indigenous	G4	NA
Cypriniformes	Cobitidae	Pangio oblonga	Panlon	Indigenous	G4	NA
Siluriformes	Pangasiidae	Pangasius polyuranodon	Panlyu	Exotic	G11	LC
Siluriformes	Pangasiidae	Pangasius conchophilus	Pannch	Indigenous	G2	LC
Siluriformes	Pangasiidae	Pangasius pangasius	Pannga	Exotic	G11	NA
Siluriformes	Pangasiidae	Pangasius sanitwongsei	Pannit	Indigenous	G2	CR
Siluriformes	Pangasiidae	Pangasius elongatus	Panong	Indigenous	G8	DD
Siluriformes	Pangasiidae	Pangasianodon hypophthalmus	Panpop	Indigenous	G2	EN
Siluriformes	Pangasiidae	Pangasius larnaudii	Panrna	Indigenous	G2	LC
Cypriniformes	Cobitidae	Pangio fusca	Pansca	Indigenous	G4	DD
Siluriformes	Pangasiidae	Pangasius nasutus	Pansut	Indigenous	?	NA
Siluriformes	Sisoridae	Pareuchiloglanis gracilicaudata	Paraci	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Parachela siamensis	Parame	Indigenous	G4	LC
Perciformes	Chandidae	Parambassis siamensis	Paramen	Indigenous	G5	LC
Cypriniformes	Cyprinidae	Parachela maculicauda	Parcul	Indigenous	G4	LC
Perciformes	Chandidae	Parambassis wolffi	Parlff	Indigenous	G4	NA
Pleuronectiformes	Cynoglossidae	Paraplagusia bilineata	Parlin	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Parachela williaminae	Parlli	Indigenous	G4	LC
Perciformes	Chandidae	Parambassis apogonoides	Parogo	Indigenous	G4	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	Paralaubuca typus	Parpus	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Paralaubuca harmandi	Parrma	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Paralaubuca barroni	Parro	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Paralaubuca riveroi	Parver	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Parachela oxygastroides	Paryga	Indigenous	G4	LC
Siluriformes	Sisoridae	Pareuchiloglanis myzostoma	Parzos	Indigenous	G1	NA
Myliobatiformes	Dasyatidae	Pastinachus sephen	Pasphe	Indigenous	G7	DD
Perciformes	Gerreidae	Pentaprion longimana	Penngi	Indigenous	G10	NA
Perciformes	Gobiidae	Periophthalmodon septemradiatus	Perpte	Indigenous	G7	NA
Cypriniformes	Balitoridae	Physoschistura meridionalis	Phyrid	Indigenous	G1	NA
Characiformes	Characidae	Piaractus brachypomus	Piaach	Exotic	G11	NA
Anguilliformes	Ophichthidae	Pisodonophis boro	Pisro	Indigenous	G8	NA
Scorpaeniformes	Platycephalidae	Platycephalus indicus	Pladic	Indigenous	G10	NA
Siluriformes	Plotosidae	Plotosus lineatus	Plonea	Indigenous	G10	NA
Siluriformes	Plotosidae	Plotosus canius	Ploniu	Indigenous	G7	NA
Perciformes	Polynemidae	Polynemus melanochir	Pollan	Indigenous	G7	LC
Perciformes	Polynemidae	Polynemus multifilis	Pollti	Indigenous	G7	NA
Perciformes	Polynemidae	Polynemus longipectoralis	Polngi	Indigenous	G7	NA
Perciformes	Polynemidae	Polynemus borneensis	Polrne	Indigenous	G7	NA
Perciformes	Polynemidae	Polynemus aquilonaris	Poluil	Indigenous	G7	LC
Cypriniformes	Cyprinidae	Poropuntius cf.laonensis	Por.la	Indigenous	?	NA
Cypriniformes	Cyprinidae	Poropuntius huangchuchieni	Porang	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Poropuntius deauratus	Poraur	Indigenous	G1	EN

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	Poropuntius sp. Cf. deauratus	Poraura	Indigenous	?	NA
Cypriniformes	Cyprinidae	Poropuntius speleops	Porele	Indigenous	G1	VU
Cypriniformes	Cyprinidae	Poropuntius exigua	Porigu	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Poropuntius solitus	Porlit	Indigenous	G1	EN
Cypriniformes	Cyprinidae	Poropuntius bolovenensis	Porlov	Indigenous	G1	EN
Cypriniformes	Cyprinidae	Poropuntius consternans	Pornst	Indigenous	G1	EN
Cypriniformes	Cyprinidae	Poropuntius bantamensis	Pornta	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Poropuntius laoensis	Poroen	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Poropuntius carinatus	Porrin	Indigenous	G1	LC
Rhinopristiformes	Pristidae	Pristis microdon	Pricro	Indigenous	G10	NA
Perciformes	Nandidae	Pristolepis fasciata	Prisci	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Probarbus labeamajor	Probea	Indigenous	G2	EN
Cypriniformes	Cyprinidae	Probarbus labeaminor	Probean	Indigenous	G2	NT
Cypriniformes	Cyprinidae	Probarbus jullieni	Prolli	Indigenous	G2	EN
Siluriformes	Bagridae	Pseudomystus siamensis	Pseame	Indigenous	G3	LC
Siluriformes	Bagridae	Pseudomystus stenomus	Pseeno	Indigenous	G3	NA
Siluriformes	Sisoridae	Pseudecheneis sulcatoides	Pselca	Indigenous	G1	NA
Siluriformes	Sisoridae	Pseudecheneis immaculata	Psemac	Indigenous	G1	DD
Siluriformes	Bagridae	Pseudomystus bomboides	Psembo	Indigenous	G3	DD
Cypriniformes	Cyprinidae	Pseudorasbora parva	Pserva	Exotic	G11	LC
Cypriniformes	Cyprinidae	Pseudohemiculter dispar	Psespa	Indigenous	G3	NA
Siluriformes	Loricariidae	Pterygoplichthys disjunctivus	Ptesju	Exotic	G11	NA
Cypriniformes	Cyprinidae	Puntioplites waandersi	Punand	Indigenous	G3	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	<i>Puntius brevis</i>	Punevi	Indigenous	G6	LC
Cypriniformes	Cyprinidae	<i>Puntius spilopterus</i>	Punilo	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Puntioplites falcifer</i>	Punlci	Indigenous	G3	LC
Cypriniformes	Cyprinidae	<i>Puntioplites bulu</i>	Punlu	Indigenous	G3	DD
Cypriniformes	Cyprinidae	<i>Puntius binotatus</i>	Punnot	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Puntioplites proctozysron</i>	Punoct	Indigenous	G3	NA
Cypriniformes	Cyprinidae	<i>Puntius stoliczkanus</i>	Punoli	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Puntius rhombeus</i>	Punomb	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Puntius orphoides</i>	Punpho	Indigenous	G5	NA
Cypriniformes	Cyprinidae	<i>Puntius partipentazona</i>	Punrti	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Racoma grisea</i>	Racise	Indigenous	G1	NA
Cypriniformes	Cyprinidae	<i>Racoma lantsangensis</i>	Racnts	Indigenous	G1	NA
Cypriniformes	Cyprinidae	<i>Raiamas guttatus</i>	Raitta	Indigenous	G1	LC
Perciformes	Scombridae	<i>Rastrelliger brachysoma</i>	Rasach	Indigenous	G10	NA
Cypriniformes	Cyprinidae	<i>Rasbora hobelmani</i>	Rasbel	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Rasbora rubrodorsalis</i>	Rasbro	Indigenous	G4	LC
Cypriniformes	Cyprinidae	<i>Rasbora myersi</i>	Rasers	Indigenous	G4	NA
Cypriniformes	Cyprinidae	<i>Rasbora trilineata</i>	Rasili	Indigenous	G4	LC
Cypriniformes	Cyprinidae	<i>Rasbora spilocerca</i>	Rasilo	Indigenous	G4	LC
Cypriniformes	Cyprinidae	<i>Rasbora palustris</i>	Raslus	Indigenous	G4	NA
Perciformes	Scombridae	<i>Rastrelliger kanagurta</i>	Rasnag	Indigenous	G10	NA
Cypriniformes	Cyprinidae	<i>Rasbora septentrionalis</i>	Raspte	Indigenous	G4	DD
Cypriniformes	Cyprinidae	<i>Rasbora borapetensis</i>	Rasrap	Indigenous	G4	LC
Cypriniformes	Cyprinidae	<i>Rasbora atridorsalis</i>	Rasrid	Indigenous	G4	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Cyprinidae	Rasbora tornieri	Rasrni	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Rasbora aurotaenia	Rasrot	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Rasbora dorsinotata	Rasrsi	Indigenous	G4	NA
Cypriniformes	Cyprinidae	Rasbora spp. Thai Catch/ Mkt	Rasspp	Indigenous	G4	NA
Cypriniformes	Cyprinidae	Rasbora pauciperforata	Rasuci	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Rasbora paviei	Rasvie	Indigenous	G4	NA
Perciformes	Callionymidae	Repomucenus fluviatilis	Repuvi	Indigenous	G10	NA
Perciformes	Gobiidae	Rhinogobius maculicervix	Rhicul	Indigenous	G1	DD
Perciformes	Gobiidae	Rhinogobius taenigena	Rhieni	Indigenous	G1	LC
Perciformes	Gobiidae	Rhinogobius sp"khmer"	Rhispk	NA	G1	NA
Clupeiformes	Clupeidae	Sardinella gibbosa	Sarbbo	Indigenous	G10	NA
Aulopiformes	Synodontidae	Saurida undosquamis	Saudos	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Scaphiodonichthys acanthopterus	Scaant	Indigenous	G1	LC
Cypriniformes	Cyprinidae	Scaphognathops stejnegeri	Scaejn	Indigenous	G3	LC
Perciformes	Scatophagidae	Scatophagus argus	Scagus	Indigenous	G7	LC
Cypriniformes	Cyprinidae	Scaphognathops bandanensis	Scanda	Indigenous	G3	VU
Perciformes	Gobiidae	Scartelaos histophorus	Scasto	Indigenous	G10	NA
Cypriniformes	Balitoridae	Schistura crabro	Schabr	Indigenous	G1	DD
Cypriniformes	Balitoridae	Schistura quaesita	Schaes	Indigenous	G1	NA
Cypriniformes	Balitoridae	Schistura aramis	Schami	Indigenous	G1	DD
Cypriniformes	Balitoridae	Schistura breviceps	Schevi	Indigenous	G1	DD
Cypriniformes	Balitoridae	Schistura sigillata	Schgil	Indigenous	G1	DD
Cypriniformes	Balitoridae	Schistura kohchangensis	Schhch	Indigenous	G1	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Balitoridae	Schistura athos	Schhos	Indigenous	G1	LC
Cypriniformes	Balitoridae	Schistura punctifasciata	Schnct	Indigenous	G1	NA
Cypriniformes	Balitoridae	Schistura procera	Schoce	Indigenous	G1	LC
Cypriniformes	Balitoridae	Schistura coruscans	Schrus	Indigenous	G1	DD
Cypriniformes	Balitoridae	Schistura cataracta	Schtar	Indigenous	G1	LC
Cypriniformes	Balitoridae	Schistura laterivittata	Schter	Indigenous	G1	NA
Cypriniformes	Balitoridae	Schistura latifasciata	Schtif	Indigenous	G1	NA
Cypriniformes	Balitoridae	Schistura daubentoni	Schube	Indigenous	G1	LC
Osteoglossiformes	Osteoglossidae	Scleropages formosus	Sclrmo	Indigenous	G1	EN
Perciformes	Scombridae	Scomberomorus commerson	Scomm	NA	G10	NA
Perciformes	Scombridae	Scomberomorus sinensis	Sconen	Indigenous	G10	DD
Perciformes	Carangidae	Selaroides leptolepis	Selpto	Indigenous	G10	NA
Cypriniformes	Cobitidae	Serpenticobitis zonata	Sernat	Indigenous	G1	DD
Cypriniformes	Cobitidae	Serpenticobitis cingulata	Serngu	Indigenous	G1	VU
Cypriniformes	Cobitidae	Serpenticobitis octozona	Sertoz	Indigenous	G1	DD
Clupeiformes	Engraulidae	Setipinna breviceps	Setevi	Indigenous	G10	NA
Clupeiformes	Engraulidae	Setipinna melanochir	Setlan	Indigenous	G7	NA
Clupeiformes	Engraulidae	Setipinna taty	Setty	Indigenous	G10	NA
Cypriniformes	Balitoridae	Sewellia diardi	Seward	Indigenous	G1	DD
Perciformes	Siganidae	Siganus guttatus	Sigtta	Indigenous	G10	NA
Cypriniformes	Cyprinidae	Sikukia flavicaudata	Sikavi	Indigenous	G4	DD
Cypriniformes	Cyprinidae	Sikukia gudgeri	Sikdge	Indigenous	G4	DD
Cypriniformes	Cyprinidae	Sikukia stejnegeri	Sikejn	Indigenous	G4	LC
Perciformes	Sillaginidae	Sillago aeolus	Silolu	Indigenous	G10	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Siluriformes	Siluridae	Silurichthys hasseltii	Silsse	Indigenous	G1	NA
Cypriniformes	Cyprinidae	Sinilabeo yunnanensis	Sinnna	Indigenous	G3	NA
Cypriniformes	Cyprinidae	Sinilabeo cirrhinoides	Sinrrh	Indigenous	G3	NA
Cypriniformes	Cyprinidae	Sinilabeo discognathoides	Sinsco	Indigenous	G3	NA
Scorpaeniformes	Platycephalidae	Sorsogona tuberculata	Sorber	Indigenous	G10	NA
Carcharhiniformes	Sphyrnidae	Sphyrna lewini	Sphwin	Indigenous	G10	NA
Perciformes	Sphyraenidae	Sphyraena sp.	Sphysp	Indigenous	G10	NA
Perciformes	Gobiidae	Stigmatogobius pleurostigma	Stieur	Indigenous	G7	NA
Clupeiformes	Engraulidae	Stolephorus dubiosus	Stobio	Indigenous	G10	NA
Clupeiformes	Engraulidae	Stolephorus baganensis	Stogan	Indigenous	G10	NA
Clupeiformes	Engraulidae	Stolephorus chinensis	Stoine	Indigenous	G10	NA
Clupeiformes	Engraulidae	Stolephorus commersonii	Stomme	Indigenous	G10	NA
Clupeiformes	Engraulidae	Stolephorus insularis	Stosul	Indigenous	G10	NA
Beloniformes	Belonidae	Strongylura incisa	Strcis	Indigenous	G10	NA
Beloniformes	Belonidae	Strongylura leiura	Striur	Indigenous	G10	NA
Osmeriformes	Salangidae	Sundasalanx mekongensis	Sunkon	Indigenous	G3	LC
Pleuronectiformes	Soleidae	Synaptura commersonii	Synmme	Indigenous	G3	NA
Pleuronectiformes	Soleidae	Synaptura marginata	Synrgi	Indigenous	G3	NA
Cypriniformes	Cyprinidae	Systemus johorensis	Syshor	Indigenous	G4	NA
Perciformes	Gobiidae	Taenioides gracilis	Taeaci	Indigenous	G7	NA
Clupeiformes	Clupeidae	Tenualosa thibaudeaui	Teniba	Indigenous	G3	VU
Clupeiformes	Clupeidae	Tenualosa toli	Tenli	Indigenous	G10	NA
Perciformes	Terapontidae	Terapon theraps	Terera	Indigenous	G10	LC
Perciformes	Terapontidae	Terapon jarbua	Terrbu	Indigenous	G10	LC

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Perciformes	Terapontidae	Terapon puta	Terta	Indigenous	G10	NA
Tetraodontiformes	Tetraodontidae	Tetraodon nigroviridis	Tetgro	Indigenous	G7	NA
Tetraodontiformes	Tetraodontidae	Tetraodon fluviatilis	Tetuvi	Indigenous	G7	NA
Cypriniformes	Cyprinidae	Thynnichthys thynnoides	Thyynn	Indigenous	G4	LC
Cypriniformes	Cyprinidae	Tor ater	Torer	Indigenous	G1	VU
Cypriniformes	Cyprinidae	Tor polylepis	Torlyl	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Tor tambroides	Tormbr	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Tor tambra	Tormbra	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Tor sinensis	Tornen	Indigenous	G1	DD
Cypriniformes	Cyprinidae	Tor laterivittatus	Torter	Indigenous	G1	DD
Perciformes	Toxotidae	Toxotes chatareus	Toxata	Indigenous	G7	NA
Perciformes	Toxotidae	Toxotes microlepis	Toxcro	Indigenous	G7	LC
Perciformes	Carangidae	Trachurus sp.	Tracsp	Indigenous	G10	NA
Perciformes	Osphronemidae	Trichogaster microlepis	Tricro	Indigenous	G6	LC
Perciformes	Osphronemidae	Trichogaster pectoralis	Tricto	Indigenous	G6	LC
Perciformes	Osphronemidae	Trichogaster leerii	Trieri	Indigenous	G6	NT
Perciformes	Belontiidae	Trichopsis schalleri	Trihal	Indigenous	G6	LC
Perciformes	Osphronemidae	Trichogaster trichopterus	Triich	Indigenous	G6	LC
Cypriniformes	Cyprinidae	Trigonostigma espei	Tripei	Indigenous	G4	LC
Perciformes	Trichiuridae	Trichiurus lepturus	Triptu	Indigenous	G10	NA
Perciformes	Belontiidae	Trichopsis spp.	Trispp	Indigenous	G6	NA
Perciformes	Belontiidae	Trichopsis vittata	Tritta	Indigenous	G6	LC
Cypriniformes	Cyprinidae	Troglocyclocheilus khammouanensis	Troamm	Indigenous	?	VU
Pleuronectiformes	Soleidae	Typhlachirus elongatus	Typong	Indigenous	G7	NA

Order	Family	Scientific Name	Short Name	Invasive Status	Guild	IUCN Category
Cypriniformes	Balitoridae	Vanmanenia serrilineata	Vanrri	Indigenous	G1	DD
Siluriformes	Siluridae	Wallago micropogon	Walcro	Indigenous	G3	DD
Siluriformes	Siluridae	Wallago leerii	Waleri	Exotic	G11	NA
Siluriformes	Siluridae	Wallago attu	Waltu	Indigenous	G3	NT
Beloniformes	Belonidae	Xenentodon cancila	Xennci	Indigenous	G5	LC
Beloniformes	Belonidae	Xenentodon canciloides	Xenncil	Indigenous	G5	LC
Pleuronectiformes	Soleidae	Zebrias zebra	Zebbra	Indigenous	G10	NA
Beloniformes	Hemiramphidae	Zenarchopterus ectuntio	Zentun	Indigenous	G7	NA

Annex 5: Samples in Each Cluster

Cluster	Sample Members
1	"CKD07" "CKT14" "CKT11" "LBX07" "LBX08" "LBX09" "LBX10" "LBX11" "LBX12" "LBX13" "LBX14" "LBX17" "LBX18" "LPB08" "LPB09" "LPB10" "LPB11" "LPB12" "LPB13" "LPB14" "LPB17" "LPB18" "LPO08" "LPO09" "LPO10" "LPO13" "LPO14" "LPO17" "LPO18" "LVT08" "LVT09" "LVT11" "LVT12" "LVT14" "LVT17" "LVT18" "TCK07" "TCK08" "TCK09" "TCK11" "TCK12" "TCK13" "TCK18" "TKR07" "TKR08" "TKR09" "TKR11" "TKR12" "TKR13" "TKR17" "TKR18" "TSK11" "TSK17" "TUT07" "TUT08" "TUT09" "TUT11" "TUT12" "TUT13" "TUT17" "VAP14" "VCM14" "VTS14"
2	"CBT11" "CBT12" "CBT13" "CBT14" "CBT15" "CBT17" "CBT18" "CKC12" "CKC13" "CKC14" "CKC15" "CKC17" "CKC18" "CKD08" "CKD09" "CKD10" "CKD11" "CKD12" "CKD13" "CKD14" "CKD15" "CKD16" "CKD17" "CKD18" "CKTh12" "CKTh13" "CPT14" "CPT15" "CPT17" "CPT18" "CPS12" "CPS13" "CPS14" "CPS15" "CPS17" "CPS18" "CSR12" "CSR13" "CSR14" "CSR15" "CSR17" "CSR18" "CST09" "TNK08" "TNK09" "TNK12" "TNK13" "TNK18" "TSK07" "TSK08" "TSK09" "TSK12" "TSK13" "TSK18" "VAP07" "VAP08" "VAP09" "VAP10" "VAP11" "VAP12" "VAP13" "VCM07" "VCM08" "VCM09" "VCM10" "VCM11" "VCM12" "VCM13" "VCM17" "VCM18" "VTS07" "VTS08" "VTS09" "VTS10" "VTS11" "VTS12" "VTS13" "VTS17" "VTS18"
3	"CKC11" "CKT07" "CKT08" "CKT09" "CKT10" "CKT11" "CKT12" "CKT13" "CKT15" "CKT16" "CKT17" "CKT18" "CPS11" "CSK07" "CSK08" "CSK09" "CSK10" "CSK11" "CSK12" "CSK13" "CSK14" "CSK15" "CSK16" "CSK17" "CSK18" "CSP07" "CSP08" "CSP09" "CSP10" "CSP11" "CSP12" "CSP13" "CSP14" "CSP15" "CSP16" "CSP17" "CSP18" "CSR11" "CSS07" "CSS08" "CSS09" "CSS10" "CSS11" "CSS12" "CSS13" "CSS14" "CSS15" "CSS16" "CSS17" "CSS18" "CST07" "CST08" "CST10" "CST11" "CST12" "CST13" "CST14" "CST15" "CST16" "CST17" "CST18" "LVT10" "LVT13" "TUT18" "VAP17" "VAP18"
4	"VTV07" "VTV08" "VTV09" "VTV10" "VTV11" "VTV12" "VTV13" "VTV14" "VTV17" "VTV18" "VVL07" "VVL08" "VVL09" "VVL10" "VVL11" "VVL12" "VVL13" "VVL14" "VVL17" "VVL18"





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