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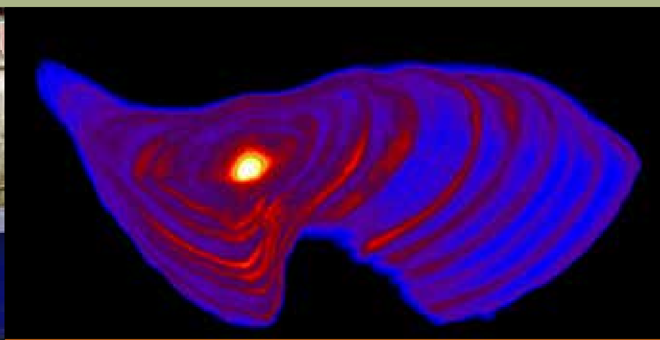

Diadromous fish of the Mekong and management of long distance fish migrations at mainstem dams sites

Report prepared for ACIAR

Report No. 163

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Acknowledgements

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I. Introduction

The Mekong is home to over one thousand freshwater fish species which are an important source of biodiversity, food security and essential to economic productivity. These species produce about 2.3 million tonnes per year of fish and other aquatic animals, equivalent to 11 billion USD (So *et al.* 2015). Most people participate in fishing for household consumption in the Lower Mekong Basin (LMB). For example, about 80% of households in rural areas of Laos, Thailand, and Cambodia, and 60–95% of households in Vietnam participate in fishing to a certain extent (Hortle 2007). Their fish catch was often consumed domestically. Each person in the LMB consumed 34 kg of fish and other aquatic animals per year (Hortle 2007). However, fish yield and catch rates likely decrease recently over years (Ngor *et al.* 2018; Vu *et al.* 2021).

Majority of Mekong fishes are migratory. They can be classified into 2 broad groups (diadromy: migrating regularly between fresh and salt water; and potamodromy: (living within freshwater only). There is three sub-categories of diadromy (anadromy: living in the sea and migrating to freshwater for spawning, catadromy: living in freshwater and migrating to the sea for spawning; and amphidromy: migrating between freshwater and seawater not for the purpose of spawning (Myers 1949) (Figure 1). Various factors have driven the Mekong fisheries. Altered hydrological regimes, habitat loss or modification, and overfishing are the key threats to freshwater fisheries production and biodiversity (Baran *et al.* 2003; Lintermans 2013). Hydropower and irrigation likely contribute to severe declines in fish populations due to changes in hydrological regimes and habitat degradation. These water regulation devices have either dramatically restricted, or entirely prevented, the movements of fish between critical habitats in rivers, floodplains, and coastal areas for spawning, nursing, and feeding. Consequently, fisheries resources, biodiversity and communities that rely on fish are at risk. The long-term sustainability of productive fisheries in the Mekong are threatened by mainstem dam construction.

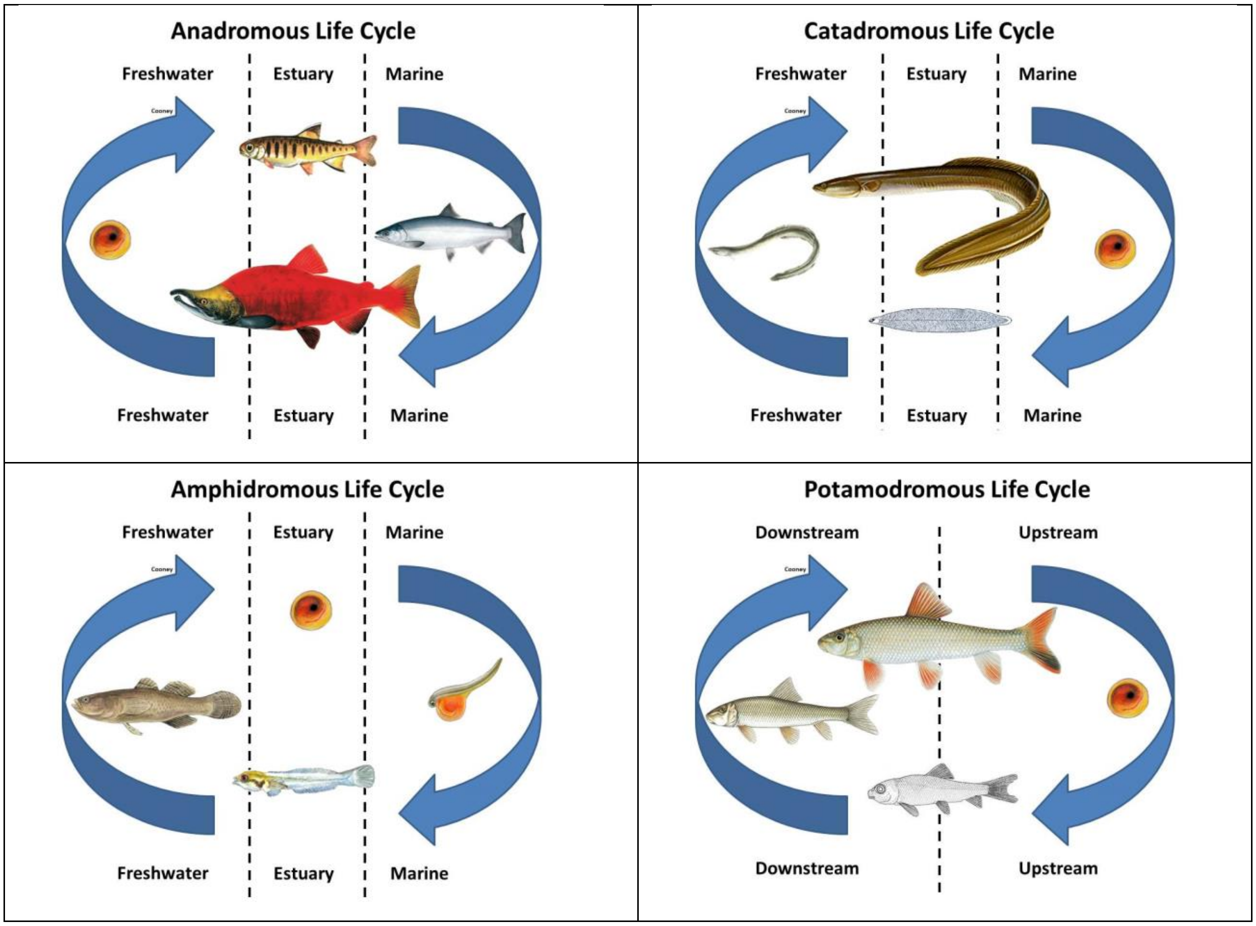

Figure 1: Life cycles of riverine fish species.
Source: https://thefisheriesblog.com/2013/05/20/anadromous-catadromous-amphidromous-oceanodromous-or-potamodromous/

There are hundreds of existing and proposed dams in the LMB (Schmutz and Mielach 2015). Particularly, there are some large mainstem dams in China while twelve mainstem dams have been proposed in the LMB, two of them have been constructed (Don Sahong and Xayaburi dams). Don Sahong dam without fishway is constructed in an important channel in the Khone Falls, other channels may act as migration routes through the waterfalls. Meanwhile Xayaburi dams is blocked completely the Mekong mainstream, a fishway was constructed along the dam for fish migration. Construction of these dams have raised concerns to the Mekong fisheries as most Mekong fishes are migratory, some of them migrate for hundreds of kilometers for spawning (Hogan *et al.* 2007). There is now a pressing need to research mitigation measures at each dam site. Dam development is highly contentious in Lao PDR. Most citizens support dam construction but many international organisations oppose it.

High number of fish species were recorded in the Don Sahong and Xayaburi dams. Particularly, there were over 100 fish species around Don Sahong dam where many Mekong fishes spawn around this site (Poulsen *et al.* 2002; Baird *et al.* 2004). Many of them are highly economic species that contribute a major component to the Mekong fisheries production, however they face significant threats from a massive hydropower development boom in the region. Otoliths (ear-bones) chemistry has proved as a powerful tool to examine fish migrations between habitats (Carlson *et al.* 2017; Walther 2019). Elements such as Sr and Ba (including Sr:Ca and Ba:Ca) have been used frequently to understand fish movements across salinity gradients (Walther 2019). Objective of this study is to understand fish migration of key species in the LMB by otolith chemistry. Findings of this species are critical to protect against hydropower development. Developers must ensure they incorporate adequate fish migration facilities for fish migrations through a dam.

II. Methodology

2.1. Fish collection for otolith removals

Seven fish species were collected during the spawning season (in 2020) around two dam sites (Don Sahong and Xayaburi) (Table 3). These species are highly important to the Mekong fisheries, most of them are large-size species and high-economic species (Table 1 and Figure *2*).

Table 1: Fish collection for otolith chemistry

Scientific name	Dam site		Mean weight (g)±SD	Number of otoliths for	
	Don Sahong	Xayaburi		LA-ICMPS	SXFM
Anguilla martorata	1	-	578	1	1
Tenualosa thibaudeaui	2	2	90±46	3	1
Cosmochilus harmandi	-	24	3,350±1,204	24	1
Hemibargrus wyckioides	-	8	782±654	8	0
Pangasius krempfi	2	-	5,550±495	2	1
Pangasius mekongensis	4	-	15,325±7,565	4	4
Pangasius bocourti	1	-	5,790	1	1

LA-ICMPS*: Laser Ablation – Inductively Coupled Plasma Mass Spectrometer. SXFM: Scanning X-ray fluorescence microscopy.*

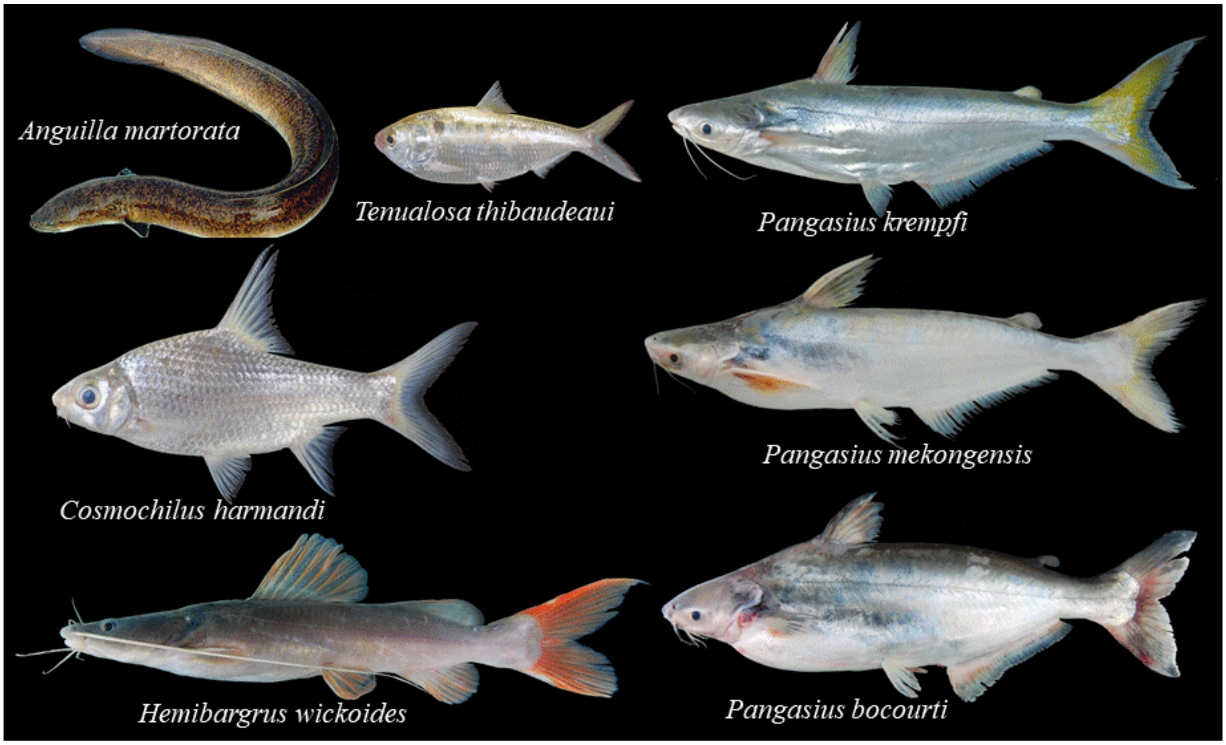

Figure 2: Fish collection for otolith chemistry. Images from FishBase and Kano *et al.* (2013)

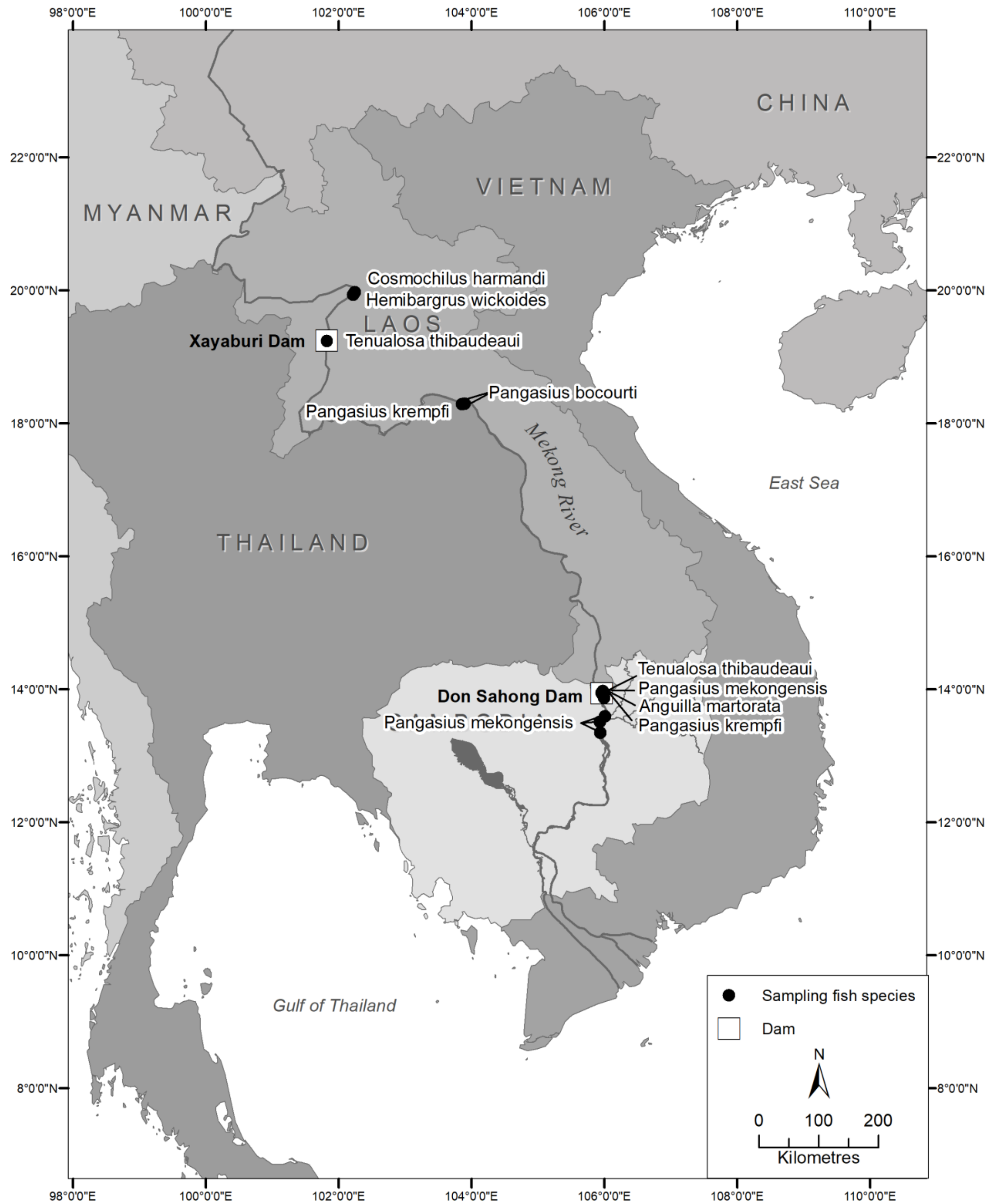

Figure 3: Sampling sites in the Lower Mekong Basin. See Annex 1 for more details.

2.2. Otolith collection and preparation

The largest pair of otoliths (either sagittae or lapilli, Figure 4) were removed from all species (Table 1). Length and weight of each fish individuals were measured prior to extracting their otoliths. Otoliths were washed and stored in paper envelopes in the field and labeled properly. They were washed again with Milli-Q water to remove any tissues around otoliths, air-dried in the laboratory and stored in plastic vials for later processing.

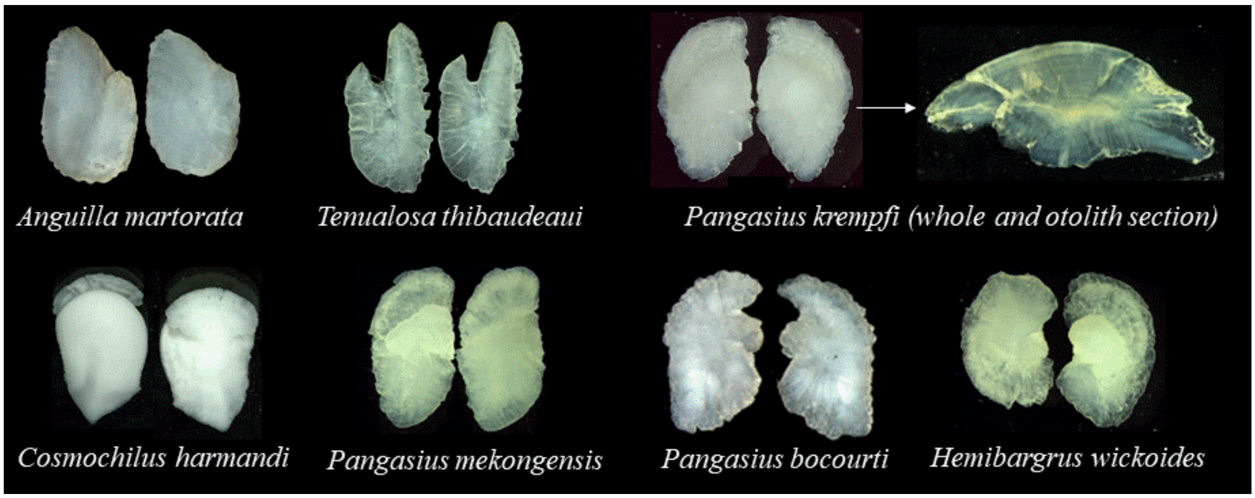

Figure 4: Otoliths images of seven species

Otoliths were embedded into Araldite epoxy (GY502) and hardener (HY956). The epoxy was solidified for three days in air temperature. Embedded otoliths were then cut into a thin section including the core by using a low-speed diamond blade saw. The otolith sections were grinded and polished until a primordium (core) was exposed. The otolith sectioned samples were sonicated, rinsed with Mill-Q water, and air-dried in a laminar flow cabinet to remove any contaminants. Finally, these otolith sectioned samples were stored in acid-washed plastic vials for later trace element analyses.

2.3. Otolith element analysis

Our main objective was to try and identify fish, near the dam sites, which had migrated from the ocean. Otolith samples were analysed for trace elements (^{44}Calcium, ^{88}Strontium, and ^{137}Barium) by LA-ICPMS at the Australian National University. The system consists of a laser ablation unit (HelEx, Laurin Technic, Canberra, Australian National University, operating at a wavelength of

193 nm) connected to an ICPMS (iCap RQ, ThermoFisher) at the Australian National University. A line transect was ablated from the core to the edge of each otolith at a pulse rate of 5 Hz, speed at 3µm s^{-1}, and spot diameter of 28 µm. Pre-ablation was applied to remove any dust or contaminants on surface samples (300 µm s^{-1} speed; pulse rate of 10 Hz, speed at 3µm s^{-1}, and spot diameter of 62 µm). A glass reference material NIST 610 and NIST 612 (National Institute of Standards and Technology), was ablated at the beginning and end of each session (NIST 612) and after very 10 samples (NIST 610). The NIST610 standard was used to correct for drift and instrument mass bias. The ablated material was transported under pure Helium carrier gas, mixed with Argon gas, into the plasma of the mass spectrometers for elemental analysis. Data reduction and elemental concentration calculation were processed using a spreadsheet in Excel. Two-dimensional maps of trace elements were produced by using GeoPIXE version 7.5 and ArcGIS software. Concentrations of Ca quantified from LA ICP MS were used to calibrate for SXFM data.

2.4. Data analysis and interpretation

Although ratios of Ba:Ca and Sr:Ca were calculated in this study, only Sr:Ca ratio was used to interpret fish movements between fresh and marine waters. Sr:Ca ratio has been often used in otolith chemistry studies as this ratio in water is often more sensitive to ambient salinity (Tran *et al.* 2019; Walther 2019; Vu *et al.* in press). Variation of Sr:Ca ratios from core to edge of otoliths was used to determine movements of fish as diadromy or potamodromy (Gillanders 2005). Moreover, we quantified trace elements of otoliths (*Pangasius krempfi*) that collected in freshwater and brackish water in a separate study to determine thresholds of environments. We propose following thresholds for use of different environments based on Sr:Ca ratios in otoliths:

Resident in freshwater	Sr:Ca x $10^{-3} < 3.25$
Resident in brackish water	$3.25 \leq$ Sr:Ca x $10^{-3} < 10.17$
Resident in marine water	Sr:Ca x $10^{-3} > 10.17$

2.5. Water chemistry

Although this study did not sample water for chemistry analysis, water from two stations near the dam sites (Luang Prabang and Pakse, Lao PDR) were taken to analyse some key elements by a separated study (Vu *et al.* in press). Both Ba and Sr (including Ba:Ca and Sr:Ca ratios) were significantly different between the two dam sites. For example, Sr and Sr:Ca ratios in upstream

(Xayaburi dam) were higher than in downstream (Don Sahong dam). Whereas, Ba is opposite (Figure 5).

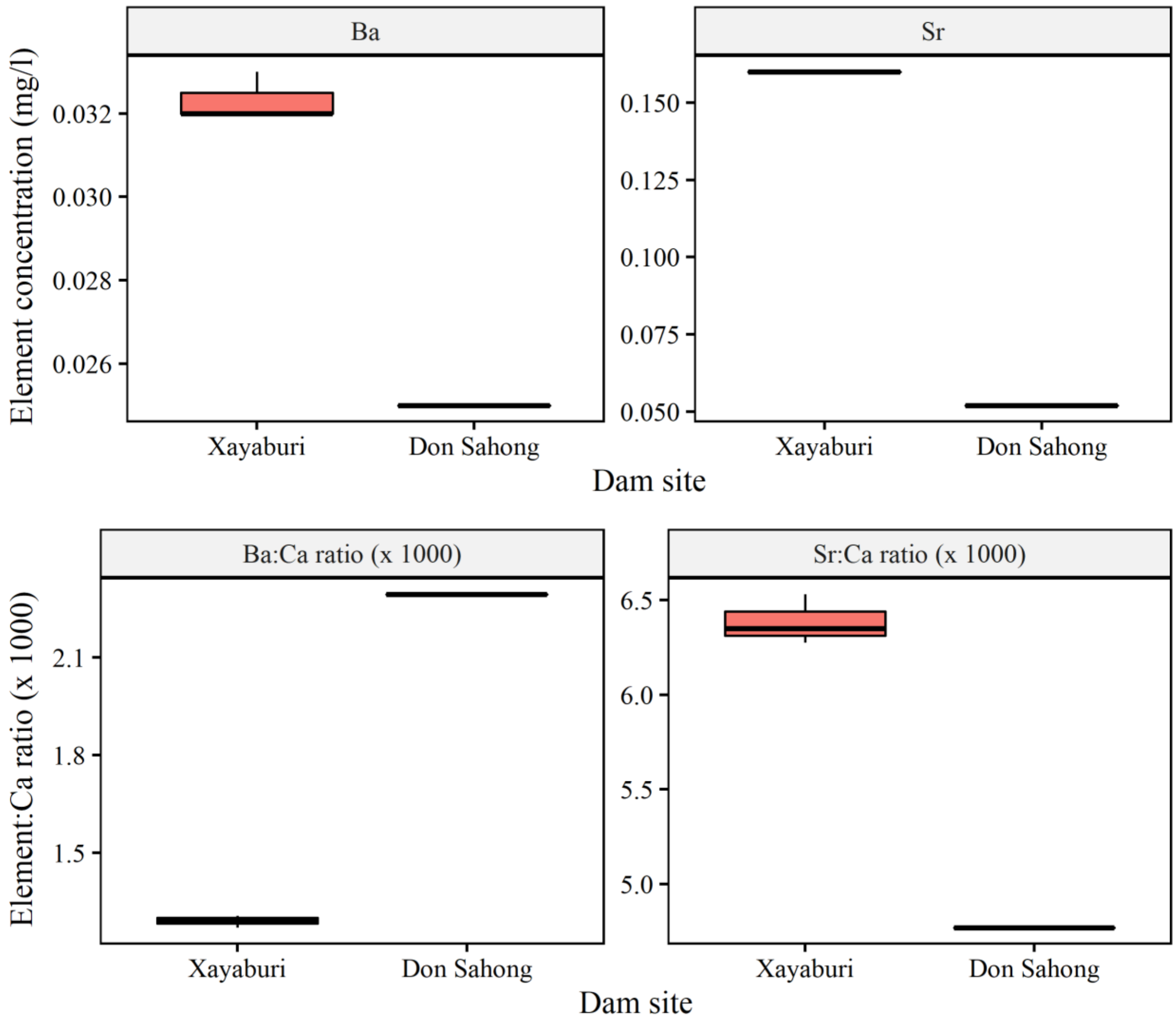

Figure 5: Water chemistry between dam sites

III. Results and Discussion

3.1. Diadromy

Otolith chemistry confirmed three Mekong fish species as diadromous based on variation of Sr:Ca ratios from core (birth) to edge of otolith (capture). Giant mottled eel (*Anguilla marmorata*) is catadromous and two Mekong catfish (*Pangasius krempfi* and *P. mekongensis*) are anadromous (Figure 6 and Figure 7).

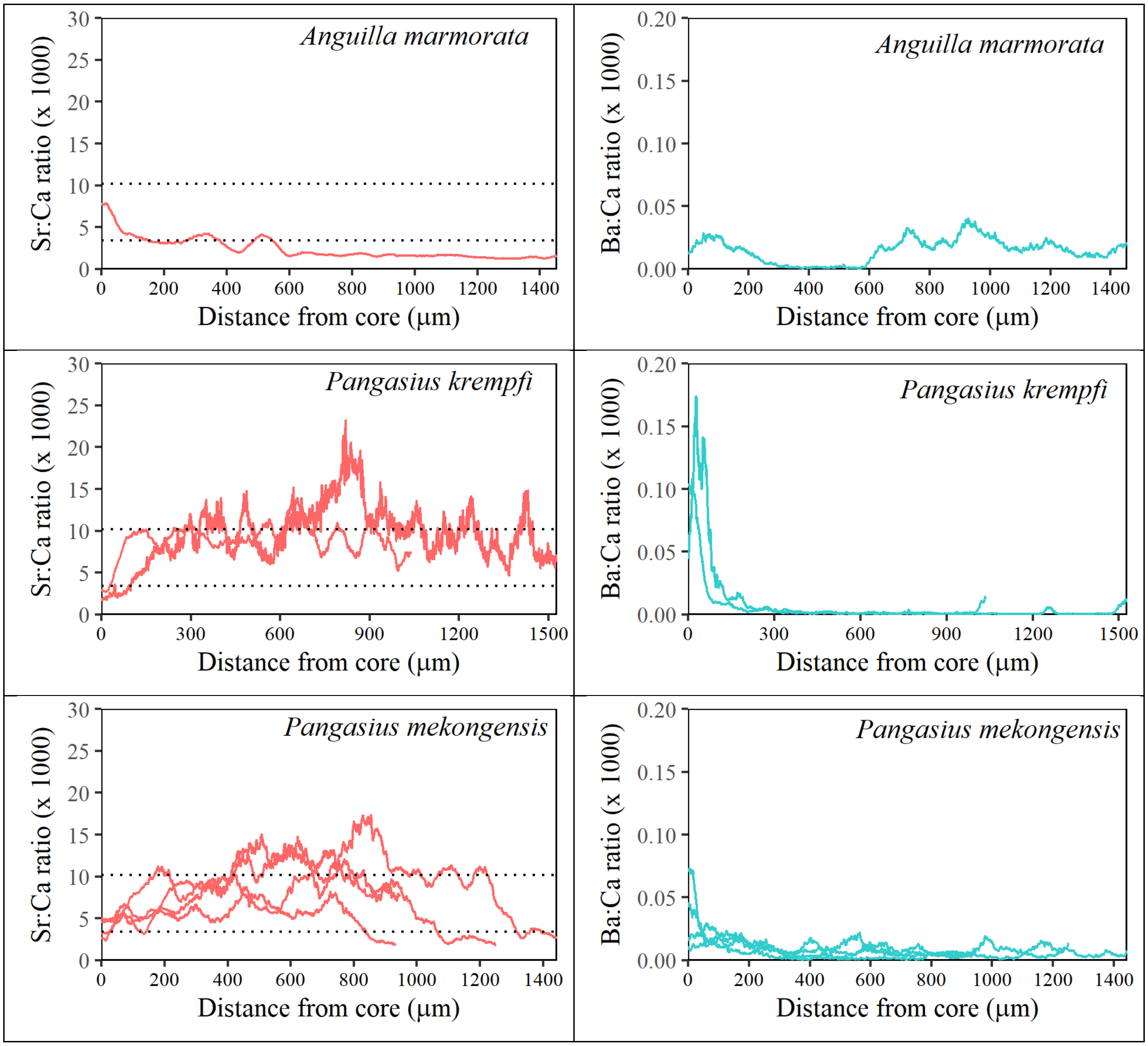

Figure 6: Variations of Sr:Ca (left) and Ba:Ca ratios (right) from core to edge of otoliths (birth-to-capture) of diadromous species. Dashed horizontal lines are environmental thresholds (freshwater residence if y<3.25; brackish water residence if 3.25 ≤ y < 10.17; and marine water residence if y>10.17).

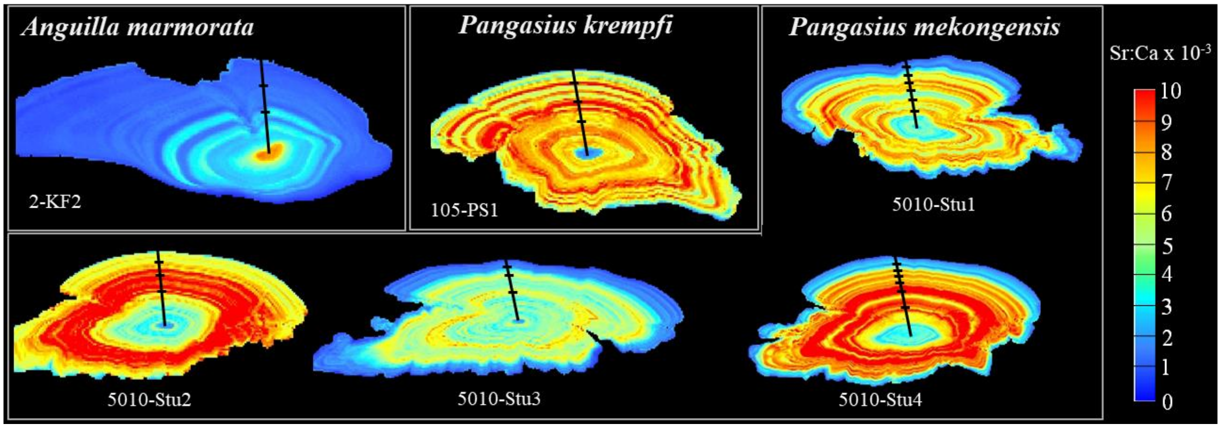

Figure 7: Two-dimensional maps of Sr:Ca ratios (x1000) of three diadromous Mekong species. Black transects from core to edge of otoliths indicate putative annuli. *Anguilla marmorata* (2-KF2, caught in Khone Falls, Don Sahong dam, Lao PDR). *Pangasius krempfi* (105-PS1) caught in Paksan, Lao PDR, 550 km downstream of the Xayaburi dam). *Pangasius mekongensis* (5010-Stu1, 5010-Stu2, 5010-Stu3, and 5010-Stu4 caught in Stung Treng, Cambodia, near Don Sahong dam).

3.1.1. Anguilla marmorata (giant mottled eel)

Variation of Sr:Ca from core to edge of otolith suggests that this eel spawned in brackish/ marine water, then moved to the Mekong River for feeding. There was no marine signature, except at the core (birth). Although giant mottled eel is known as catadromous (Arai and Chino 2012), this is the first time to re-confirm this species as catadromous in the Mekong River. Figure 7 indicates that this individual spawned in marine/brackish water, stayed within estuary for about one year, then moved to the Mekong River. Some studies found that migration patterns of giant mottled eel varied between individuals. For example, some individuals migrate regularly between fresh and marine waters (typical catadromy), while others reside in brackish/marine water only, never enter freshwater (Tsukamoto *et al.* 1998; Arai *et al.* 2013).

Giant mottled eel is relatively rare in the Mekong River. We found only one eel (578 g) in Khone Falls during spawning season in 2020, near Don Sahong hydropower dam, about 700 km from the sea. In addition, a big eel (4 kg) was observed in Kampong Cham, Cambodia (Figure 8). Although no giant mottled eel was found in upstream (Xayaburi dam), a local fisher reported an eel captured in Luang Prabang (~100 km Xayaburi dam upstream). If this information is true, giant mottled eel would migrate over 2000 km from the sea to the Mekong River.

	
A giant mottled eel (578 g; 71 cm) captured in Khone Falls (Don Sahong dam), Lao PDR in this study (14 Jul 2020)	A giant mottled eel (4 kg; 107 cm) observed in Kampong Cham, Cambodia (~280 km downstream of Don Sahong dam) (22 Aug 2020)[1]

Figure 8: Giant mottled eel in the Mekong River

3.1.2. Pangasius krempfi (krempfi catfish)

This study re-confirmed krempfi catfish as anadromy: living in brackish/marine water but migrating to the Mekong River for spawning (indicating by low Sr:Ca ratio at the core). Previous studies collected krempfi catfish in Khone Falls and the Mekong Delts of Vietnam (Hogan *et al.* 2007; Tran *et al.* 2019), this study recorded this species in Paksan (~1400 km from the sea) with marine signature (Figure 6 and Figure 7). It indicates that this species would migrate up to 1400 km to the Mekong River, through the Khone falls from the sea for spawning. This species was reported in Luang Prabang (over 2000 km from the sea), but we found no krempfi catfish in further upstream. So maintaining connectivity at the Don Sahong site will be critical for the long term persistence of this species.

Krempfi catfish is a long-distance migratory and high economic value species. Fishers often target this species along their migration route. For example, catch of krempfi catfish from the wing trap fishery in Khone Falls (banned since 2017), Southern Lao PDR accounted for nearly 5% of total

[1] *https://www.mekongfishnetwork.org/mottled-eel/*

catch (Baird *et al.* 2004). Meanwhile, over five tonnes of krempfi catfish were landed in Vam Nao fishing communities in the Mekong Delta of Vietnam (Vu *et al.* 2010). Some deep pools along their migration routes are important rest habitats, therefore these habitats should be established as conservation zones to protect this important species (Vu *et al.* 2009).

3.1.3. ***Pangasius mekongensis*** (mekongensis catfish)

This species is confirmed as anadromy. Life history is similar to krempfi catfish as described above. We captured this species in freshwater (Strung Treng, Cambodia), but marine signature was detected in their otoliths. Although this individual was captured below the Don Sahong dam, this species distribute throughout the LMB, and migrate beyond the Khone Falls for spawning (Poulsen *et al.* 2004). Hence, a hydropower dams (Don Sahong) at the Khone Falls could be a major threat for fish migration, not only for this species, but also many other Mekong species (Khone Falls is the main spawning ground for most Mekong fish species). Figure 6 and Figure 7 indicate that mekongensis catfish spawned in freshwater, larvae/ fingerlings likely remain in freshwater longer than krempfi catfish prior to migrating to the Mekong estuary for nursing and feeding. Limited information was available about this species as it was described recently in 2003. Findings of this study are critical for better management and conservation. Especially, the hydropower dam (Don Sahong) is located at the main spawning ground for Mekong fishes. Maintaining other channels as fish passage in the waterfalls is then critical for Mekong fishes.

3.2. Non-diadromy

Otolith chemistry of four Mekong species indicated that these species (*Tenualosa thibaudeaui, Cosmochilus harmandi, Hemibargrus wyckioides*, and *Pangasius bocourti*) lived mainly within freshwater only (potamodromy). Some of individuals likely moved occasionally to brackish water or freshwater upstream (indicating by high Sr:Ca ratios), probably for feeding (food availability) (Figure 9 and Figure 10).

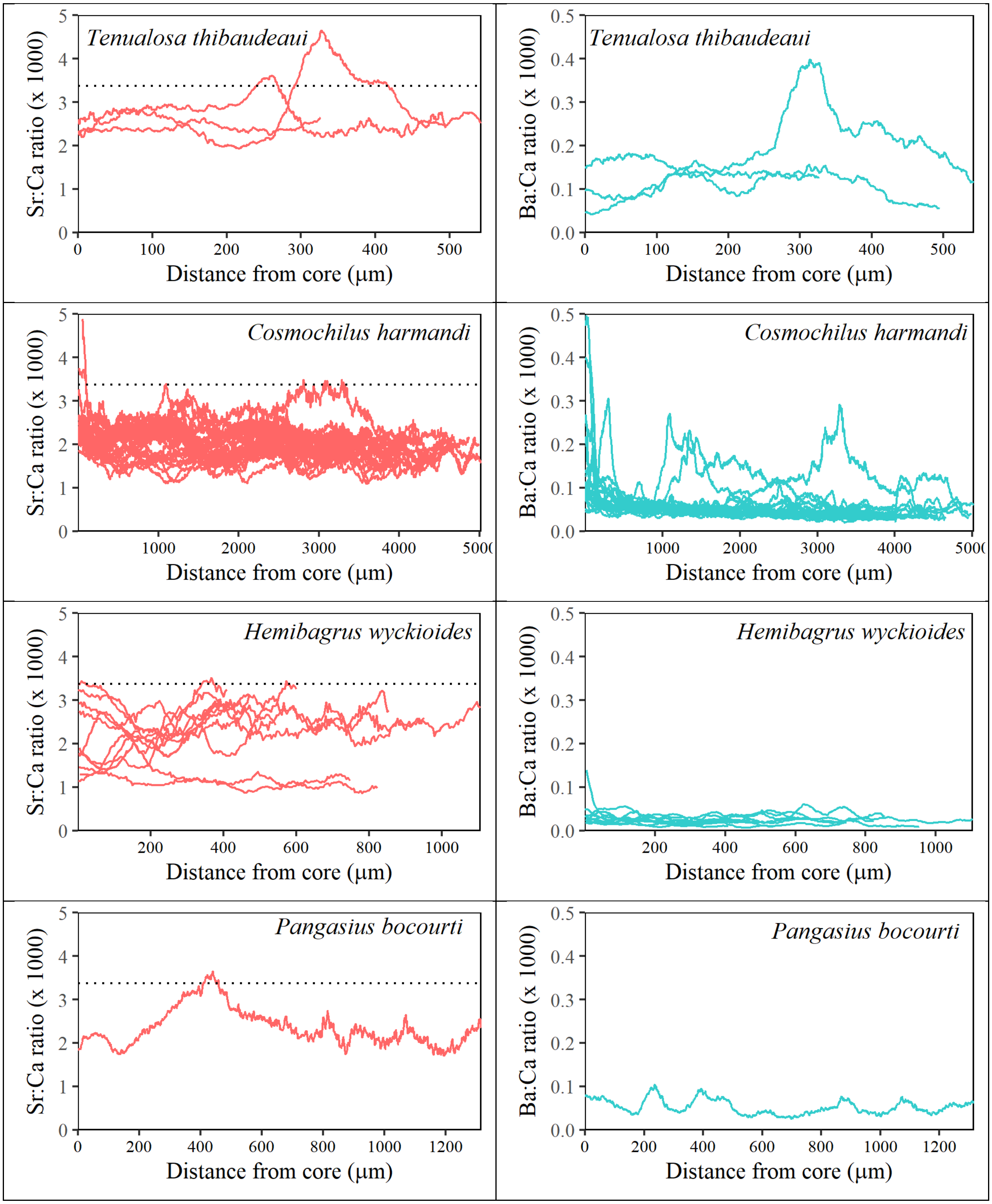

Figure 9: Variations of Sr:Ca (left) and Ba:Ca ratios (right) from core to edge of otoliths (birth-to-capture) of non-diadromous species (potamodromy). Dashed horizontal lines are environmental thresholds (freshwater residence if $y<3.25$; brackish water residence if $3.25 \leq y < 10.17$).

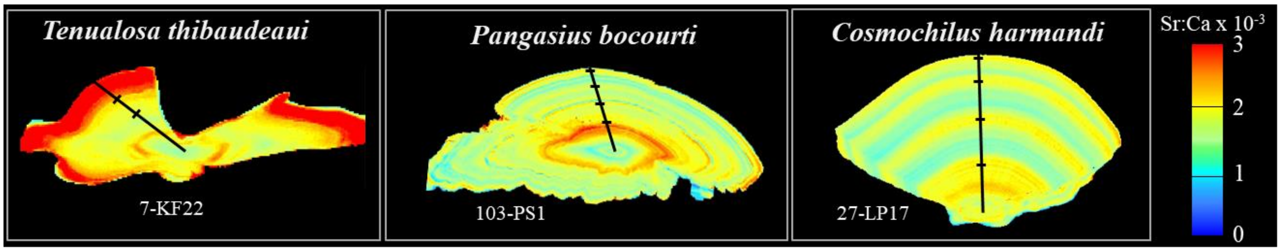

Figure 10: Two-dimensional maps of Sr:Ca ratios of three non-diadromous Mekong species. Black transects from core to edge of otoliths indicate putative annuli. *Tenualosa thibaudeai* (7-KF22, caught in Khone Falls, Lao PDR). *Pangasius bocourti* (103-PS1) caught in Paksan, Lao PDR). *Cosmochilus harmandi* (27-LP17 caught in Luang Prabang, Lao PDR).

3.2.1. *Tenualosa thibaudeai* (Laotian shad)

The Sr:Ca ratios in two-dimensional map were very different between the core (low concentration) and edge (high concentration) of otolith (Figure 10). This indicates that spawning and capture locations are different. This individual was captured in the Mekong mainstream (Khone Falls, or Don Sahong dam), it suggests that this individual would spawn in tributaries or floodplains where the elemental concentrations are likely lower than the Mekong mainstream. At least one individual of Laotian shad likely occasionally moved to brackish water (indicated by a spike in Sr:Ca ratios, (Figure 10). For those species living in freshwater, elements such as Sr and Ba are unlikely the best proxies for tracing migrations, isotopes (e.g. $^{87}Sr/^{86}Sr$) are likely better indicator for fish migrations. This is because $^{87}Sr/^{86}Sr$ ratios are often highly varied within freshwater (mainstream vs tributary), and directly related to water and otoliths chemistry (Crook *et al.* 2016). This species can be found throughout the LMB. There are probably two populations: one around the Xayaburi and another downstream (Paksan to the Mekong Delta) (Poulsen *et al.* 2004). Hydropower dams without effective fishways for fish migration through the barriers would prevent mixing of these populations.

3.2.2. *Cosmochilus harmandi*

Ratios of Sr:Ca along an otolith transect varied regularly (Figure 10). The regular variations of Sr:Ca ratios may reflect seasonal variation: probably higher Sr:Ca ratios in the dry season and low Sr:Ca ratios in the wet season. Moreover, higher Sr:Ca ratios were always found in growth marks on otolith. Highly variation of temperature was observed in the sampling sites (Luang Prabang, ~300 m above sea level, Figure 11), temperature variation usually cause slow growth (growth marks on otolith). In addition, although some studies sampled water chemistry in the LMB, seasonal variations of some important elements (Sr and Ba) were not examined yet. Other river systems found that elemental concentrations in the dry season were significantly higher than that in the wet season (Crook *et al.* 2016).

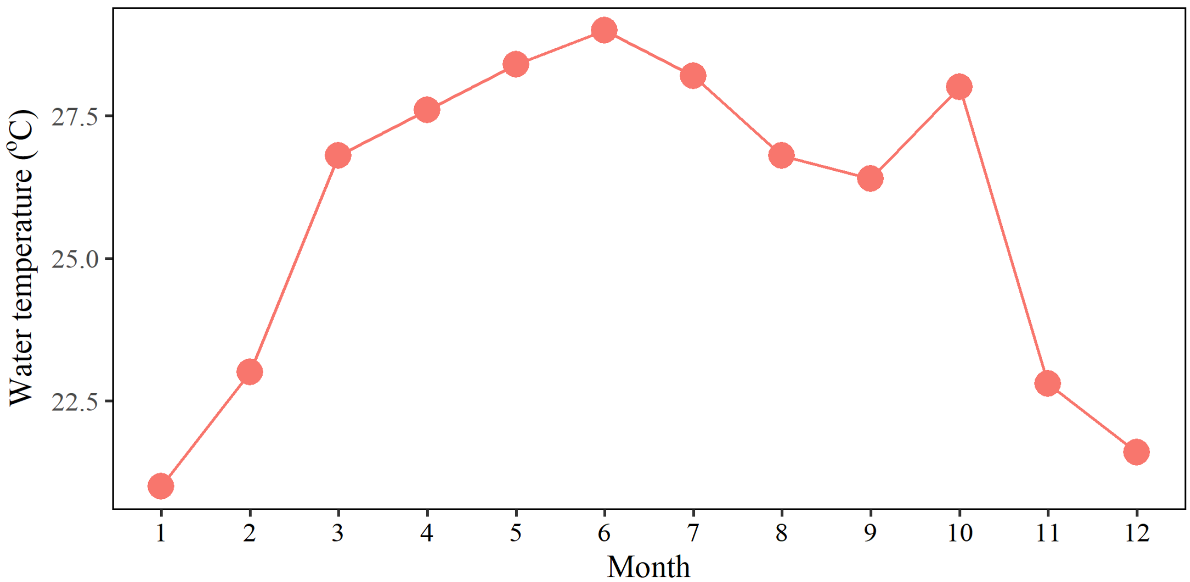

Figure 11: Monthly temperature in Luang Prabang. Data from MRC.

3.2.3. *Hemibagrus wyckioides*

Ratios of Sr:Ca was low, it suggests that this species reside within freshwater. The ratios at the core (birth) varied among individuals (Figure 9), suggesting that they spawn in different places. This species likely prefers in rocky bottoms and move for a short distance, between 0 and 4 km per day (Naughton *et al.* 2021).

3.2.4. *Pangasius bocourti*

There is no marine signature in otolith of this species. This indicates that they reside within freshwater. Acoustic telemetry study in found that this species moved between 14 and 33 km per day (Naughton *et al.* 2021). This species believes spawning in the Mekong mainstream, their eggs and larvae drift with water current for nursing and feeding downstream (Poulsen *et al.* 2004).

IV. Conclusion and Recommendations

This study examined migrations of seven high-economic fish species by otolith chemistry in the LMB to find any species spending most of its life in the ocean and returns to freshwater to breed. We confirmed three species as diadromous fish species in the LMB:

- *Anguilla martorata* (catadromy): they spawn at sea, then move to the Mekong River for feeding. The giant mottled eel was captured in Khone Falls, Lao PDR (Don Sahong dam, ~700 km from the sea);
- *Pangasius krempfi* (anadromy): They spend most of their life in brackish/marine water in the Mekong estuary, but they migrate to the Mekong River for spawning in Khone Falls area. One of individual recorded in Paksan, Lao PDR (~1400 km from the sea) with marine signature in their otolith. It means they are able to migrate through the Khone Falls, where many Mekong fish species cannot move up the falls;
- *Pangasius mekongensis* (anadromy): Migration of this species is similar to *Pangasius krempfi*. However, this species was recorded in Stung Treng, Cambodia, ~700 km from the sea (below Khone Falls, Don Sahong).

These diadromous species above were recorded around Don Sahong dam (Khone Falls), one of them migrate through the falls. Although none of these species were found in Xayaburi dam in our study, giant mottled eel and krempfi catfish were reported in Luang Prabang by fisheres. If this information is validated, these species would migrate for a long distance (over 2000 km from the sea to the Mekong River) for breeding or feeding. Facilities such as fish passage or fishway should be maintained properly for fish migration at the dam sites.

Other four species (*Tenualosa thibaudeaui*, *Cosmochilus harmandi*, *Hemibargrus wyckioides*, and *Pangasius bocourti*) live within freshwater (potomodromy). Most of them are large-size, high-economic species.

Recommendations and Synergies

This student internship integrated into project FIS/2017/018 (Xayaburi Fish Pass investigations) to determine how far migratory fish dependent on seawater were moving up the Mekong. The project served as a pilot to determine if otolith-based analyses could yield additional information as a method not widely used in the Mekong. The project served this purpose adequately. The team were able to integrate some innovative methods into the work and, with good planning, will continue to collect otoliths from select species, if found at the study sites, to add to data sets in the future. An area not able to be explored was migrations within freshwater. A number of species were identified which did not have any marine signature at all. These "potamodromous" fish could be further traced to sites of significance (i.e. Spawning locations or otherwise) using isotopic tracers. This was beyond the scope of the current study but could, with further development, contribute to the knowledge of the impacts of dams on migratory fish. These could be integrated into further student assignments into the future if required.

Annex 1: Fish species collection for otolith chemistry

#	Code	Species	Latitude	Longtitude	Length (cm)	Weight (g)
1	2-KF2	*Anguilla martorata*	13.973484°	105.975109°	71.0	578
2	7-Xa1	*Tenualosa thibaudeaui*	19.240361°	101.818893°	186.0	92
3	7-Xa2	*Tenualosa thibaudeaui*	19.240361°	101.818893°	194.0	103
4	7-KF22	*Tenualosa thibaudeaui*	13.973484°	105.975109°	215.0	137
5	7-KF23	*Tenualosa thibaudeaui*	13.973484°	105.975109°	128.0	27
6	27-LP1	*Cosmochilus harmandi*	19.975624°	102.240063°	na	3,000
7	27-LP2	*Cosmochilus harmandi*	19.975624°	102.240063°	na	3,000
8	27-LP3	*Cosmochilus harmandi*	19.975624°	102.240063°	na	4,000
9	27-LP4	*Cosmochilus harmandi*	19.975624°	102.240063°	na	4,000
10	27-LP5	*Cosmochilus harmandi*	19.975624°	102.240063°	na	4,000
11	27-LP6	*Cosmochilus harmandi*	19.975624°	102.240063°	na	4,000
12	27-LP7	*Cosmochilus harmandi*	19.975624°	102.240063°	na	5,000
13	27-LP8	*Cosmochilus harmandi*	19.975624°	102.240063°	490.0	2,400
14	27-LP9	*Cosmochilus harmandi*	19.975624°	102.240063°	510.0	2,600
15	27-LP10	*Cosmochilus harmandi*	19.975624°	102.240063°	500.0	2,650
16	27-LP11	*Cosmochilus harmandi*	19.975624°	102.240063°	490.0	2,340
17	27-LP12	*Cosmochilus harmandi*	19.975624°	102.240063°	550.0	3,000
18	27-LP13	*Cosmochilus harmandi*	19.975624°	102.240063°	550.0	3,000
19	27-LP14	*Cosmochilus harmandi*	19.975624°	102.240063°	550.0	3,000
20	27-LP15	*Cosmochilus harmandi*	19.975624°	102.240063°	470.0	na
21	27-LP16	*Cosmochilus harmandi*	19.975624°	102.240063°	480.0	na
22	27-LP17	*Cosmochilus harmandi*	19.975624°	102.240063°	590.0	5,700
23	27-LP18	*Cosmochilus harmandi*	19.975624°	102.240063°	640.0	6,800
24	27-LP19	*Cosmochilus harmandi*	19.975624°	102.240063°	490.0	2,200
25	27-LP20	*Cosmochilus harmandi*	19.975624°	102.240063°	485.0	2,200
26	27-LP21	*Cosmochilus harmandi*	19.975624°	102.240063°	540.0	3,000
27	27-LP22	*Cosmochilus harmandi*	19.975624°	102.240063°	480.0	2,200
28	27-LP23	*Cosmochilus harmandi*	19.975624°	102.240063°	na	3,200
29	27-LP24	*Cosmochilus harmandi*	19.975624°	102.240063°	na	2,400
30	87-LP1	*Hemibargrus wickoides*	19.935624°	102.211394°	27.0	280
31	87-LP2	*Hemibargrus wickoides*	19.935624°	102.211394°	38.0	700
32	87-LP3	*Hemibargrus wickoides*	19.935624°	102.211394°	19.5	90
33	87-LP4	*Hemibargrus wickoides*	19.935624°	102.211394°	48.0	2,100
34	87-LP5	*Hemibargrus wickoides*	19.935624°	102.211394°	48.0	1,045
35	87-LP6	*Hemibargrus wickoides*	19.935624°	102.211394°	47.0	1,200
36	87-LP7	*Hemibargrus wickoides*	19.935624°	102.211394°	28.0	340

#	Code	Species	Latitude	Longtitude	Length (cm)	Weight (g)
37	87-LP8	*Hemibargrus wickoides*	19.935624°	102.211394°	33.0	500
38	105-KF6	*Pangasius krempfi*	13.949641°	105.950864°	80.7	5,200
39	105-PS1	*Pangasius krempfi*	18.291487°	103.851075°	76.5	5,900
40	5010-Stu1	*Pangasius mekongensis*	13.346606°	105.932689°	na	18,200
41	5010-Stu2	*Pangasius mekongensis*	13.874380°	105.988902°	na	16,000
42	5010-Stu3	*Pangasius mekongensis*	13.594540°	106.002666°	na	4,700
43	5010-Stu4	*Pangasius mekongensis*	13.511671°	105.928372°	na	22,400
44	103-PS1	*Pangasius bocourti*	18.296549°	103.889583°	69.5	5,790

Annex 2: Pictures in the field

Anguilla marmorata

Hemibargrus wyckioides

Tenualosa thibaudeaui

Pangasius krempfi (right)
Pangasius bocourti (left)

 *Pangasius mekongensis*	 *Cosmochilus harmandi*
 Don Sahong dam under construction on the Mekong River	 Xayaburi dam *https://www.thaipbsworld.com/laos-and-xayaburi-dam-deny-responsibility-for-dry-mekong-river/*

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