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ECOGEOGRAPHICAL DIVERSITY AND DRY SEASON CHANGES ALONG THE MAINSTREAM MEKONG RIVER IN THAILAND, LAOS AND CAMBODIA

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ABSTRACT

The Mekong River is experiencing dramatic hydrological and sediment transport changes, largely due to the development of hydropower dams, both on its mainstream and tributaries. We ask, "how well do local people with a lifetime of experience living along and interacting with the Mekong River on a daily basis understand the changes that are occurring?" In this article, we present the results of research conducted with groups of villagers living in 44 communities located along the mainstream Mekong River from Chiang Saen District, Chiang Rai Province, in northern Thailand, downstream to Stung Treng Town in Stung Treng Province, northeastern Cambodia. Local people are well aware that changes are occurring and causing various types of negative environmental and social impacts, such as to seasonally inundated forests and vegetation along the river, sandbars, birds, algae, fish, mollusks, crabs and shrimps, semi-aquatic earthworms, and insects. Mitigation measures, such as the construction of river embankments, are causing their own adverse environmental impacts. Here, we argue that local knowledge related to the ecogeographical diversity of the Mekong River has been underappreciated, particularly as a result of increased reliance on remote sensing to understand environmental changes along the Mekong, and that local ecological knowledge can help us better understand Mekong River changes.

Keywords: diversity, hydropower dams, local ecological knowledge, Mekong, river change

INTRODUCTION

The mainstream Mekong River has undergone dramatic change over the last few decades due to various factors, but especially because of large-scale hydropower dam development (Kano *et al*., 2016; Soukhaphon *et al*., 2021; Middleton, 2022). Major hydrological changes have already occurred due to the construction of many large hydropower dams (Räsänen *et al*., 2012, 2017; Li *et al*., 2017; Binh *et al*., 2020a; Binh *et al*., 2021), with sediment transport significantly altered (Kummu & Varis, 2007; Fu *et al*., 2008; Kummu *et al*., 2010; Xue *et al*., 2011; Kondolf *et al*., 2014; Baran *et al*., 2015; Chuenchom *et al*., 2023). Sand mining is also having a significant impact through removal of sand and gravel from the river, compounding the immense loss of sediment due to dam sediment-trapping (Kondolf *et al*., 2018; Timmins, 2019; Hackney *et al*., 2020; Chua & Lu, 2022; Chuenchum *et al*. 2023).

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In this study, we investigate what these changes look like to the people who have been living with and relying on the Mekong throughout their lives, since before significant hydropower dam development began. How have particular species and wider ecosystems been impacted? How can the local ecological knowledge accumulated across generations and gained through a lifetime of personal experiences help us to better understand the changes that are occurring? We report on the findings of community-based research conducted in 44 villages located along the mainstream Mekong River from Chiang Saen District, Chiang Rai Province, northern Thailand; to northeastern Thailand; to Champasak Province, southern Laos; to Stung Treng Town in Stung Treng Province, northeastern Cambodia (Fig. 1). See, also, Appendix 1.

In recent years, remote sensing has become a powerful way to monitor environmental change. Indeed, it is now possible to track hydrological changes in reservoirs along the river using satellite imagery (see, for example, Vu *et al.*, 2022; Eyler & Basist, 2024; Eyler *et al.*, 2024; Mahto *et al.*, 2024). Remote sensing can also be used to assess riverbank erosion (Kummu *et al.*, 2008b; Tha *et al.*, 2022), and even to estimate the number of sand mining operations (Hackney *et al.*, 2021). Satellite technology is immensely valuable, but it can sometimes lead to erroneous assumptions. It has become much easier to gather data about hydrological changes in the Mekong from water level gauges and remote sensing technology that it is increasingly likely that the views of people living along the river are not being sufficiently considered, leading to local conditions and explanations being overlooked.

This research is focused on learning from community members, heretofore underappreciated in past studies, about changes in the Mekong River over the last few decades, since before large hydropower dams started being built in southern China in the 1990s. Bringing the voices of those experiencing the changes along the river is an important, indeed essential, addition to studies that focus primarily on river hydrology and flow. We also supported this research with interviews with experts and government officials, and available quantitative data.

Before we describe our methods and results of our interviews, we will provide a brief history of dam building on the Mekong River, the major cause of changes that adversely affect local villagers downstream. Following this, we will describe our study area in more detail.

THE MEKONG RIVER BASIN AND HYDROPOWER DEVELOPMENT

The Mekong River flows for approximately 4,900 km, with its origin situated in the high mountains of the Tibetan Plateau in China. The river passes through, or borders, six nation states. It acts as the border between Myanmar and China, then Myanmar and Laos, then Laos and Thailand, passing fully through northern Laos before again serving as the border between Laos and northeastern Thailand. The river then flows into southern Laos before crossing into Cambodia and eventually flowing into the Mekong Delta in Vietnam, and finally emptying into the South China Sea.

The first hydropower dams in the Mekong Basin were built on tributaries in Thailand beginning in the late 1950s (Zeller, 2014). Later, plans were developed for a series of mainstream Mekong dams along the Thailand–Laos border, but tensions of the Cold War made these projects impossible to implement (Sneddon, 2015). However, some tributary

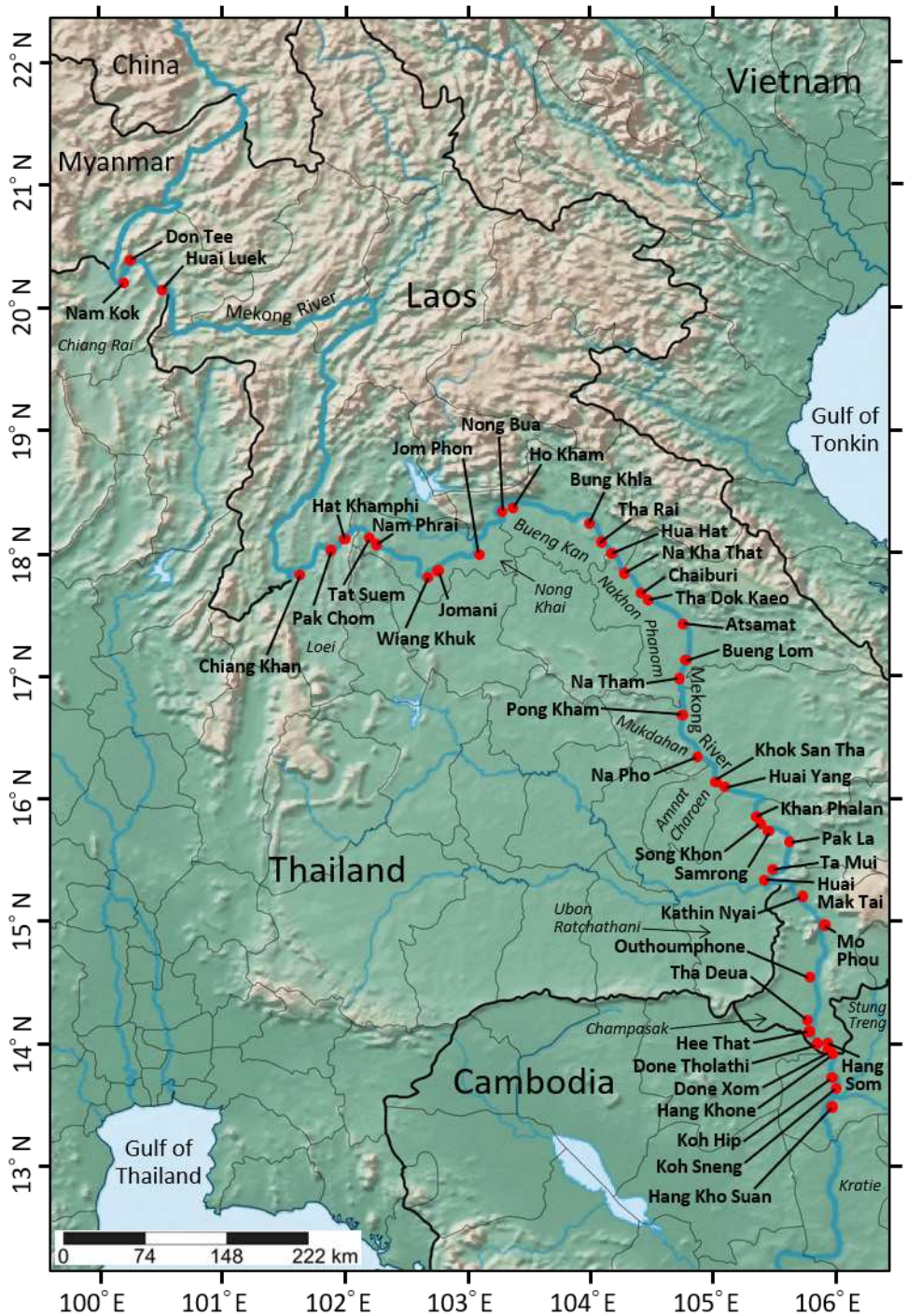


Figure 1. Map of the 44 villages (solid red circles) where focus group discussions were conducted along the mainstream Mekong River in March and April 2024. National borders and provincial borders are shown in bold and thin black lines, respectively. However, parts of the mainstream Mekong River serve as the national border and are in blue. Only names of provinces mentioned in the present study are shown (in italics).

hydropower dams were developed in the Mekong River Basin in Laos and Thailand between the 1960s and 1990s (Soukhaphon *et al*., 2021; Roberts, 1993; Foran & Manorom, 2009), and a network of large irrigation dams was developed on tributaries in northeastern Thailand in the 1990s (Sneddon, 2003).

The first dam on the mainstream Mekong ("Lancang" in Chinese) River in China, the Manwan Dam, began construction in the early 1990s and was completed in 1995 (Magee, 2006). It began trapping sediment by 1993 (Fu *et al*., 2008). Ten more dams were built on the Lancang River in China during the 2000s and 2010s (Hennig *et al*., 2016). There are also approximately 95 smaller dams located on tributaries in China. Two dams on the mainstream river have particularly large reservoirs: the Xiaowan and the Nuozhada, both located in southern Yunnan Province (Eyler & Basist, 2004; Eyler *et al*., 2024).

In Laos, the end of the Cold War resulted in economic reforms that led to the opening of the country to foreign investment, including development of hydropower. Hence, in the 1990s several dams were developed on Mekong tributaries in Laos (International Rivers Network, 1999; Barney, 2007; Whitington, 2018). The Lao PDR government also started encouraging foreign investment in large dam development through build-own-operate-transfer (BOOT) projects (Wyatt, 2004).

In the 1990s, the government of France supported the preparation of an ambitious plan for developing a cascade of large dams on the lower mainstream river basin in Laos, Thailand, and Cambodia (Hill & Hill, 1994; Roberts, 1995). While some of the projects being developed in the 1990s were completed as planned, hydropower dam-building in Laos largely came to a halt following the 1998–1999 Asian financial crisis, which caused the economy and electricity demand in the region to dramatically decline (International Rivers, 2008). The release of the World Commission on Dams (2000) final report also negatively affected the image of large dams internationally, and the prospects for developing new large dams in the region.

Beginning in mid-2000s, hydropower dam development resumed in the region, particularly on tributaries in Laos (Shoemaker & Robichaud, 2018; Whitington, 2018). Once again, however, the global financial crisis of 2008 slowed dam-building momentum. Beginning in the early 2010s, however, hydropower development increased rapidly on various tributaries in Laos, and the Xayaburi and Don Sahong dams were constructed on the mainstream Mekong River during this period. In 2014, construction on the Lower Sesan 2 Dam on a major Mekong tributary in northeastern Cambodia also commenced (Soukhaphon *et al*., 2021).

While the 2020–2021 COVID-19 pandemic again slowed construction of some dams in Laos, there are presently well over 100 hydropower dams in the planning and construction stages of development, and over the past few years dozens of dams of various sizes have been completed on Lao tributaries (Stimson Institute, 2024).

It is well documented that there is now significantly more water flowing down the Mekong River during the dry season than was the case before dams started being built on the Lancang River in China during the early 1990s, and especially more recently in the 2000s and 2010s after more dams were completed. This has negatively impacted perennial plant species found in the riverbed, as well as species growing on the riverbank, as documented in this study.

The most significant intergovernmental body focused on issues related to the Mekong, the Mekong River Commission (MRC), includes only four of the six countries bordering the Mekong: Laos, Thailand, Cambodia and Vietnam (China has refused to join). However,

the MRC is only a research and advisory body; it has no power over the decisions of governments regarding constructing and managing dams.

STUDY AREA

Study Populations

The people we met along the Mekong River during the study mainly categorize themselves as farmers. Most cultivate lowland wet rice, but many also grow vegetables and other crops on islands and sandbars in the river, on its banks, or on land within a few kilometers of their villages and the river (Fig. 2). Small-scale fishing also has provided subsidence and income to people living along the river, and villagers consume other aquatic animals such as mollusks, crabs and shrimps, aquatic insects, and more. This continues to be the case today, but the overall importance of the river to local livelihoods has generally declined, due to general changes to society and the economy that have occurred throughout the riparian countries.

The population along the Mekong is generally aging, and is increasingly reliant on remittances from their children and other relatives working in urban areas and overseas. Agricultural practices have become more market-based and dependent on technological innovations in crop production and chemical inputs. Still, the livelihoods of many people



Figure 2. Villagers in Chiang Khong District, Chiang Rai Province, northern Thailand, March 2024 (photo by Ian Baird).

are still closely linked to the river and its natural abundance, and many in the villages we visited still rely heavily on fishing and other activities directly associated with the river, even if fisheries are not as productive as they once were, due to the cumulative impacts of dams, to changes resulting from riverbank embankment, overfishing, and the use of destructive fishing practices such as electric fishing that are occurring throughout the study area.

The River

The Mekong River is not uniform, with changes in width, depth, substrate and morphology, even over short distances. For example, at Song Khon Village in Ubon Ratchathani Province, northeastern Thailand, the width of the river during the dry season is just 56 meters (see Fig. 3), while just above the Khone Falls in southern Laos it is 5,723 meters wide. These key attributes have a huge impact on local biodiversity, among other things. The water tends to be deeper and flow faster where the river is narrow. Figure 4 includes relative values (from 1 to 5, plotted along an axis that represents the relative distance between each of the villages) for important physical attributes of the river, as recorded in 43 communities (measurements were not taken in Jomani Village, Nong Khai, northeastern Thailand).



Figure 3. The Mekong River at Song Khon Village, Phosai District, Ubon Ratchathani Province, northeastern Thailand, at one of its narrowest points (56 m wide) (photo by Ian Baird).

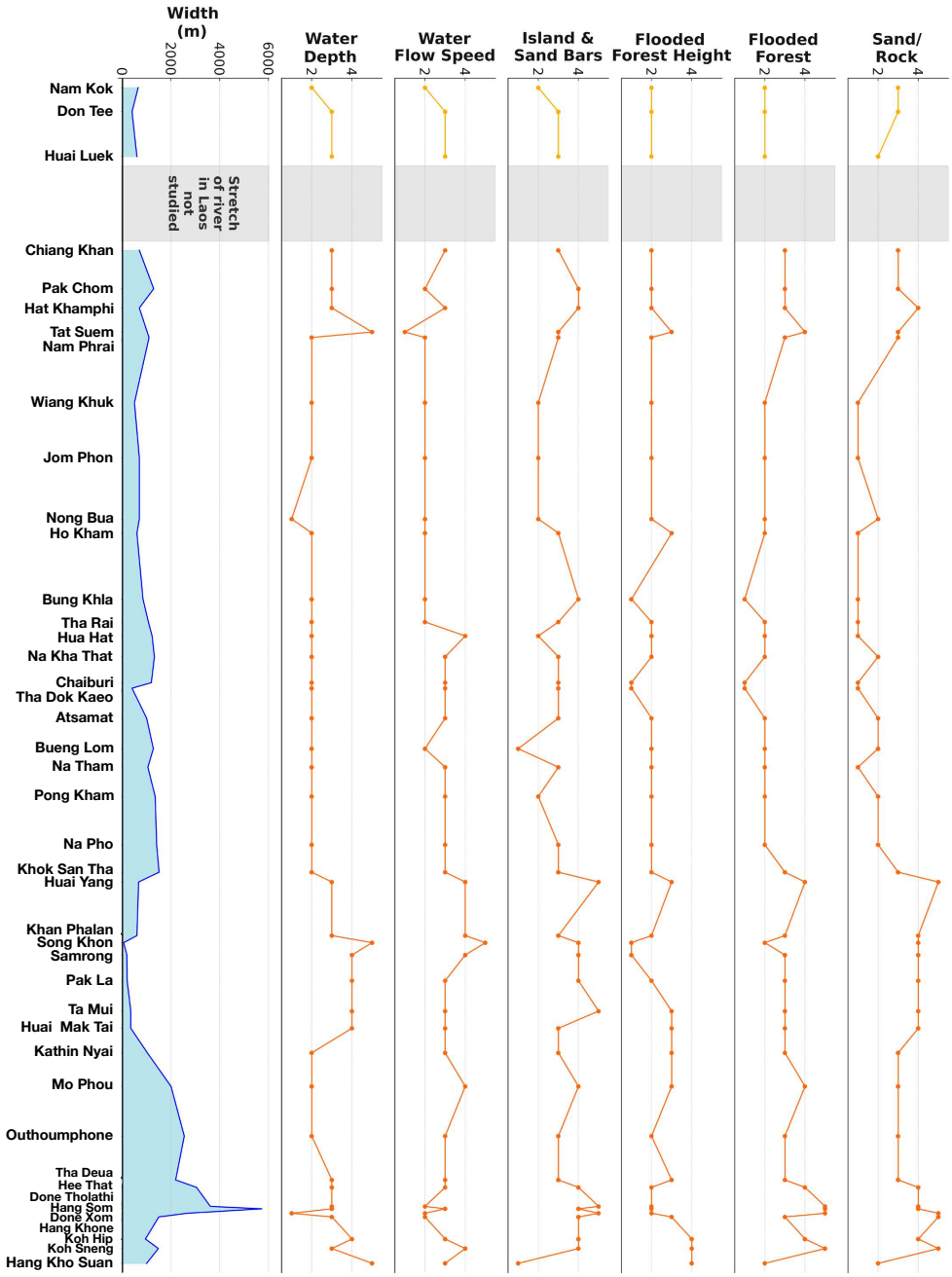


Figure 4. Relative abundance or extent of certain attributes of the Mekong River at the communities visited during the study, on a scale of 1 (minimum) to 5 (maximum). The relative distance between the villages is represented by their respective spacing along the axis.

The upstream part of the river in our study area, in Chiang Rai Province, northern Thailand, is generally rocky. This is also the case in Loei Province, northeastern Thailand, but from Nong Khai downriver to Amnat Charoen Province the substrate is much sandier, and the river is generally wide. In Ubon Ratchathani Province downriver to Stung Treng the river is rockier, although there are sandy sections. Some parts of the river host expansive seasonally flooded forests, especially in places with rocky substrates, while areas with sandier substrates are bare. The flooded forest tree species are generally much taller and much more extensive in the downstream parts of the study area than upstream parts.

Sediment transport along the Mekong River has significantly declined over the last few decades, and various authors have reported that the amount of sediment coming down the Mekong River has declined dramatically in recent years (Allison *et al.*, 2017; Chuenchom *et al.*, 2023; Baird *et al.*, 2025). Apart from the blocking of sediment by hydropower dams, the extraction of sand and rocks from the river for various purposes has also been responsible for significant environmental impacts (Bravard *et al.*, 2013, 2014; Binh *et al.*, 2020b; Asif & Van Arragon, 2023).

Due to the Mekong dams holding back significant amounts of sediment, increased erosion and scouring occurs downstream. This is referred to as the 'hungry water' effect, referring to when sediment-deficient water is released from dams and then picks up more sediment downstream. It also prevents the replenishment of sandbars, and results in lower wet-season water levels (McCully, 2001; Baird & Thorne, 2023). Riverbed incision has affected some areas with sandier riverbeds more than other parts of the river with a rockier substrate (Baird *et al.*, 2025). This has resulted in differing impacts on sandbars, as in parts of the river, riverbed incision has resulted in the perception that there is less water in the Mekong River during the dry season, when there is actually more water.

Seasonally Flooded Forest

The seasonally inundated riverine forests along the mainstream Mekong River vary with riverbed morphology. In parts of the river lying on bedrock, seasonally flooded plant species can more easily attach their roots, allowing them to survive the strong force of water flow during the height of the rainy season. Therefore, the areas that have historically supported the most flooded forest are the upper part of the study area in northern and northeastern Thailand where the riverbed is rockier, and in the southernmost part of Laos and below the Lao border in Cambodia. Between Nong Khai and southern Mukdahan provinces the river is sandier and there is less forest.

The main perennial flooded forest tree and bush species change as one goes downstream. In Chiang Rai, northern Thailand, *Homonoia riparia* (Fig. 5) and *Salix tetrasperma* are the main forest species. This continues to be true all the way down to Ubon Ratchathani Province, where the taller *Anogeissus rivularis* and *Acacia harmandiana* trees start appearing along parts of the river. Below the Khone Falls in northeastern Cambodia they are the dominant species. In Champasak Province, other species appear, including *Telectadium edule, Rotula* cf. *aquatica,* and *Flueggia jullieni* (Fig. 6). *Crateva magna* and *Syzygium hancei* are found throughout the study area, as are many species of annual plants (Appendix 2). The species found in Stung Treng Province are also different from those found farther downstream and along the Tonlesap Lake (McDonald *et al.*, 1997; Maxwell, 2001).

These seasonally flooded forests have died in large numbers (see Figs. 7–9) due to the construction of large dams upriver in China (Lu *et al.*, 2014; Baird & Thorne, 2023;



Figure 5. *Homonoia riparia* in Mekong River, Khong District, Champassak Province, southern Laos, March 2024 (photo by Ian Baird).



Figure 6. *Homonoia riparia* (left) and *Telectadium edule* (center and right), Done Xom Village, Khong District, Champassak Province (just above Khone Falls in southern Laos), March 2024 (photo by Ian Baird).



Figure 7. *Anogeissus rivularis* (*lam saeng*) dead at Huai Yang Village, Khemmarat District, Ubon Ratchathani Province, northeastern Thailand (photo by Ian Baird).



Figure 8. Comparison between flooded forests in Khemmarat, Ubon Ratchathani Province, northeastern Thailand in March 2015 (above) and in March 2020 (below) (compliments of Watcharin Pudpong).



Figure 9. Dead *Anogeissus rivularis* (*lam saeng*) trees in Stung Treng Province, northeastern Cambodia, April 2024 (photo by Ian Baird).

Chen *et al*., 2024) and in the mainstream Mekong River in Laos, as well as in the tributaries in Thailand and Laos (Soukhaphon *et al*., 2021). Downstream impacts of dams have historically been underappreciated and under-mitigated, and the villagers impacted have generally received insufficient consideration and compensation (Wyatt & Baird, 2007; Richter *et al*., 2010; Baird *et al*., 2021).

The plant species found along the Mekong River are listed in Appendix 2, and details of flooded forests by province are given in Appendix 3.

METHODS

The main focus in this article is on how changes in the river during the dry season affect villagers, when the Mekong River waters are typically at their lowest, between February and April. Hence, we conducted our field research during this season. We visited villages along the Mekong River in Thailand, Laos and Cambodia between March 1 and April 3, 2024 (Fig. 1). These villages are located at intervals of approximately 50 km, all the way from Chiang Saen District, Chiang Rai Province, in northern Thailand, down to Stung Treng Town in Stung Treng Province, northeastern Cambodia, except for the section where the Mekong flows fully into Laos at Kaeng Pha Dai, and then returns to form the Lao–Thai border in Loei Province. We did not randomly select the villages, but chose them based on a few different factors, such as proximity to important wetland areas adjacent to the Mekong River, which we examined using satellite images prior to fieldwork. We also chose villages with travel planning in mind. In addition, we already had contacts in some communities, due to

past work, or because of information provided by non-government organizations (NGOs) and their allies working along the Mekong River. Thus, some residents of villages were active members of NGO networks.

Our method is partially based on previous research conducted along the Mekong River in Stung Treng Province, northeastern Cambodia, in June 2022. At that time, we interviewed local people living along the Mekong River and made use of national hydrological data to understand how the river has changed during the dry season, and particularly why much of the seasonally inundated forests located within the riverbed and along its banks have died in recent years (Baird & Thorne, 2023; Lovgren, 2024). That research inspired the current work, which has the goal of scaling up the geographic range to learn from local people living along a longer stretch of the river about how the river has changed, and how those changes have affected them. We have tried to engage with villagers in a manner that was most conducive to learning from them (see Baird, 2006).

Research in different parts of the world has revealed the value of local ecological knowledge in understanding how aquatic ecosystems function, and how resources can be sustainably managed. Such knowledge is often important for improving policy and ecosystem management (Haggan *et al*., 2007; Silvano *et al*., 2023; Hamelin *et al*., 2024), particularly for complex tropical ecosystems where less research has been conducted (Johannes *et al*., 2000; Baird, 2006, 2007; Baird & Manorom, 2019).

The interviews were semi-structured and similar in design. The same topics were covered in all interviews of villagers, based on a pre-determined list of topics and questions. However, we also pursued other issues that villagers brought up during the course of interviews, in order to ensure that all their topics of concern were considered. Detailed notes were taken during all interviews. In the results, to avoid redundancy of sentences, the country name of each province is omitted from the text in most cases. However, readers can easily recognize the country to which each locality belongs from Appendix 1 and Figure 1. Percentages provided in the paper were estimated by villagers during interviews.

During community visits, groups of villagers, both men and women, mostly between their 40s and 70s, informally met us at various locations along the river (Fig. 2). These focus group interviews were sometimes conducted in central Thai (in Chiang Rai), but were mainly done using various dialects of Lao, including northern Lao, Isan Lao, southern Lao, and northeastern Cambodian Lao. The first author, who is fluent in all these languages and dialects, led the interview and discussion process in the villages, with each group interview and discussion taking between one and two hours. At all locations we made assessments of embankments, potential sand mining operations, river width measurements, riverbed strata and abundance of river vegetation. In addition, we sometimes combined interviews with short walks, drives and boat trips to observe aspects of the Mekong River, often together with interviewees.

During this study, we recorded the width of the Mekong River at each interview location using satellite data. We also visually assessed the riverscape, and obtained information from villagers about riverbed morphology. We applied a relative scoring system of 1 to 5 for water depth, based on villager reports, water flow speed, number of islands and sand bars in the river, the height of the flooded forest tree species in the area, the amount of flooded forest in the area, and the riverbed morphology in the area (from fine sand to large rocks) (Fig. 4).

RESULTS

Villager Interview Responses

The results of the interviews conducted for this study demonstrate that the local conditions along different sections of the river vary significantly, and have been impacted by upstream dams in different ways. Although different parts of the river are intricately connected to each other through the flow of water, the ecogeographical variation along the river is considerable. We start by reviewing aspects that communities across the study area consistently reported.

First, everyone we interviewed was fully aware that the Mekong has already changed; that change is continuing; and that past and current changes are negatively affecting the biological diversity and productivity of the river. Particularly in relation to the dry season, villages were in consensus that:

1) There have been significant changes to the hydrology of the river, with water fluctuating considerably on a daily basis (see, also, Morovati *et al*., 2024). While this was reported throughout the study area, it was particularly pronounced in northern Thailand, but was least evident in northeastern Cambodia.

2) The color of the river in the dry season has significantly changed, from being silty and sediment-rich to being clearer and greener or darker.

3) These changes have negatively impacted biological diversity and productivity along the river in various ways, depending on local circumstances.

Villagers were not in agreement regarding whether there is more or less water in the Mekong River during the dry season than formerly, before construction of the dams. Villagers in Chiang Rai and Loei provinces in the upper part of the study area believed there is more water. but between Nong Khai and Mukdahan provinces, villagers believed that there is less water. Villagers between southern Mukdahan Province in Thailand and Stung Treng Province in northeastern Cambodia believed there is more water during the dry season. The area between Nong Khai and Mukdahan has sandy substrates and a lot of sand mining operations. We therefore believe the disagreement is likely due to the riverbank incision and riverbed erosion, particularly in the middle section, and also the removal of large amounts of pebbles and sand from the riverbed, which has led to the mistaken impression that there is less water in the dry season when in reality there is more, as the hydrological data verify (Baird *et al*., 2025).

Seasonally Flooded Forests

Appendix 3 includes detailed accounts of changes in flooded forests along various stretches of the Mekong. Villagers were in overall agreement throughout the study area that there has been a significant reduction in flooded forests. Villagers believed that there are important reasons why these losses have occurred, especially changes in the hydrological patterns of the river due to upstream hydropower dams.

Another factor related to the decline in flooded forests has been river embankment construction, which has led to the loss of riverbank habitat along the edge of the river (see section below). This is especially true along the stretch of the river that borders Thailand,

as most of the river on the Thai side has been embanked in recent years. Villagers are well aware of the impacts, but generally claim that the embankments are necessary because of the increased amount of erosion that is occurring along the river due to changes in the annual water regime and the reduction of sediment flow downriver.

River Embankments

Increased riverbank erosion and incision attributed to the upriver dams has resulted in the loss of significant amounts of land adjacent to the Mekong River (Tha *et al*., 2022; Pattanamongkol, 2023). In turn, this has led to the embankment of much of the Thai side of the Mekong River (reportedly at least 83% of the river has already been embanked). Villagers recognize that embankments have caused environmental impacts, but they generally believe that the erosion that was occurring before they were constructed justified embankment construction (Fig. 10). One noticeable consequence that could be observed where embankments had been constructed along the Thai side of the river was increased erosion at previously unaffected stretches a short distance downriver on the Lao side of the river. Locals also frequently reported this to be the case.

In Don Tee Village, Chiang Khong District, and Nam Kok Village in Chiang Saen District, Chiang Rai Province, *C. magna* trees died when the embankment near their villages was built. Villagers in Nam Kok Village found, however, that vegetation still occurred on the Lao side of the river, since it had not been fully embanked. However, still only 30–40% remain on the Lao side as high dry season water levels caused some trees to die.

In Bung Khla District, Bueng Kan Province, villagers stated that 40–50 meters of land had been lost to riverbank erosion prior to an embankment being built. Coconut and tamarind trees next to the Mekong ended up falling into the river. In other communities along the Mekong less erosion was experienced.

In Bung Khla, erosion and then embankment construction has impacted the aquifer as far as 15 km away from the river. Previously, wells had been just 20 meters deep, but now needed to be 80–100 meters deep to access the same amount of water. Moreover, these deep wells often hit salt pans, resulting in the water pumped up being salty. This has caused problems with accessing clean water, as deep wells are expensive. Increased groundwater extraction may also be contributing to these aquifer challenges.

In Pak Khat District, Bueng Kan Province, embankment construction has negatively impacted various species of native vegetation, including *Asparagus racemosus*. The impact of river embankments on plants along this part of the river, where there are few islands, was particularly severe, and most *H. riparia* and *S. tetrasperma* were lost. In some cases, these native species were replaced by *Mimosa pigra,* an invasive species.

In Bung Khong Long District, Bueng Kan Province, almost all of the *H. riparia* were lost when an embankment was built over 20 years ago, but a small amount has grown back since then. In Ban Phaeng and Tha Uthen districts, Nakhon Phanom Province, and Don Tan District, Mukdahan Province, embankments have destroyed all the *H. riparia*, and the only remaining flooded forest trees are on the Lao side of the river where there are no embankments. A. racemosus, *ton mak hoong heo*, *phak khi on*, and *phak hom nam* have all apparently been lost due to unusual water fluctuations and embankment construction. In Tha Uthen District, Nakhon Phanom Province, *H. riparia* and *A. racemosus* had also been lost due to embankment construction. In Don Tan District, Mukdahan Province, most of



Figure 10. Newer river embankment at Kaeng Kabao, Ubon Ratchathani Province, northeastern Thailand, March 2024 (photo by Ian Baird).

the *C. magna* in the area were destroyed by river embankment less than a decade ago. In Huai Mak Tai Village, Khong Chiam District, Ubon Ratchathani Province, some *H. riparia* were also destroyed by embankment.

In Tha Uthen District, Nakhon Phanom Province, the number of sandbars has declined dramatically due to erosion, and the deepest part of the river was on the Lao side because of embankment construction on the Thai side. In this province there are more river embankments than elsewhere, and sometimes embankments have become layered. For example, in Ban Phaeng District, a new embankment is being built on a previous one extending a further 100 meters into the river (Fig. 11). At the provincial capital, three layers of embankments have been constructed. In That Phanom District, when a second embankment was being built on an existing one, Lao authorities complained. This caused construction to temporarily stop (but was resumed later).

In Ban Phaeng District, Nakhon Phanom Province, the bivalve *Pseudodon vondembuschianus* has benefited from the creation of river embankments, since they inhabit crevices between the rocks used in construction, and in Mueang District, Nakhon Phanom Province, some kinds of fish hide between the rocks, and in Wanyai District, Mukdahan Province, *kapoo khi lek* crabs stay between the embankment rocks. However, the negative impacts certainly outweigh the positive ones.

In Wanyai District, Mukdahan Province, river embankments have negatively affected large Mekong earthworms. In Don Tan District, Mukdahan Province, and Chanuman District, Amnat Charoen Province, embankment construction also reduced a large earthworm population but the species could still be found on islands in the river.



Figure 11. Second river embankment being constructed in Ban Phaeng District, Nakhon Phanom Province, northeastern Thailand, March 2024 (photo by Ian Baird).



Figure 12. Riverbank gardening on older river embankment at Chiang Khan, Loei Province, northeastern Thailand, March 2024 (photo by Ian Baird).

In Samrong Village, Phosai District, Ubon Ratchathani Province, the construction of river embankments has resulted in the loss of important small pool (*boong*) habitat along the river. People in several villages claimed that dragonflies, mayflies, grasshoppers, *maeng ee* and *maeng sawn* insects have all declined due to unusual river water fluctuations and the destruction of their habitat by embankments. In contrast, villagers from an as yet un-embanked village in Phosai District, Song Khon, affirmed that dragonflies are still abundant.

There are fewer river embankments downstream in Champasak and Stung Treng provinces, and as a result, riverbank dependent species were rarely reported as being impacted in the same way.

Overall, villagers agree that while justified due to increased riverbank erosion, river embankment construction, particularly in Thailand, has had negative impacts on various plant and animal species dependent on the Mekong River.

The UNDP's BIOFIN Programme was extremely critical of Thailand's subsidies for environmentally damaging canals and embanking of rivers, particularly by the Water Resources Department, and the Irrigation Department before them, and by local governments in various parts of the country (UNDP, 2020).

River Embankment and Vegetable Gardens

Hydrological and sediment flow changes have negatively impacted riverbank vegetable gardening along the Mekong River. For example, in Don Tee Village, Chiang Khong District, Chiang Rai Province, villagers used to grow gourds, peanuts, corn and watermelon on sandbar islands, but this is less possible now due to the loss of islands, and the unusually fluctuating water levels during the dry season.

At Nam Kok Village, Chiang Saen District and Huai Luek Village in Wiangkaen District, Chiang Rai Province riverbank gardening had stopped altogether, due to changes in river hydrology during the dry season. In Hat Khamphi Village, Pak Chom District, Loei Province, villagers formerly grew peanuts, corn and *man dang* tubers on islands in the Mekong before, but they could no longer do so due to the fluctuating water levels. Similarly, villagers from Pak Chom District Center previously cultivated *man dang* tubers and tobacco on islands in the Mekong, but this was also no longer possible. In addition, villagers in Mueang District, Bueng Kan Province used to grow peanuts, tomatoes and *man dang* tubers during the dry season, but now most people have stopped also due to the water levels.

As a result of these unusual water fluctuations in the dry season, many villagers have tried moving their gardens higher up on the bank, thus reducing the area available for planting, but even these gardens are sometimes prematurely flooded. Most villagers in Khong Chiam District, Ubon Ratchathani Province, had reportedly stopped riverbank gardening after losing their seeds one year due to dry season flooding.

Villagers widely believed that the quality and quantity of sediment deposited during the rainy season decreased the fertility of riverbank gardens. The construction of river embankments replaces sediment with rock and concrete, but in some cases, such as at Chiang Khan, Loei Province, and in Tha Rai Village, Bung Khong Long District, Bueng Kan Province, further sediment accumulation some 20 years after embankment construction now allows for gardening on the river embankment itself, set back from the river well beyond the reach of the highest flood levels (Fig. 12). Likewise, villagers in Tha Uthen

and Mueang districts, Nakhon Phanom Province, resumed vegetable gardening on river embankments a decade after they had been built. However, in other places, such as at Bueng Lom Village in Mueang District, Nakhon Phanom Province, and Don Tan District, Mukdahan Province, even after many years gardeners are still not able to grow vegetables on the embankments due to lack of sediment accumulation.

Villagers in Ta Mui Village, Khong Chiam District, Ubon Ratchathani Province used to grow rice on the edge of the Mekong River near *boong* areas, when the water receded, but this has not been possible for about 20 years due to unusual water fluctuations and reduced sediment deposition. They previously cultivated a native red variety of glutinous rice called *khao abai*.

Overall, villagers reported that hydrological and water quality changes along the Mekong River have reduced riverbank gardening activities, especially due to the unusual water fluctuations during the dry season and reduced sediment deposition in the river. Riverbank gardening has been negatively impacted by river embankments, although some impacts have subsequently been mitigated by renewed sediment deposition following their construction. Nonetheless, deposition is much slower than in the past due to decreased sediment flow in the river.

Sandbars

Sandbars are useful parts of the river, ideal spots for various communal activities. Grass-covered sandbars are used for grazing by water buffalos. The situation regarding sandbars was found to vary widely from village to village, and from river section to river section. People from some villagers reported dramatic declines in sandbars, but sometimes other nearby villagers reported increases in sandbars. Some said the changes in sandbars seemed abnormal compared to the past, while others reported that shifting sandbars are normal. But we know that the amount of sediment in the river has declined dramatically, so overall there are certainly fewer sandbars than before. However, this is not the case in every section of the Mekong, due to local morphological differences along the river.

In Chiang Rai Province, reports suggest a 70–80% decline in the extent of sandbars and islands in the river, compared with the early 1990s, and that the river banks have also become rockier and steeper due to sediment loss and erosion. In Don Tee Village, Chiang Rai Province, there is less grass to feed water buffaloes, as there are fewer islands for the grass to grow on. In Loei Province, there has been a 40–80% decline in sandbars. However, in Tat Suem and Nam Phrai villages in Sangkhom District, Nong Khai Province, there are twice as many sandbars compared to the past, and there has been a significant increase in sandbars in Bung Khla District, Bueng Kan Province. Farther downriver, in Hang Khone Village, Khong District, Champasak Province, immediately below the Khone Falls, only 10% of the sandbars remain.

Near the provincial capital of Nong Khai, an important large sandbar was present near the bridge across the Mekong River, called Hat Jomani. It was especially well-known for being the site for the important Songkran festival and other community activities where small vendors sold goods. A well-known song was even inspired by the sandbar. However, that sandbar has now eroded and disappeared, leading to a considerable loss of income for the community.

Sand mining has been blamed for the increased erosion and the loss of sandbars. Some changes were seen as typical for the river, but in many cases these changes appeared

to be abnormal and exceptional. Thai government data clearly indicates that the amount of sediment flowing down the Mekong River each year has declined dramatically compared to the years before dams were constructed on the Mekong River in the early 1990s (Baird *et al.*, 2025).

Algae

Edible algae in the Mekong River is affected by Mekong River changes, particularly in the upper part of the study area where algae was previously an important source of food and livelihood. In Don Tee Village, Chiang Khong District, and Huai Luek Village in Wiangkaen District, Chiang Rai Province, the quality of *khai*, a riverine green alga belonging to the family Cladophoraceae that typically grows on rocky substrates in flowing water, has declined. Villagers used to collect and dry it, making *khai phaen*, which they sold. They still harvest it, but its quality and quantity have declined.

Villagers in Nam Kok Village used to collect algae for eating, and it was economically important downstream in the Luang Prabang area of northern Laos. Villagers in Huai Luek Village collected edible algae between January and March in shallow rocky areas, but now the water levels fluctuate so that it is often too deep for the algae to grow. Villagers also believe that river water temperatures have declined due to the Chinese dams releasing cooler water, and that this might be preventing the growth of algae.

In Don Tee Village, *dawk hin*, a blue-green alga (Cyanobacteria) of the family Nostocaceae, has become less common in recent years. Villagers in Chiang Khan, Loei Province, also collected and consumed *khai hin*, but did not dry it or sell it as in Chiang Rai Province. In Chiang Khan, the amount of algae harvested varied from year to year, there being more in years of lower water levels.

Another type of edible filamentous algae, called *thao* (*Spirogyra* sp.), typically inhabits small non-flowing pools (*eng*) during the dry season in Don Tee Village and Huai Luek Village in Wiangkaen District, Chiang Rai Province. This habitat has become rare due to increased dry season water levels. A type of alga known as *nyae* (Cladophoraceae), which shrimp used to inhabit, has also declined in recent years.

Villages downstream from Loei Province considered the different types of algae in the Mekong River to be "dirty" and therefore generally did not consume them, preferring instead to harvest edible algae from ponds and streams.

Overall, edible algae is harvested and consumed mainly in the upstream part of the study area; people farther downriver have never consumed algae from the river. Those who do consume algae maintain that changes in hydrology and water quality have reduced its quality and quantity, and that higher water levels during the dry season also make it more difficult for people to collect algae.

Birds

A number of species of birds, such as the Indian Skimmer (*Rynchops albicollis*) and the Black-bellied Tern (*Sterna acuticauda*), as well as species of large waterbirds, such as Black-necked Stork (*Ephippiorhynchus asiaticus*), have long since been extirpated from the study area, in some cases as long as a century or more ago (Deignan, 1945; Duckworth *et al.*, 1999; Collar *et al.*, 2001).

More recently, many other species of birds have become less common due to changes along the Mekong River. However, it is not always easy to understand exactly how different bird species are affected by hydrological and other changes. The most obvious impacts appear to involve sandbar-nesting birds (Claassen, 2004, 2016; Keithmaleesatti *et al*., 2022): sandbar habitat has been reduced by upriver hydropower dam development and reduced sediment flow (Baird & Thorne, 2023). In addition, higher dry season water levels due to upstream water releases have also contributed to a reduction in sandbar habitat in some areas (Baird & Thorne, 2023). Sudden dry season water releases may also cause catastrophic inundation of the eggs and young of sandbar-nesting birds. Appendix 4 includes the impacted bird species discussed with villagers.

In Chiang Rai and Loei provinces the population of small pratincole (*Glareola lactea*), probably the most numerous and widespread sandbar nester, and a common species throughout our study area, has declined along the Mekong, and in Pak Chom District, only about 10 % of them remained. Populations have declined farther downriver as well. Locals believe that the reduction of sandbar habitat is a major reason for the decline. Keithmaleesatti *et al*. (2022) argued that nesting success of small pratincoles had decreased in Bueng Kan Province due to unusual water fluctuations during the dry season.

In Nam Kok Village, Chiang Rai Province, fewer Asian Green Bee-eaters *(Merops orientalis)* and Chestnut-headed Bee-eaters *(Merops leschenaulti)*, which nest in burrows excavated in riverbanks, are observed, due to the construction of concrete river embankments. The number of bee-eaters has declined in Pak Chom District, Loei Province, with fewer nests in the riverbank than previously. In Bueng Kan Province, bee-eaters could only be found on the Lao side of the river, since the Thai side has been embanked, destroying their riverbank nesting habitat. Populations have also reportedly declined in other downriver locations. In Sneng Island Village, Stung Treng Province, for example, bee-eater populations have declined by 40%. The Asian Plain Martin *(Riparia chinensis)*, less well-known to villagers, nests in colonies along riverbanks, and its population along the river has also declined. Another unidentified bird species, locally known as *nok pong peo/nok ka dep*, has also declined due to embankments.

In Chiang Khan District, Loei Province; Pak Khat District, Bueng Kan Province, and Tha Uthen and That Phanom Districts, Nakhon Phanom Province, there are fewer sandbar-nesting Little Ringed Plovers (*Charadrius dubius*) than previously. In Phon Phisai District, Nong Khai Province, Little Ringed Plovers and another species, locally known as *nok khikadeuan sang*, have significantly declined, especially the latter species. Nesting Little Ringed Plovers has been reduced by fluctuating water levels caused by upstream dam operations (Keithmaleesatti *et al*., 2022).

Populations of River Lapwings (*Vanellus duvaucelii*), a globally near-threatened sandbar-nesting bird found along the river in the study area, have declined at many locations. Locals have claimed that river lapwings have become rare or in some cases have completely disappeared in recent years.

The River Tern (*Sterna aurantia*), a globally vulnerable species which nests on sandbars and is rarely found away from rivers, and the Whiskered Tern (*Chlidonias hybrida*), a species of least concern and a non-breeding visitor to the study area, have become either rare or absent. It is often hard for villagers to distinguish the two species. People in Tha Rai Village, Bung Khong Long District, Bueng Kan Province, stated that terns tended to migrate upriver with migrating fish in April each year. This fits with similar reports from southern Laos and

northeastern Cambodia (Baird & Manorom, 2019). Terns could still be found in small numbers in most areas, although in Done Tholathi Village in Khong District, Champasak Province, they have now disappeared. They can no longer be seen in Hang Khone Village, where they were common in the 1990s. In Koh Sneng Village, Stung Treng Province, the River Tern population has declined by 70%. According to the birding website, *eBird*, River Terns are mainly found downriver from the Khone Falls, with only a few recent sightings from upstream areas in Ubon Ratchathani and Amnat Charoen provinces (eBird, 2025).

There used to be Great Thick-knees (*Esacus recurvirostris*), a near-threatened species, near many village communities, but they have now disappeared from some areas and are rare in others. This species relies on sandbar habitat for nesting.

Populations of the near-threatened and endemic Mekong Wagtail (*Motacilla samveasnae*) may have declined due to nests being inundated during the dry season. Some people reported that this species, which was only described as a new species in 2001 (Duckworth *et al.*, 2001), sometimes nests in association with *Salix tetrasperma* trees. However, the Mekong Wagtail may likely be confused with the White Wagtail (*Motacilla alba*), both a scarce breeder and a much commoner non-breeding winter visitor to the study area.

In Samrong Village, Phosai District, Ubon Ratchathani Province, villagers no longer raise as many water buffaloes or collect bird eggs for food as they used to, and this has benefited some riverine birds. Claassen (2016) found that egg collection and water buffalo trampling were damaging to sandbar-nesting birds along the mainstream Mekong River in northeastern Cambodia.

In Chanuman District, Amnat Charoen Province, some birds such as weavers make their nests in *Homonoia riparia* bushes, and a reduction in flooded forest has reduced their nesting habitat.

In Pak La and Huai Mak Tai Villages, Khong Chiam District, Ubon Ratchathani Province, *nok en nam* or *nok en lom*, another swift or swiftlet species, make nests in small caves in rocks adjacent to the river, some of which may have been flooded due to unusual water fluctuations.

In summary, declines in most of the key bird species dependent on the Mekong River for nesting during the dry season were often blamed on the reduction of sandbars, along with higher water levels during the dry season.

Fish and Fisheries

The Mekong River Basin is well-known for its high fish diversity (Rainboth *et al.*, 2012; Taki *et al.*,2021; Baird & Hogan, 2023; Grudpan *et al.*, 2023), and may support the most important freshwater fishery in the world (Baran & Borin, 2012). However, hydropower dam development on the Mekong/Lancang River has had dramatic impacts on fish and fisheries in the basin. The relative impacts of dams and types of fishing gear on Mekong fisheries have been debated (see Kummu *et al.*, 2008a). Villagers have experienced significant declines in fish populations and fisheries over the last few decades. Appendix 5 includes the main species claimed by villagers as having been negatively impacted by Mekong River changes.

It is difficult to determine the exact reasons for fish population declines, as they are likely to be due to a combination of factors, including changes in habitat, the obstruction of migrations, destructive overfishing, and pollution. Many people have expressed concerns about the downstream impacts of dams, but in many areas they have also criticized the prevalence of electric fishing. Gillnets, the main type of fishing gear used throughout

the study area, tended not to be blamed, although they are probably also a significant cause of population declines.

Villagers in Chiang Rai Province were particularly concerned that many fish species that used to migrate upriver have declined dramatically, presumably due to the construction of the Xayaburi Dam. This includes the iconic giant catfish *Pangasianodon gigas* and *Pangasius sanitwongsei*, and also the important small cyprinids (*Henicorhynchus* spp.) and others (Robinson *et al*., 2024).

In Chiang Rai Province, populations of some species have been harmed by a reduction in flooded forest habitat. These include *Labeo pierrei*, *Cirrhinus prosemion*, *Labeo chrysophekadion*, *Hemibagrus filamentus, H. spilopterus*, and also soft-shelled turtles (*Amyda cartilaginea*).

In Pak Chom District Center and at Hat Khamphi Village, Pak Chom District, Loei Province, below the Xayaburi Dam, the number of *Crateva magna* bushes has declined considerably, reducing the food supply of pangasiid catfishes such as *Pangasius larnaudii* and other species that eat the fruits of this plant. Baird (2007) also reported this as happening in southern Laos.

Declines in the fish *Acantopsis* spp. have occurred, as they are known to inhabit sandy areas that are now less prevalent. Villagers from Huai Luek Village, Chiang Rai Province, stated that they generally believed that fish spawning was being reduced by the unusual Mekong River water fluctuations.

In Chiang Khan and Pak Chom districts, Loei Province, there used to be more flooded forest, and fish species that laid their eggs on *Homonoia riparia* bushes, including *Labeo chrysophekadion, L.* sp., *Hemibagrus filamentus, H. spilopterus* and *Chitala ornata* now have less breeding habitat. One villager in Hat Khamphi Village, Loei Province, stated that *H. riparia* bushes used to be "houses for fishes."

Fishing activities have become more difficult due to river changes. For example, in Huai Luek Village, Wiangkaen District, Chiang Rai Province, villagers could not fish with castnets for anymore, as the water was either too deep in the main channel, or too rocky near the edge due to the loss of sand. Villagers from Huai Luek are not being able to put out gillnets where they used to, due to changes in sediment deposits. In addition, the Mekong River is clearer than before, and that due to this change they cannot catch fish as easily using drift gillnets because the fish can see them.

In Hang Khone Village, Khong District, Champasak Province, below the Khone Falls, villagers affirmed that *Hemiarius verrucosus*, *Cephalocassis borneensis,* and *Polynemus aquilonaris* have all largely disappeared in recent years for unknown reasons. The first two species were previously common around Hang Khone, but were never found above the Khone Falls (Roberts & Baird, 1995). Villagers from Done Xom Village rarely encounter these species anymore. At Koh Hip Village in Stung Treng Province, fewer *Hemiarius verrucosus* and *Cephalocassis borneensis* are caught than before, and *Polynemus aquilonaris* has totally disappeared.

Fish migrations and complex fish interactions, as well as other factors such as fish harvesting, make it difficult to precisely pinpoint the impacts of hydrological and water quality changes. However, virtually all local people we spoke with were of the opinion that changes caused by dam construction have reduced fish populations, by blocking their movements and interfering with their feeding and spawning activities. They also believe that the loss of flooded forests and sandbars have had adverse effects on particular fish

species. For example, *Acantopsis* spp. are widely believed throughout the study area to have declined due to reduction of sand in the river. The loss of food species such as mollusks and aquatic insects have also had negative effects.

Although a marine mammal and not a fish, the Irrawaddy dolphin (*Orcaella brevirostris*) was never known to inhabit the Mekong River above the Khone Falls along the Laos-Cambodia border (Baird & Mounsouphom, 1997). During Stacey's master's degree research in 1994, over 20 dolphins inhabited the area below the Khone Falls (Stacey and Hvenegaard, 2002). However, the species is no longer seen below the Khone Falls or upstream of Stung Treng town, and was not found in the study area, although some Irrawaddy dolphins remain downstream from Stung Treng town and in parts of Kratie Province.

Gastropods and Bivalve Mollusks

The Mekong River supports a high diversity of mollusks (Gargimony & Bouchet, *in litt.*). However, mollusks have been affected by hydrological and water quality changes, and some species have also been reduced by overharvesting.

In Chiang Rai and Loei provinces, villagers stated that large bivalves, particularly *Pseudodon* sp. (*hoi kap yai/kouang*), and the slightly smaller *Pseudodon vondembuschianus*, have been largely eliminated, and that there are also fewer edible gastropods (*Filopaludina* spp.). Declines were attributed to reduction of sand in the river. In Huai Luek Village, Wiangkaen District, Chiang Rai Province, there has been declines in the number of small pools (*boong* or *eng*) along the river, something that people in Loei Province also noted. In Phon Phisai District, Nong Khai Province, river embankments have reduced the habitat available for *P. vondembuschianus*. Villagers in Bung Khong Long District, Bueng Kan Province, believed that the demise of some shellfish such as *P. vongdembuschianus* was related to the loss of *H. riparia*, although harvesting probably also played a role.

In Tha Uthen District, Nakhon Phanom Province, and Chanuman District, Amnat Charoen Province, declines in the populations of *P. vongdembuschianus* and the freshwater snail *F. martensi*, have occurred, partially due to the disappearance of small pools. Villagers from Tha Dok Keo Village in Tha Uthen District, found that *F. martensi* has declined due to changes in sedimentation. Now there is only sand, whereas before there was mud mixed with sand. People from other downstream villages also reported declines in edible gastropods, primarily due to loss of sandbars. In Sanasomboun District, Champasak Province, Laos, the river has become much deeper in the dry season, making it more difficult to harvest *P. vongdembuschianus* and *Filopaluidina* spp. In Wanyai District, Mukdahan Province, a small gastropod called *hoi sang noi*, which they previously harvested, has now disappeared.

On Done Xom, at the Khone Falls in Khong District, Champasak Province, the bivalve *hoi khe* has been harmed because the species follows water level changes, and now water levels are fluctuating too rapidly for it to adapt. However, the bivalve *hoi khom* has been less affected because it stays in deeper waters. In Samrong Village, Phosai District, Ubon Ratchathani Province, the large edible shellfish *hoi hawn* has disappeared. This may have been due to over-collection.

The small introduced and invasive species of shellfish *hoi maeng phu* has become more common at Chiang Khan, Loei Province; Ban Phaeng District, Chaiburi Sub-district, Tha Uthen District and That Phanom District, Nakhon Phanom Province; and Wanyai District, Mukdahan Province, and is causing problems for local people. It is not edible but sticks to

the bottom of boats and to gillnets. The species is gradually spreading downstream and has reached Mukdahan Province. People have found a small number in Na Tan District, Ubon Ratchathani Province, but none have been found further downstream. A non-native bivalve, *hoi nyai*, has been found in Mounlapoumok District, Champasak Province.

Hoi laep ma, another non-native species of shellfish, now occurs in Mueang and Bung Khong Long Districts, Bueng Kan Province; Ban Phaeng District, Nakhon Phanom Province; and Samrong Village, Phosai District, Ubon Ratchathani Province.

Dramatic changes in the river are reducing populations of native mollusks while also creating opportunities for non-native, introduced species, although most of the non-native species are not edible. Appendix 6 includes the species of mollusks discussed in this article. Overall, villagers believe that apart from a few non-native introduced species, most mollusks have declined due to changes in sediments and water levels, although some species have been more impacted than others due to their more specialized habitats and other requirements.

Crabs and Shrimps

In Hat Khamphi Village, Pak Chom District, Loei Province, the populations of some species of freshwater Brachyuran crabs have declined (e.g., *kapoo khi kai*). (The local names of many species of crustaceans could not be associated with scientific names and they could not be identified.) Populations of medium and large-sized shrimp species (*Macrobrachium* spp., *koong khom*) have also declined, but not small shrimp species such as *koong foi*). *Koong foi* have also declined from Nong Khai Province down to northeastern Cambodia. Many believe that upriver dams have been the cause. *Koong foi* often inhabit the shrub *H. riparia,* so some villagers believe that declines in flooded forest may have harmed them.

In Bung Khong Long District, Bueng Kan Province, villagers reported that small crabs (*kapoo kapaeng*) may have benefited from the rocky embankment habitat and now thrive as a result. In Pak La Village, Khong Chiam District, Ubon Ratchathani Province, *kapaeng* crabs have declined in recent years. *Kapoo nam khong* crabs have become less common in Tha Uthen District, Nakhon Phanom Province, along with their *H. riparia* bush habitat.

Appendix 7 includes a list of crab and shrimp species that were discussed in the interviews. Overall, villagers do not believe that all species of crabs and shrimps have been directly affected by changes in the Mekong River, but have declined due to the loss of flooded forest habitat in parts of the river.

Semi-aquatic Earthworms

Various species of semi-aquatic earthworms inhabit the banks of the Mekong River, as well as its islands and sandbars, including some recently described species of *Glyphidrilus* (Chanabun *et al*., 2017). There is also a Mekong giant earthworm (*Amynthas mekongianus*), which has been negatively affected by changes to the river over the last few decades. According to villagers from Don Tee Village, Chiang Khong District, Chiang Rai Province, a species of Mekong giant earthworm (*khikadeuan lim khong*) was previously used for baiting their fishing hooks.

In Loei Province, there used to be large earthworms (cf. *A. mekongensis)* adjacent to the Mekong, which they called *khikadeuan lim khong*. It reached a length of one to two meters. Villagers believe that increased erosion along the edge of the Mekong River has led

to a dramatic decline in the species. Villagers in Nong Khai and Bueng Kan provinces affirmed that a Mekong giant earthworm (cf. *A. mekongensis*) has disappeared, but they had no idea why. They called it *khikadeuan khon*. In Huai Mak Tai Village, Khong Chiam District, Ubon Ratchathani Province, villagers claimed the presence of a two-meter-long earthworm (cf. *A. mekongensis*), which they called *khikaloi*.

Villagers in Mueang District, Bueng Kan Province, told us that another kind of large earthworm has become scarce because a market has developed for it in China as traditional medicine. Dried earthworms, including giant and regular earthworms, are presently sold for 25 baht/kg (US$1~32 baht). These semi-aquatic earthworms (cf. *Glyphidrilus* sp.) are known as *khithakthae.* In Tha Uthen District, Nakhon Phanom Province, cf. *Glyphidrilus* sp. only reach 15 cm long, which is much shorter than the long giant earthworm elsewhere. In Wanyai District, Mukdahan Province, there are two types of *khithakthae,* one long and one short. There is clearly a diversity of species along the river.

There has been a big decline in cf. *Glyphidrilus* sp. earthworms in Ban Phaeng and Tha Uthen Districts, Nakhon Phanom Province, due to various reasons including the increased use of agricultural chemicals. In the past, this species stayed in soft soil adjacent to the river, and their heads would stick out a little. Fish would sometimes eat them when water levels rose. Unusual water fluctuations and the construction of river embankments are believed to have greatly contributed to their decline.

In That Phanom District, Nakhon Phanom Province, cf. *Glyphidrilus* sp. has apparently disappeared from shoreline habitats, but some are still found in rice fields. In Khemmarat District, Ubon Ratchathani Province, cf. *Glyphidrilus* sp. has disappeared since dams were built upriver, and in Na Tan District, Ubon Ratchathani, populations have been negatively impacted by river embankment construction.

In Samrong Village, Phosai District and Pak La Village, Khong Chiam District, Ubon Ratchathani Province, a cf. *Glyphidrilus* sp. has become less common in recent years, possibly due to erosion caused by unusual water fluctuations. In Ta Mui Village, Khong Chiam District, Ubon Ratchathani Province, 30% of cf. *Glyphidrilus* sp. have been lost, allegedly due to agricultural chemicals and erosion.

The population of *khithakthae* has declined in Sanasomboun, Pathoumphone, Soukouma, Mounlapoumok and Khong districts, Champasak Province. Villagers are not sure why. In Khong District, in the southernmost part of Laos, cf. *Glyphidrilus* sp. are only found on some islands and not others. For example, they have never been found on Tholathi or Xom Islands, or Sneng Island in Stung Treng Province, but are found on Som Island and some other small islands near the Khone Falls. They have declined due to the erosion caused by fluctuating water levels.

In Samrong Village, Phosai District, Ubon Ratchathani Province, another type of earthworm, *khikadeuan hot* (possibly *Glyphidrilus* sp.) has disappeared, probably due to changing water levels in the dry season.

Overall, villagers are in agreement that all the large earthworm species dependent on the Mekong River have been affected by hydrological changes. They also believe that river embankments have also reduced the habitat of these species, but in some cases overharvesting is also believed to be a problem.

Insects and other Invertebrates

Throughout the study area, local people expressed concern about changes in populations of various types of insects, another topic previously under-researched. Appendix 8 includes the main species of insects discussed in this article.

In Don Tee Village, Chiang Khong District, Chiang Rai Province, villagers used to put glue on bamboo to catch *maeng jua*, a type of cricket that lives in grasses on the bank of the river. Unfortunately, *maeng jua* populations have declined because most of their grass habitat has been lost due to fluctuating water levels in the dry season.

In Don Tee Village populations of dragonflies and mayflies, with which they used to bait their fishing hooks, have declined by about 90% due to a loss of sand and an increase in dry season water-levels. In Huai Mak Tai Village, Khong Chiam District, Ubon Ratchathani Province, only 20% ofthe dragonflies are still present. Dragonfly larvae are also hard to find now, as there are fewer *boong* pools along the river.

Populations of mole crickets (Family Gryllotalpidae) (*maeng ji nai/maeng khi nai/maeng ji law*) along the river have similarly declined, although they can still be found outside of the riverbed. They have also declined in Hat Khamphi Village, Pak Chom District, Loei Province, allegedly due to the disappearance of sandbar habitat, while downstream in Sangkhom District, mole crickets are said to have declined even though the number of sandbars has actually increased.

Another insect, *maeng ji bom* has been affected by changing hydrological conditions in Sangkhom District, Nong Khai Province, because its eggs are flooded when water levels unexpectedly rise during the dry season.

Mole crickets have also been reduced by river embankment construction. There are more crickets on the Lao side of the river where there are fewer embankments. In Sanasomboun District, Champasak Province, Laos, mole crickets that lived near the roots of *H. riparia* bushes have declined along with the flooded forests, and at Ta Mui Village, Khong Chiam District, Ubon Ratchathani Province, two kinds of mole crickets, as well as other insects known as *maeng ee* and *maeng sawn,* have also declined due to the reduction of flooded forest. Villagers in various communities along the Mekong have also noted that there has been a decline in *jak jan* (cicadas) also attributed to a reduction in sandbars and *H. riparia* bushes along the river.

Grasshoppers, *takataen*, has declined along the river in Nong Khai and Ubon Ratchathani provinces. In the former, Samrong Village, Phosai District, the crickets like to stay in *nya lao* and *nya aw* grasses near the river. In the latter, Song Khon Village, Phosai District, villagers argued that this could be partly because people are collecting more due to market price increases for this cricket.

Turning now to jellyfish, in Sangkhom District, populations of the Mekong jellyfish (*Moerisia* sp.) have declined because of loss of slow-flowing pools in the river, and in Khemmarat District, Ubon Ratchathani Province, they have declined because of excessive water during the dry season.

Gold Panning

Locals from the upper part of the study areas, including Huai Luek Village, Wiangkaen District, Chiang Rai Province and Pak Chom District, Loei Province, used to pan for gold

in the river during the dry season. Now that dry-season water levels remain high from dam releases, and sediment levels are lower, this activity is much less viable.

In Hat Khamphi Village, Pak Chom District, Loei Province, In the former, Samrong Village, Phosai District, the crickets like to stay in *nya lao* and *nya aw* grasses near the river. gold panners used to make about 1,500 baht a day, but people can now make only about 400 baht, due to a decline in the amount of mineral sediment.

Water Release for Boat Navigation

The construction of large dams along the Lancang/Mekong River in China now allows the Chinese to significantly alter downstream hydrological processes, particularly during the dry season (Eyler & Weatherby, 2020; Lu & Chua, 2021). Water is sometimes released from upstream dams in China to facilitate boat passage during the dry season. At Nam Kok Village, Chiang Saen District, Chiang Rai Province, water releases are often scheduled to coincide with the movement of convoys of five or six 300–400-ton Chinese commercial vessels. The bow-waves created by these large boats worsen riverbank erosion.

Lao commercial vessels occasionally get stuck during the dry season on riverine sandbars near Huai Luek Village, Wiangkaen District, Chiang Rai Province. When this occurs the boat owners sometimes pay about 12,000,000 Lao kip (US$1=20,000 kip) to the Chinese dam operators for them to release water from the Jing Hong Hydropower Project, the dam in China closest to northern Thailand.

DISCUSSION AND CONCLUSIONS

Since upriver dams have been constructed since the 1990s and especially from 2000s onwards, the altered hydrology and sediment flow of the Mekong have caused substantial downriver impacts. Secondary impacts, caused by embankment construction and sand extraction through mining, have accentuated changes along the river. From a large number of interviews conducted, we have been able to piece together a picture of how these dams have altered the environment and livelihoods of those that live along a substantial stretch of the Mekong River.

Local people are in agreement that various species of flooded forest plant species, and other river-dependent plants that rely on a drying-out period each year, have been particularly impacted, and that the loss of these plant species has had a cascading effect on sandbars and the various species that rely on them, including birds, algae, fish, mollusks, crabs and shrimps, semi-aquatic earthworms, and aquatic insects. Gold panning has also been rendered uneconomic due to increased water-levels during the dry season.

One of the main points we wish to make in this article is that there is great ecogeographical diversity along the mainstream Mekong River, and that local conditions play an important role on how the biodiversity has been impacted by the upriver dams. We have demonstrated the complex linkages that exist between Mekong hydrological and turbidity changes and the various types of impacts that are occurring. For example, villagers reported that dams have led to increased downstream riverbank erosion. The erosion that has occurred has justified the construction of many river embankments. While these have reduced the extent of erosion, the embankments in turn have also had negative environmental and social impacts.

For example, the destruction of seasonally flooded forest has reduced species of animals important to local villagers. Changing flows have also reduced riverbank gardening which is important to the local economy.

Although all the people living along the Mekong River that we interviewed agreed that the river has and is undergoing significant hydrological and water quality changes, it is crucial to recognize that not all parts of the river have been impacted in the same ways, due to the diverse geographical conditions along the river. For example, the geomorphological situation a little above the Khone Falls in Khong District, Champasak Province, southern Laos, in which the river widens considerably just above waterfalls that drain water downriver unusually quickly, has resulted in less impact due to increased dry season flow than in areas just below the Khone Falls (see Baird & Thorne 2023). This illustrates why ground-truthing approaches to investigating changes and impacts of riverine developments are needed.

This study has not only demonstrated the impacts that are occurring due to hydrological and water quality changes, but also the reasons for these various local impacts, based on villager reports. We have highlighted some of the linkages between the changes caused by the upstream dams and by river embankments and the survival of species that have received little attention in the past, such as on semi-aquatic earthworms and insects.

Based on villager reports, we have tried to focus on the relationships between different species, emphasizing the importance of the ecogeographical diversity of the river for understanding the disruptions that are occurring. While we embrace the importance of the powerful remote sensing technologies available, we maintain that they should not cause us to ignore the local ecological knowledge that comes from people who have spent their lives interacting with this vital, yet changing river. We believe that local ecological knowledge should be carefully considered by governments for developing policies for managing resources and reducing environmental impacts.

While this article provides information about the downstream impacts of upstream dams in the Mekong River Basin, and the impact of the construction of river embankments that are a consequence of increased erosion caused by the dams, there is no doubt that more follow-up research is needed regarding the impacts reported by local people on aquatic species and their habitats. We need more detailed understanding of the hydrological aspects of the Mekong itself and their economic effects on people downstream. Thus, this study should be considered a starting point rather than an end point. There is much more to learn.

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This article is dedicated to the late Tyson R. Roberts.

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Appendix 1. Study locations (44 villages) of the present study.

Village	District	Province	Country
Nam Kok	Chiang Saen	Chiang Rai	Thailand
Don Tee	Chiang Khong	Chiang Rai	Thailand
Huai Luek	Wiengkaen	Chiang Rai	Thailand
Chiang Khan	Chiang Khan	Loei	Thailand
Pak Chom	Pak Chom	Loei	Thailand
Hat Khamphi	Pak Chom	Loei	Thailand
Tat Suem	Sangkhom	Nong Khai	Thailand
Nam Phrai	Sangkhom	Nong Khai	Thailand
Wiang Khuk	Mueang	Nong Khai	Thailand
Jomani	Mueang	Nong Khai	Thailand
Jom Phon	Phon Phisai	Nong Khai	Thailand
Nong Bua	Pak Khat	Bueng Kan	Thailand
Ho Kham	Mueang	Bueng Kan	Thailand
Bung Khla	Bung Khla	Bueng Kan	Thailand
Tha Rai	Bung Khong Long	Bueng Kan	Thailand
Hua Hat	Ban Phaeng	Nakhon Phanom	Thailand
Na Kha That	Thanthem	Nakhon Phanom	Thailand
Chaiburi	Tha Uthen	Nakhon Phanom	Thailand
Tha Dok Kaeo	Tha Uthen	Nakhon Phanom	Thailand
Atsamat	Mueang	Nakhon Phanom	Thailand
Bueng Lom	Mueang	Nakhon Phanom	Thailand
Na Tham	That Phanom	Nakhon Phanom	Thailand
Pong Kham	Wanyai	Mukdahan	Thailand
Na Pho	Don Tan	Mukdahan	Thailand
Khok San Tha	Chanuman	Amnat Charoen	Thailand
Huai Yang	Khemmarat	Ubon Ratchathani	Thailand
Khan Phalan	Na Tan	Ubon Ratchathani	Thailand
Song Khon	Pho Sai	Ubon Ratchathani	Thailand
Samrong	Pho Sai	Ubon Ratchathani	Thailand
Pak La	Khong Chiam	Ubon Ratchathani	Thailand
Ta Mui	Khong Chiam	Ubon Ratchathani	Thailand
Huai Mak Tai	Khong Chiam	Ubon Ratchathani	Thailand
Kathin Nyai	Sanasomboun	Champasak	Laos
Mo Phou	Pathoumphone	Champasak	Laos
Outhoumphone	Soukhouma	Champasak	Laos
Tha Deua	Mounlapoumok	Champasak	Laos
Hee That	Khong	Champasak	Laos

Appendix 1 (continued).

Village	District	Province	Country
Done Tholathi	Khong	Champasak	Laos
Hang Som	Khong	Champasak	Laos
Done Xom	Khong	Champasak	Laos
Hang Khone	Khong	Champasak	Laos
Koh Hip	Thala Borivat	Stung Treng	Cambodia
Koh Sneng	Thala Borivat	Stung Treng	Cambodia
Hang Kho Suan	Stung Treng	Stung Treng	Cambodia

Appendix 2. Flooded forests riverine plant species in the study area.

Family	Genus and Species	English Common Name	Local Name	Notes
Amaranthaceae	*Chenopodium album*	Lamb's Quarter	*phak hom keua*	-
Amaryllidaceae	*Crinum thaianum*	Buce Plant	*phap pheung nam khong*	Water onions
Apiaceae	*Centella asiatica*	Gotu Kola, or Cica	*phak nawk*	-
Apocynaceae	*Sarcostemma secamone*	Rosy Milkweed	*phak mai*	-
Apocynaceae	*Telectadium edule*	N/A	*khai kin dawk* or *khai mae*	In southern Laos, two local names are used.
Araceae	*Crispatula loeiensis*	N/A	*ya weet*	Mekong endemic first described in 2015
Asparagaceae	*Asparagus racemosus*	Shatavari	*phak sisang*	-
Aspleniaceae	*Thelypteris prolifera*	Water Fern	*phak koot nam*	-
Asteraceae	*Acmella oleracea*	Toothache Plant, Szechuan Buttons, Paracress, Jambu, Buzz Buttons, Tingflowers, or Electric Daisy	*phak tom hoo*	-
Asteraceae	*Crassocephalum crepidioides*	Ebolo, Thickhead, Redflower Ragleaf, or Fireweed	*phak jaruat*	-

Appendix 2 (continued).

Family	Genus and Species	English Common Name	Local Name	Notes
Asteraceae	*Cyanthillium cinereum*	Little Ironweed	*maw noi nam*	-
Boraginaceae	*Rotula* cf. *aquatica*	N/A	*khai hang nak*	-
Capparaceae	*Crateva magna*	Large Garlic Pear	*koom*	-
Combretaceae	*Anogeissus rivularis*	N/A	*lam saeng*	In the study area, only in the southern part of northeastern Thailand, southern Laos and northeastern Cambodia
Cucurbitaceae	*Coccinia grandis*	Ivy Gourd, or Scalet Gourd	*phak tamnin*	-
Euphorbiaceae	*Homonoia riparia*	Willow Leaf Croton	*khai nam, khai phou*, or *khai khi lao*	It is *khai nam* in the upriver parts of the survey area, and *khai phou and khai khi lao* in southern Laos and northeastern Cambodia
Europhorbiaceae	*Sauropus* sp. or *Breynla* sp.	N/A	*kang pa*	-
Fabaceae	*Acacia harmandiana*	Thorn Tree, or Acacia	*phiman nam*	In the study area, only in southern Laos and northeastern Cambodia
Fabaceae	*Caesalpinia pulcherrima*	Red Bird of Paradise	*ton hang nok yoong*	-
Fabaceae	*Mimosa pigra*	Giant Sensitive Tree	*mai yarap yak*	Non-native species
Lamiaceae	*Mentha* sp.	Spearmint	*phak ee lae*	-
Marsileaceae	*Marsilea scalaripes*	Helicopter Fern	*phak wen*	-
Molluginaceae	*Glinus oppositifolius*	N/A	*phak khi khom/ phak dang khom/ phak dang som*	-
Myrtaceae	*Syzygium hancei*	Hance's Syzygium	*wa nam*	-
Plantaginaceae	*Plantago major*	Plantain	*phak kat nam*	-

Appendix 2 (continued).

Family	Genus and Species	English Common Name	Local Name	Notes
Phyllanthaceae	*Flueggia jullieni*	Bushweed	*khai kham*	In the study area, only in southern Laos and northeastern Cambodia
Poaceae	*Saccharum spontaneum*	Wild Sugarcane	*naw lao*	-
Rubiaceae	*Nauclea orientalis*	Leichardt Tree	*ton kanleuang*	-
Salicaceae	*Salix tetrasperma*	Indian Willow	*khai noon*	-
Sterculiaceae	*Byttneria crenulata*	N/A	*phak khi on*	-
U/I	U/I	N/A	*khai keum*	-
U/I	U/I	N/A	*ton saboo*	-
U/I	U/I	N/A	*khai som*	-
U/I	U/I	N/A	*phak kieu khai*	-
U/I	U/I	N/A	*phak hom*	-
U/I	U/I	N/A	*phak kat hong*	
U/I	U/I	N/A	*bua dawk phap pheung* or *bua nam*	-
U/I	U/I	N/A	*sida nam*	-
U/I	U/I	N/A	*som nep*	-
U/I	U/I	N/A	*nya oi noo*	-
U/I	U/I	N/A	*phak kian khai*	-
U/I	U/I	N/A	*phak khi pa*	-
U/I	U/I	N/A	*phak khi khom*	-
U/I	U/I	N/A	*phak khi kai*	-
U/I	U/I	N/A	*phak moi pho kha*	-
U/I	U/I	N/A	*khai kheua*	-
U/I	U/I	N/A	*mak hoong heo*	-
U/I	U/I	N/A	*phak liam*	-
U/I	U/I	N/A	*phak buang*	-
U/I	U/I	N/A	*phak hang ma*	-
U/I	U/I	N/A	*phak khi thao*	-
U/I	U/I	N/A	*phak hom nam*	-

Appendix 2 (continued).

Family	Genus and Species	English Common Name	Local Name	Notes
U/I	U/I	N/A	*phak ya mawng*	-
U/I	U/I	N/A	*phak hang ma*	-
U/I	U/I	N/A	*phak khai hoo*	-
U/I	U/I	N/A	*ton kheet khong*	-
U/I	U/I	N/A	*phak kadon nam*	-
U/I	U/I	N/A	*phak hom sai*	-
U/I	U/I	N/A	*nya boua*	A type of grass
U/I	U/I	N/A	*nya phak pet*	A type of grass
U/I	U/I	N/A	*nya long khawng*	A type of grass

U/I = unidentified; N/A= not available

Appendix 3. Details of flooded forests as reported by villagers.

Chiang Rai Province, northern Thailand

In Chiang Rai Province, there have been various changes along the Mekong River (c.f. Wiwatwicha & Andriesse, 2020). Various species of riverbed and riverbank plants have been affected due to life-cycle disruptions caused by dramatic hydrological changes. For example, some edible plants, such as *Mentha* sp. and *Asparagus racemosus*, have been lost, and perennial flooded forest species have significantly declined, including *Homonoia riparia* (reduced to 5–20%), Salix tetrasperma (reduced up to 20 %), and an unidentified species called *khai keum* (reduced to 20 %). In the nearby village of Huai Luek, Wiangkaen District, other riverbed plant species, including *khai som* and *ton saboo*, have also been reduced. In recent years at least 40 species of riverine plants have been affected by changes in the river, particularly *A. racemosus* and *phak ong nok*. It was explained that these species were often inundated by excessive water level fluctuations before they could produce seeds, thus leading to reduced reproductive success.

Villagers in Don Tee Village, also in Chiang Rai, used to cut the branches of *H. riparia* and put them in the water to attract shrimps, which they would then scoop up, but now there are not enough *H. riparia* left to do that. In addition, villagers used to use a type of worm that fed on *H. riparia* to bait hooks to catch *Hemibagrus filamentus, H. spilopterus, Pangasius* cf. *macronema* and other fish species. Villagers also mentioned that a type of bee called *min* used to make its nests in *H. riparia*, but that the bee population has declined along with *H. riparia.* In Pak Chom District, Loei Province, *Psittacula* sp. (*nok bia*), a species of parakeet, has declined due to the decline in *S. tetrasperma.*

These reports stress the importance of flooded forest plants to other species, and how their demise has afffected various other species.

Loei Province, northeastern Thailand

Downstream, in Chiang Khan, Loei Province, various species of edible riverbank vegetation have declined, including *A. racemosus*, *Thelypteris prolifera*, *Glinus oppositifolius*, *phak kieu khai*, *Centella asiatica*, *Plantago major*, *Caesalpinia pulcherrima*, *Saccharum spontaneum*, and *phak hom*. This was said to be due to the plants becoming inundated

unseasonally before they could reproduce. Villagers from Pak Chom, Loei Province, added that *Nauclea orientalis* and *phak kat hong* were impacted, along with *bua dawk phap pheung* or *bua nam,* a species of plant especially found on sandbars. These species have become rare due to riverine change.

At Hat Khamphi Village, in Loei Province, only 5–20% of *H. riparia* and just 1–5% of *S. tetrasperma* have survived, and only 5–50% of *S. hancei* bushes remain. However, *Crateva magna*, *H. riparia*, and *Sauropus* (or *Breynla)* have not been reduced, as their habitat is farther up the riverbank. Villagers also stated that just 1% of *sida nam* remain, and 30% of *Crinum thaianum*, 5% of *som nep*, 1% of *Sarcostemma secamone*, and 1% of *Cyanthillium cinereum*. Only about half of a recently described new species of riverbed plant, *Crispatula loeiensis* (Idei *et al.*, 2017), remain, and *A. racemosus* has totally disappeared. *H. riparia* had been replaced by a type of tall grass known as *nya oi noo*. Invasive *Mimosa pigra* has also become more dominant. The ecosystem transition from native to non-native species represents an important sign of stress (MacDougall & Turkington, 2005).

Nong Khai Province, northeastern Thailand

Between Nong Khai and Mukdahan provinces, water levels are not higher in the dry season than in previous years before the dams were built. Gauges upriver do not corroborate this perception. The most likely cause of this misunderstanding is incision erosion in the riverbed caused by a reduction of sediment, thus giving the impression that there is less water due to the sinking of the riverbed (Baird *et al.*, 2025). As a consequence, unlike in Chiang Rai and Loei, flooded forests were not said to have died as a direct result of high dry season water levels. However, flooded forests have died due to erosion and river embankment construction, a topic expanded on below.

In Sangkhom District *A. racemosus* has declined dramatically, again apparently due to fluctuating water levels. Other species impacted include *Syzygium hancei*, *Crassocephalum crepidioides*, *phak khi pa*, *phak khi khom*, *phak khi kai* and *phak kian khai*.

In Nam Phrai Village about 80% of *H. riparia* and *S. tetrasperma* have disappeared, but just upriver, in Tat Suem and Wiang Kuk villages, these species were not affected, thus demonstrating the complexity of local geographies.

In Phon Phisai District, *A. racemosus*, *Chenopodium album* and *Byttneria crenulate* have significantly declined in recent years also due to unusual daily water fluctuations.

Bueng Kan, Nakhon Phanom, Mukdahan and Amnat Charoen provinces, northeastern Thailand

In Bueng Kan Province *Byttneria crenulata* and *phak moi pho kha* have disappeared, and in Mueang District, *A. racemosus* and *phak hom keua* have declined significantly due to dry season fluctuating water levels, and that only 10% of *khai kheua* still exist. In Bung Khong Long District, Bueng Kan Province, *A. racemosus* has also declined, and *mak hoong heo* has disappeared.

In That Phanom District, Nakhon Phanom Province, *A. racemosus*, *phak liam*, and *phak buang* have become rare due to the changing hydrological conditions.

In Wanyai District, Mukdahan Province, the *H. riparia* near their village have died. Villagers associated the death of the trees with a lack of sediment in the river. Villagers also mentioned that when *H. riparia* flowers, water levels sometimes rapidly increase for short periods, leading to erosion that causes the trees to die. The impacts along this part of the river are mainly due to daily water fluctuations caused by upriver dam operation.

In Chanuman District, Amnat Charoen Province, *H. riparia* have largely died due to high water during the dry season, and also possibly due to erosion, which is similar to what people in Chiang Rai and Loei Provinces reported.

Ubon Ratchathani Province, northeastern Thailand

In Ubon Ratchathani villagers consistently reported that too much water in the Mekong during the dry season has had various impacts. For example, in Huai Yang Village, Khemmarat District, higher dry season water levels have caused many *Anogeissus rivularis* to die. By 2019, 60% had already died, along with 30% of *H. riparia*. Some flooded forests were lost when river embankments were constructed, and some *S. hancei* died then too. Non-native *Mimosa pigra,* however, have become more dominant. Very few new *A. rivularis* were becoming established (see Figs. 7 and 8).

In Na Tan District, *H. riparia* has been lost due to both high water levels and embankment construction.

In Samrong Village, Phosai District, *A. racemosus*, *phak hang ma*, *phak khi thao, phak hom nam*, *phak hom keua* have largely disappeared, while *phak ya mawng* and *nya long khawng* could still be found, but in reduced quantities. In Song Khon Village, Phosai District, there used to be *R.* cf. *Aquatica* in the area, but it has disappeared in recent years. In Samrong Village, Phosai District, about 80% of *S. hancei* and *H. riparia* have been lost, especially since 2018–2019.

In Pak La and Khong Chiam districts, *A. racemosus, Coccinia grandis*, *Glinus oppositifolius Marsilea scalaripes, phak hang ma*, and *phak hom keua* have been lost due to the hydrological changes. Half the *H. riparia* have died due to unusually high dry season water-levels and also due to erosion caused by fluctuating water levels. Some were also cut down for agricultural purposes. River embankment was also one of the reasons.

In Huai Mak Tai Village, Khong Chiam Village, some *A. rivularis* and *S. tetrasperma* have died due to high water levels. In Ta Mui Village, 70% of *H. riparia*, 80% of *S. tetrasperma*, 20% of *Acacia harmandiana,* 80% of *Anogeissus rivularis*, and 70% of *S. hancei*, were lost due to high dry season water. Various natural edible riverside vegetables, including *A. racemosus*, *phak hom keua, phak hang ma*, *Acmella oleracea*, *phak khai hoo*, and *ton kheet khong*, were lost.

Champasak Province, southern Laos

Villagers in Champasak Province all recognized that water levels were higher now than was the case during the pre-dam era. In Mo Phou Village, Pathoumphone District, various flooded forest plant species have been affected by high dry-season water levels, including 90% of *T. edule*, 90% of *H. riparia*, 95% of *A. rivularis*, and 100% of *S. tetrasperma*. Villagers believed that high water levels were the cause, but sand mining in the area is also believed to have contributed to the impacts.

In Tha Deua Village, Mounlapoumok District, 50% of *Telectadium edule* has been lost due to erosion, and 70% of *A. rivularis* has been lost for the same reason. A. racemosus*, phak hom keua* and *phak khi on* have also declined.

In Hee That Village, Khong District, only about 30% of *T. edule*, *H. riparia*, *Flueggia jullieni* and *C. magna*, and 10% of *A. rivularis,* remain.

While water levels during the dry season are about 50 cm higher than during the pre-dam era in upriver parts of Khong District, the difference declines rapidly near the Khone Falls.

Illustrative of this, at Done Tholathi Village, Khong District, Champasak Province, water levels are only about 20 cm higher. As a result, most flooded forest species have not been impacted. However, two forms of grass that grew on rocks in the river have now disappeared: *nya boua* and *nya phak pet*. As on Tholathi Island, people from Hang Som Village in Khong District experience water levels just 20 cm higher than during the pre-dam period, and as a result, very few impacts have been reported. Just above the Khone Falls changes have been more limited.

At Done Xom Village, which straddles the Khone Falls, many *A. rivularis* and some *A. harmandiana* just below the Khone Falls have died, along with 20% of *T. edule*. Crucially, in Hang Khone Village, which is entirely below the falls, water levels are 1–2 meters higher than they were before the dams were built. As a result, 70% of *A. rivularis* have died. *Nya phak pet* has disappeared. In Koh Sneng in Stung Treng Province, *nya phak pet* and *nya boua* have disappeared from the area due to fluctuating water levels. *Nya phak pet* is sometimes used as a traditional medicine.

Stung Treng Province, northeastern Cambodia

Downstream from Khone Falls, in Stung Treng Province in northeastern Cambodia, the situation is similar to Hang Khone Village. On Hip Island, 10% of *H. riparia* has died, as well as 30% of *A. harmandiana*, 50% of *A. rivularis*, 70% of *T. edule* and *R.* cf. *Aquatica ton*, while all the *F. jullieni* are gone. This coincides with the past findings in Stung Treng (Baird & Thorne, 2023).

There have been similar declines at Sneng Island village, farther downriver: 10–20% *of H. riparia*, 60% of *A. rivularis,* 80% of *T. edule* and *S. hancei*, and 100% of *F. jullieni* have died. 70% of *ton kadon nam* have died (Fig. 9). The loss of flooded forest has made navigation along the river more difficult, as these trees and bushes previously indicated where rocks that they needed to avoid are located. They also found that *A. racemosus* has disappeared, and that *phak hom sai* has declined. Most edible riverside vegetables have been affected by both high dry season and unusually fluctuating water levels.

Appendix 4. Bird Species in the study area discussed in detail with villagers.

Family	Genus and Species	English Common Name	Local Name	Notes
Burhinidae	*Esacus recurvirostris*	Great Thick-knee	*nok muam*	Called *nok sang yiap* in Nakhon Phanom; Near-threatened species; sandbar nesting
Charadriidae	*Charadrius dubius*	Little-Ringed Plover	*nok khikadeuan*	Sandbar nesting
Charadriidae	*Vanellus duvaucelii*	River Lapwing	*nok tae tae nam*	Near-threatened species; sandbar nesting
Glareolidae	*Glareola lactea*	Small Pratincole	*nok khao sai*	Sandbar nesting
Laridae	*Chlidonias hybrida*	Whiskered Tern	*nok sida*	Non-breeding in study area
Laridae	*Sterna aurantia*	River Tern	*nok sida*	Vulnerable species; sandbar nesting
Meropidae	*Merops orientalis*	Asian Green Bee-eater	*nok jiew*	-
Meropidae	*Merops leschenaulti*	Chestnut-headed Bee-eater	*nok jiew*	-
Motacillidae	*Motacilla alba*	White Wagtail	*nok kadet dao*	Common non-breeding winter visitor
Motacillidae	*Motacilla samveasnae*	Mekong Wagtail	*nok kadet dao*	Mekong endemic; near-threatened species; riverine nesting

Appendix 5. Main fish species discussed during the study.

Family	Genus and Species	English Common Name	Local Name	Notes
Ariidae	*Hemiarius verrucosus*	N/A	*pa khat ok*	-
Ariidae	*Cephalocassis borneensis*	N/A	*pa khat ok*	-
Bagridae	*Hemibagrus filamentus*	N/A	*pa kot leuang*	-
Bagridae	*Hemibagrus spilopterus*	N/A	*pa kot leuang*	-
Cobitidae	*Acantopsis* spp.	Horseface Loach	*pa hak kuai*	*Pla rak kluai* in central Thai
Cyprinidae	*Cirrhinus prosemion*	Mud Carp	*pa kaeng*	-
Cyprinidae	*Henicorhynchus* spp.	Siamese Mud Carp	*pa soi hua laem*	-
Cyprinidae	*Labeo chrysophekadion*	Black Sharkminnow	*pa phia*	-
Cyprinidae	*Labeo pierrei*	N/A	*pa wa suang*	-
Notopteridae	*Chitala ornata*	Clown Featherback	*pa tong seua lao*	-
Pangasiidae	*Pangasianodon gigas*	Mekong Giant Catfish	*pa beuk*	-
Pangasiidae	*Pangasius larnaudii*	Spot Pangasius	*pa hoo mat or pa peung*	This species is called *pa hoo mat* in the upstream part of the study and *pa peung* in the downstream part of the study area.
Pangasiidae	*Pangasius* cf. *macronema*	N/A	*pa nyone*	-
Pangasiidae	*Pangasius sanitwongsei*	Giant Pangasius	*pa leum*	-
Polynemidae	*Polynemus aquilonaris*	Northern Paradise Fish	*pa chin*	-

N/A= not available

Appendix 6. Gastropods and bivalve mollusks in the study area.

Family	Genus and Species	English Common Name	Local Names	Notes
Unionidae	*Pseudodon vondembuschianus*	Bivalve	*hoi kap noi/hoi ki*	Large native species
Unionidae	U/I	Bivalve	*hoi kap yai/kouang*	Large native species
Viviparidae	*Filopaludina* sp.	River Snail	*hoi joop and hoi salee*	Native gastropod
Viviparidae	*Filopaludina martensi*	Ghost Wizard Piano Snail	*hoi salee*	Native gastropod
U/I	U/I	Bivalve	*hoi khom*	-
U/I	U/I	Bivalve	*hoi khe*	-
U/I	U/I	N/A	*hoi hawn*	-
U/I	U/I	N/A	*hoi maeng phu*	Small non-native species
U/I	U/I	N/A	*hoi nyai*	Large non-native species
U/I	U/I	N/A	*hoi laep ma*	Small non-native species

U/I = unidentified; N/A= not available

Appendix 7. Crab and shrimp species in the study area.

Suborder/ Family	Genus and Species	English Common Name	Local Name	Notes
Brachyura	U/I	Crab	*kapoo khi kai*	-
Brachyura	U/I	Crab	*kapoo nam khong*	-
Brachyura	U/I	Crab	*kapoo kapaeng*	-
Palaemonidae	*Macrobrachium* spp.	Shrimp	*koong khom*	-
Palaemonidae	*Macrobrachium* spp.	Shrimp	*koong foi*	-

U/I = unidentified

Appendix 8. Insect species and other invertebrates in the study area.

Order/Suborder/ Infraorder/Family	Genus and Species	English Common Name	Local Name	Notes
Anisoptera	U/I	Dragonfly	*maeng po, maeng po nam*	-
Anisoptera	U/I	Larvae of Dragonfly	*maeng nang nyam*	-
Caelifera	U/I	Grasshopper	*takataen*	-
Cicadidae	U/I	Cicada	*jak jan*	-
Ephemeroptera	U/I	Mayfly	*maeng siphakhao*	-
Gryllotalpidae	U/I	Mole Cricket	*maeng ji nai/maeng khi nai/maeng ji law*	-
U/I	U/I	N/A	*maeng ee*	-
U/I	U/I	N/A	*maeng ji bom*	-
U/I	U/I	N/A	*maeng jua*	-
U/I	U/I	N/A	*maeng sawn*	-
Almidae	cf. *Glyphidrilus* sp.	Giant Earthworm	*khithakthae/ khikadeuan hot*	-
Megascolecidae	*Amynthas mekongianus*	Giant Earthworm	*khikadeuan lim khong/khikadeuan khon/khikaloi*	-
Moerisiidae	*Moerisia* sp.	Mekong Jellyfish	*maeng nyoum hat*	-

U/I = unidentified; N/A= not available