



Assessment of the Status of the Fishery of Indwagyi Lake, Myanmar Using Traditional Ecological Knowledge

Luca Opperman¹, John Connalin², A. Wren Opperman^{3*}, Zau Lunn⁴
and Htoo Naing Tun⁴

¹Duke University, United States.

²Charles Sturt University, Australia.

³Chagrin Falls High School, United States.

⁴Fauna and Flora International, Myanmar.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Indawgyi Lake, in northern Myanmar, is the country's largest lake and among the largest in Southeast Asia. Although the lake's fishery provides an important source of food and livelihoods, relatively little is known about the status of its fishery and how human actions are affecting it. Further, some basic information on fish populations has not been documented, such as the extent to which fish migrate, either downstream toward the Ayeyarwady River or into the lake's tributaries. Similar to other lakes in the region (e.g., Inle Lake in central Myanmar), the fishing practices of Indawgyi Lake appear to be intensifying. Thus, improved understanding of the lake's fishery and fish-migration patterns can inform future management.

Study Design: To gather preliminary information, we surveyed 6 villages around Indawgyi Lake collecting Traditional Ecological Knowledge (TEK) about the migratory behavior of fish and current state of the fishery.

Place and Duration of Study: Hepa, Hepu, Lone Ton, Lonsant, Mamon Kaing, and Nyaung Bin along Indawgyi Lake in Myanmar

Methodology: We interviewed in large groups at 6 villages (approximately 60 fishermen overall), aggregating results into the six village groups due to the consensus style of interviews. We performed subsequent analyses using Google Earth Engine.

Results: Fishermen reported that nearly all the fish they commonly catch are migratory, with most using upstream tributaries for spawning during the wet season. Fishermen also reported that, although most tributaries remained in good condition, several have been severely impacted by land-use changes, including gold mining. Fishermen consistently reported that harvest levels have declined dramatically in the past two decades even as they deploy more nets. Across the villages interviewed, the top recommendation to combat declines was to increase/strengthen enforcement of regulations.

Conclusion: This research demonstrates the utility of TEK to provide preliminary information on poorly studied systems that can inform conservation and management.

Keywords: Freshwater fishery; TEK; Indawgyi Lake; Myanmar.

1. INTRODUCTION

This paper investigates the various ways that human actions are impacting the fishery of Indawgyi Lake, a largely unmodified freshwater lake in northern Myanmar. Situated in a remote area that was, until recently, restricted for visitation from foreigners, relatively little is known about the lake or its fishery beyond historical inventories of species [1] and one more recent broad survey [2]. Within Myanmar and much of the developing world, fish are a vital source of protein and livelihoods for local people [3]. Evidence from Myanmar's other major lake, Inle Lake, indicates that its fishery is declining due to increasing population, fishing pressure, and pollution [4].

This study relied on Traditional Ecological Knowledge (TEK) to develop this preliminary information on Indawgyi Lake. TEK refers to the evolving body of knowledge acquired by indigenous and/or local peoples over time, developed through direct contact with the environment and specific to a location [5]. TEK can include insights on the relationships between plants, animals, and landscapes, the life histories of species, and information on the status of resources managed through hunting, fishing, trapping, agriculture, and forestry [6,7]. Scientists typically collect TEK in a target area by interviewing and surveying the local people, an approach that can provide valuable information in a relatively short amount of time and identify where additional research may be needed. For example, Nunes et al. [8] collected TEK to understand fish migration in the Tapajos River (Brazil) and Millar et al. [9] used TEK to understand fishing practices, changes in harvest

levels, and recommendations for improved management from fishers around a floodplain wetland in Laos. Additionally, Silvano and Valbo-Jorgensen [10] compared local knowledge of fish ecology and behavior to existing knowledge from the biological literature in order to improve fisheries management.

Although fish surveys in Indawgyi Lake have documented the species present in the lake [2], there is currently very limited published information on fishing practices, fish-population trends, or threats in Myanmar overall and in Lake Indawgyi specifically. This paper collects basic information from fishermen about the fish species they harvest, including migration behavior, and their specific fishing activities. Further, this research explored changes in fishing practices, effort and harvest levels over the past two decades compared to today to understand trends, inform management and identify issues for further research. In addition to providing preliminary information to contribute to management of Indawgyi Lake's fishery, this study can demonstrate the utility of TEK to begin to fill information gaps on poorly studied freshwater systems and fisheries [6].

The research described here intends to provide preliminary information on the status of Indawgyi Lake's fishery and the life histories of fish species that are harvested and produce initial recommendations for improving management. Further, this study can identify where additional research is needed on this economically and ecologically important fishery.

2. METHODOLOGY

2.1 Study Area

Indawgyi Lake is a 24 km long and 13 km wide freshwater lake in the Kachin State of Myanmar (Fig. 1), with a total of 12,000 hectares of open water. There are 13 villages along the shores of the lake. The people living in this region are mostly indigenous Kachin and migrants that arrived in the 1990s who make a living off small-scale fisheries and rice farming. The lake is within the Indawgyi Lake Wildlife Sanctuary established in 1999. Half of Indawgyi Lake wildlife sanctuary is forest and $\frac{1}{3}$ is wetland. The area is also an important bird area, an ASEAN Heritage Park, and has been nominated as a Ramsar site. The site hosts important populations of migrating water birds, turtles, including the endemic Burmese Peacock Turtle, and at least three fish species that are endemic to the lake [11].

2.1 Interview Methods

To collect TEK, we conducted a series of interviews over three days (two villages per day) with fishermen from six villages around the lake: Hepa, Hepu, Lone Ton, Lonsant, Mamon Kaing, and Nyaung Bin (Fig. 1). These villages were selected primarily due to access and availability of fishermen for interviews. We used a survey with primarily open-ended questions in three main categories: fish migration, status of the fishery, and management (Appendix A). These questions were prepared in conjunction with Fauna and Flora International (FFI) and their working knowledge of the fishing community. While the interviews were guided by this survey, we also allowed discussion to flow organically with follow-up discussions and further exploration into mentioned topics. We interviewed 6 groups of fishermen (a total of approximately 60 – although the exact number was not ascertained as fishermen came and left the groups over the course of the interview process), aggregating results into the six village groups due to the consensus style of interviews.

In each village, we interviewed between 4 and 15 men, with an estimated age range of late teens to early sixties. Most of the participants had been fishing their entire lives-- often several decades. Fishermen were assembled by notifying the village headman ahead of time and establishing a fixed day for participation. Fishermen participated on a voluntary basis and there was

no effort made to exhaustively interview all the fishers in the community. The questions were posed in English and translated into Burmese for the villagers. For each question, the group of fishermen engaged in a discussion before one of them, generally an older fisherman, provided the answer. In general, fishermen appeared to agree on the answers.

Through this process, data were collected at the level of the village rather than for individual fishermen. Because this study relies on TEK and people's perceptions, data were primarily qualitative or estimates of quantitative values. Data were analyzed through discussions with the interpreter and an agreement on the category of response. Because the fishermen were interviewed in a group and there was ample discussion around each response, there were no discrepancies to resolve within the groups. Our methods followed similar processes to other researchers using TEK [12–14].

3. RESULTS AND DISCUSSION

3.1 Fish Migration

Across all villages, fishermen stated that most fish species in the lake migrated at some point during the year, either between the lake and the Ayeyarwady River and/or between the lake and upstream tributaries. They emphasized a few specific fish that migrated from Ayeyarwady River to spawn in the lake and/or the lake's tributaries, including *Labeo catla* (a cyprinid) and *Wallago attu* and *Labeo catla* (a catfish). Fishermen noted that fish migrated to tributaries during the wet season (mid-May to late October) to spawn and nearly all the villages reported that most fish preferred to spawn in "current water" (i.e., areas with flowing water). They also frequently mentioned that fish used floodplains along the tributaries as habitat for spawning and feeding. Fishermen reported that most of the tributaries were in good condition, with the exception of those affected by gold mines (discussed below) and one village reported that irrigation infrastructure on some of the eastside tributaries blocked fish access to the floodplain.

3.2 Fish Yield

Estimates of fish yield were given in viss (a unit of weight common in Myanmar) and converted to kilogram (1 viss = 1.6 kg). All six groups of fishermen reported both increased fishing effort and a steady decline in the daily harvest over the

past 20 years (Fig. 2). Among the six villages, estimates of number of nets deployed per night in the past (20 years ago) ranged from two to five (average estimate was 4.1 ± 0.9 (standard deviation)) and estimates of past daily harvest ranged from 8 to 32 kg (22.8 ± 9.4 kg of fish). In

contrast, estimates of number of nets deployed per night currently ranged from 15 to 30 (22.5 ± 3.2 nets deployed per night) and estimates for current daily harvest ranged from 1.6 to 3.2 kg (average 2.4 ± 0.7 kg) of fish (Fig. 2).

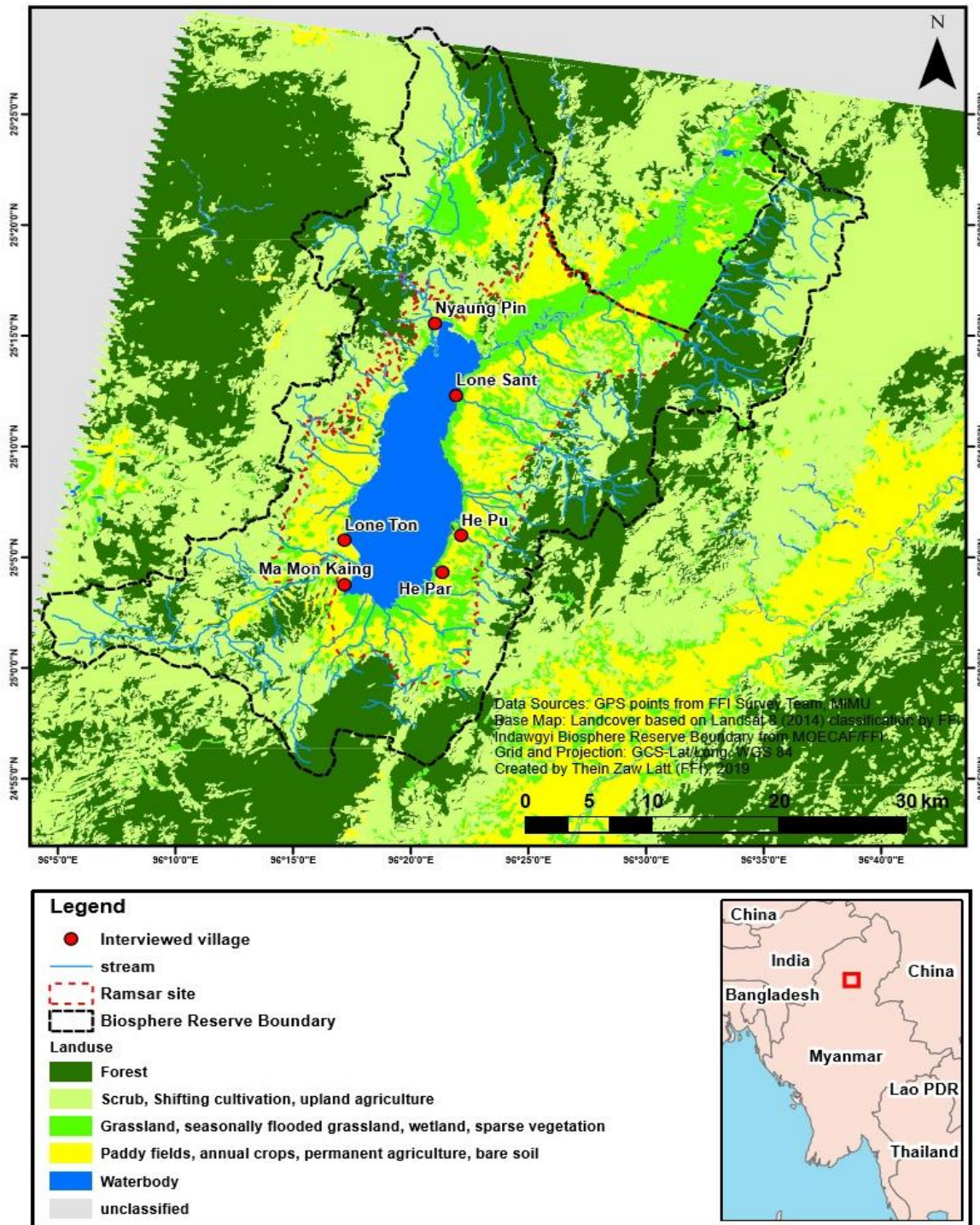


Fig. 1. Villages around Indawgyi Lake surveyed for traditional ecological knowledge on fish and the fishery

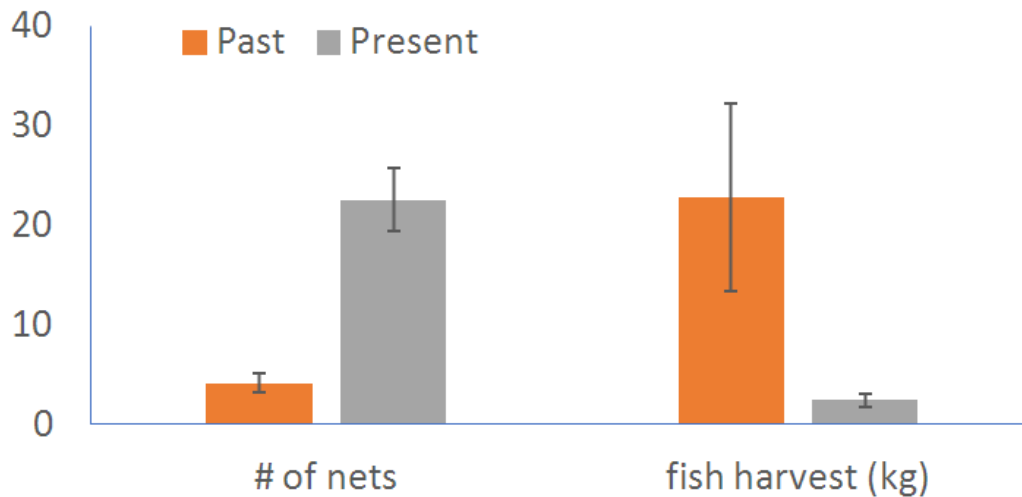


Fig. 2. Estimates from fishermen about the number of nets they deployed and level of daily harvest (kg) twenty years ago (past) and today (present); Bars indicate the average of estimates and error bars are the standard deviation of the estimates a period

3.3 Reasons for Decline in Fish Harvest

All six villages reported that overfishing was to blame for the decline in fish. Interviewees consistently reported that people have been migrating to Indawgyi Lake from both Inle Lake and surrounding areas. Interviewees reported that, although the Department of Fisheries registered 461 fishermen in 2016-17, the actual number is closer to 600. Further, the Indawgyi fishermen reported that the new fishermen have introduced new fishing gear that is not technically illegal but still negatively affects the health of the fishery.

Additionally, five out of the six villages identified gold mining in the tributaries as a relatively new activity that was negatively impacting fish in the lake. Fishermen from Mamon Kaing (Fig. 1), one of the southernmost villages and closest to the area of mining, stated that the gold mines released chemicals (mercury) into the lake via runoff from the mining sites. According to these villagers, mines have been depositing sediment into the lake and negatively impacting important areas for breeding.

Half of the six villages identified a specific barrier as contributing to the decline of fish harvests. The Chaung-wa is a small river that drains the lake, flowing downstream to the Ayeyarwady River, the largest river in Myanmar. The fishermen reported that a section of the Chaung-wa is owned by an individual who occasionally extends a fish barrier across the river to trap and catch fish. In three of the villages, fishermen

stated that this barrier inhibits the migration of fish between Indawgyi Lake and the Ayeyarwady River. Two out of the six villages identified illegal fishing practices as contributing to some of the decline, including fishing during the closed season and illegal net sizes.

Based on these results, we examined satellite imagery over time in the watershed of the lake's primary southern tributary, where mining has been most active. Fig. 3 shows the extensive expansion of land clearing due to mining between 1995 (generally before mining began) and 2018. Using Google Earth Engine, we quantified the area of disturbed land and estimated that, by 2020, 670 hectares had been affected by mining, approximately 14% of the 4730-ha watershed. Beginning in 2016, satellite images show an expanding delta in the lake where the tributary delivers increased levels of sediment from the mining.

3.4 Management Recommendations

When asked about what management strategies they recommended to improve the fishery, fishermen's responses fell mainly into two categories: increasing enforcement of various fishing rules for the lake and increasing fish through stocking. Interestingly, even though five of the six villages cited gold mining as harmful to the health of the lake, only one village recommended closing of gold mines.

Fishermen in all six villages recommended increasing enforcement of rules, such as those

that set a minimum mesh size for nets, and/or stricter punishments on illegal fishing. Five out of the six villages recommended that stocking of fish should be continued and increased, in terms of total fish and number of species of fish (e.g., expanding beyond the current stocking of *Rohita rohita*).

3.5 Discussion

TEK results indicate that the health and productivity of the Indawgyi Lake fishery has declined significantly over the past 10-20 years. Increasing population around the lake, overfishing, and gold mining are potentially negatively affecting the health of the lake and its fishery. The consistency of responses across villages supports the validity of the conclusions. Further, research at Inle Lake has shown that a combination of overfishing, due to rapid population growth, and unregulated fishing practices has contributed to a serious decline in the health of the fishery [4]. Our results indicate

that Indawgyi could follow a similar path and end up in the same condition as Inle.

These results are important because they indicate that fish yield has declined notably over a period of decades around the lake. The most recent census indicates that the region around the lake has a population of around 30,000 spread out across a total of 13 villages [11]. The fishermen noted that many people were moving to Indawgyi from the surrounding region, specifically mentioning that many of the new inhabitants are from Inle Lake in search of a healthier fishery. Consistent with what the interviewees were stating, the movement of fishermen from Inle Lake to Indawgyi Lake could contribute to overfishing [4]. Further, interviewees noted that the fishermen from Inle were introducing fishing methods that were common to that lake but perceived to be either illegal or harmful in Indawgyi (e.g., night fishing, use of smaller traps). The most common recommendation for management was stricter

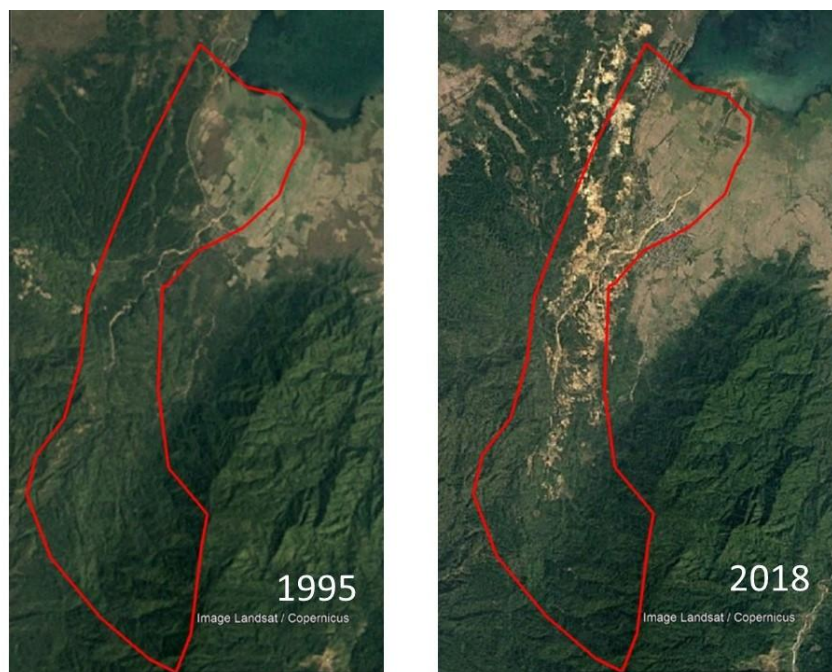


Fig. 3. Land cover south of Indawgyi Lake in 1995, before gold mining began (left) and in 2018 (right). The red line indicates the boundaries of the watershed of the tributary most affected by mining. Extensive disturbed land from mining is visible in 2018 as is the expansion of a delta in the lake and plume of sediment where the tributary enters the lake, delivering sediment produced from land clearing and mining (note that whereas the shore line roughly corresponds to the red line in 1995, the shoreline extends past the red line in 2018, indicating an expanding delta). (Google (n.d.). [Indawgyi Lake, Myanmar]. Retrieved August 1, 2021 from <https://earthengine.google.com/timelapse/#v=25.05044,96.28441,11.973,latLng&t=1.58>

enforcement on fishing around the lake, indicating that fishermen are aware of both illegal fishing practices and overfishing and that they would like management to address these problems.

TEK provided information on the migratory behavior of fish within the Lake, including that most fish in the lake use habitats in its tributaries. This indicates that the health and condition of the tributaries are important for fish populations in the lake. Interviewees specifically noted that fish from the lake use floodplains during the wet season, which is common for tropical fish within Asia and elsewhere. Fish will migrate into tributaries during the monsoon if the tributaries offer the appropriate conditions for spawning or if the nearby floodplains offer high productivity for feeding [15].

The fishermen's concern about the gold mines indicates that they are aware that broader land-use practices in the lake's basin may be affecting the fishery. Mining in general can cause widespread problems for freshwater systems, including sedimentation and impacts to water quality from mercury and other pollutants [16]. As discussed above, Fig. 3 shows the extensive expansion of mining activity.

These TEK results are similar to other TEK studies that provide initial important information that can direct future studies.

4. CONCLUSION

Although TEK was a practical methodology, it is only a first step in understanding the natural history and management challenges of Indawgyi Lake. Future research should be done to gain a better understanding of the status of the Indawgyi fishery. Fishing in the lake shows clear signs of decreased productivity, and the associated need for better planning. For example, field surveys of harvest levels, fishing practices (type of gear, number of nets), and number of fishermen could provide quantitative data to guide management. Furthermore, TEK could be used to provide more than just preliminary information. Expanded and replicated surveys could be used to provide more detailed quantitative information on many aspects of fish ecology and fisheries, including abundance trends over time, fish reproduction, and effects of environmental changes, as demonstrated in other systems [10,12].

Further, the influence of the gold mines could be studied through quantitative documentation of the sedimentation of the lake where the tributary carrying mining sediment enters from the south as well as sampling of mercury levels in the sediment, in fish, and within people that consume the fish.

Understanding fisheries in Myanmar and elsewhere is important, given the pivotal role of fishing in providing food and livelihoods for people across the developing world [17]. Indawgyi Lake is just one of the many examples of how these important resources are often not utilized sustainably or effectively managed. Indawgyi Lake also illustrates how many fisheries across the developing world have not been documented or studied. Our research provides an important step of collecting information and identifying the problems that exist to guide management toward more sustainable practices. Further, this research provides additional support for the potential value of TEK to provide preliminary information on poorly studied systems to inform management and guide further research [18]. Because many fisheries globally are not well monitored or studied, TEK could help provide initial baseline information to improve management of these important resources.

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX A

Interview Questions

Fish Migration

- Which fish migrate between lake and Irrawaddy?
- Do you know why they migrate?
- Are there any fish that never go to the Irrawaddy?
- Are there any fish that spawn in the lake?
- Which fish go into upstream tributaries and why?
- What is the condition of the upstream tributaries?

Status of the Fishery

- What type of fishing methods do you use?
- How much fish do you bring in daily?
- Is it harder to catch fish today, compared to 20 years ago?
- Has the size of the harvest changed?
- Has the size of the individual fish that you catch changed?
- Have you had to adapt your style of fishing over the years?
- Why do you think fish are decreasing?
- Are there any invasive fish?
- Do fishermen do other work?

Management

- Have you noticed a decline in any specific species or type of fish?
- Are there any forms of fishing you know to be illegal?
- How many fishermen on the lake?
- Any suggestions for how to improve management of fisheries?

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