Needs, Techniques, and Risk Assessment: Toward a Vision for Migratory Fish in Cambodia

Summary of a Workshop
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Workshop Summary

The workshop "Needs, Techniques, and Risk Assessment: Toward a Vision for Migratory Fish in Cambodia," was held on October 17 & 18, 2018, at the Hotel Cambodiana in Phnom Penh. The workshop was hosted by the Inland Fisheries Research and Development Institute (IFReDI) and the University of Nevada-Reno, and was facilitated by FISHBIO as part of the Wonders of the Mekong Project funded by USAID. The workshop was attended by 67 participants from about 26 organizations and agencies (see Appendix 1) and included a mix of presentations and small-group discussions (see agenda in Appendix 2).

The goal of this workshop was to bring together experts to identify high-priority data needs for fish migration in the Mekong Basin, develop elements of a shared vision for management and conservation of migratory fishes in Cambodia, and discuss tools and approaches that can be used to achieve this vision. The workshop consisted of four sessions:
1) Prioritizing Migratory Fish Data Needs for Cambodia
2) Techniques and Technology for Monitoring Migratory Fishes
3) Developing a Swimway Management Plan
4) Elements of a Shared Vision for Migratory Fishes

During each session, participants were split into three groups and asked to discuss a series of questions. This report summarizes the outcomes of the workshop during the four small-group discussion sessions. The opinions and recommendations compiled in this report are those of the workshop participants, and do not necessarily reflect consensus nor the opinions of the workshop organizers or the Wonders of the Mekong project partners.

Session 1: Prioritizing Migratory Fish Data Needs for Cambodia

The keynote speaker of the session, Dr. Touch Bunthang (Acting Director, IFReDI), spoke about prioritizing migratory fish data needs for Cambodia, and highlighted key needs such as identifying migration routes and key spawning sites/hotspots, as well as whether migratory fish are being replaced by non-migratory fish or non-native fish species. Three additional presenters, Mr. Chan Sokheng and Dr. Ngor Peng Bun (IFReDI), and Dr. So Nam (Mekong River Commission), described current knowledge of migratory fishes of Cambodia and the Lower Mekong Basin.

The discussion portion of this session included the following three topics, which are described in detail below:
1) What are the data and knowledge needs for migratory fish management in Cambodia? Where do we already know the most?
2) What criteria do you consider most important for prioritizing data needs for management?
3) Who are the entities (researchers and organizations) that are currently gathering data about migratory fish? Who could be involved in the future?

1.1 What are the data and knowledge needs for migratory fish management in Cambodia? Where do we already know the most?

The goal of this topic was to have participants identify key questions that need to be answered to inform migratory fish management in Cambodia. They were also asked about existing sources of information for each data need to help broadly identify which topics still need more information. Facilitators helped participants identify whether suggested data needs were referring to the multi-species/assemblage level ("migratory fishes" generally), the individual species level, or the population level within species. All groups ended up only discussing the multi-species and individual species levels, and noted that most of the data needs at the multi-species level were also applicable to the individual species level.

With regard to data sources, some participants noted that considerable data exists from fish catch monitoring programs as well as local knowledge, and that it would be beneficial to analyze this existing data before we continue to collect more. However, some of the data is in government offices and not readily accessible to others.

Table 1. Migratory fish data needs and data sources for the multi-species/assemblage level.

Level of Current Knowledge	Multi Species/Assemblage Level Data Needs	Current Data Sources
Low	Changes in response to stressors (infrastructure/dams, habitat loss, waste, etc.)	Ministry of Environment
	Connectivity of habitats and populations	
	Describing sub-basin fish communities	MRC, fish abundance monitoring, SciCap monitoring, larval studies
	Environmental variables (e.g. water quality, flow, temperature, etc.)	MRC water quality
	Fish ecological irreplaceability	Marxan planning software
	Fish passage barrier data (obstacle, location, purpose)	MRC dam maps
Low	Fishing activity/Exploitation rates	
	Food webs	Bellmont Project studies in Tonle Sap
Low	Habitat status and quality	
	Impacts of river flow on fish behavior	
	Importance to livelihoods	
	Life cycles	
	Magnitude of migrations (biomass)	
	Migration "bottlenecks" or priority hotspots	Protected Areas, MRC Report on deep pools

Level of Current Knowledge	Assemblage Level Data Need	Current Data Sources
	Migration cues and purpose	Baran 2006
Low (no specific data yet, just rivers)	Migration routes and distances	Fisheries surveys, LEK, MRC database and migration map (2003)
	Migration strategies/functional groups/guilds	MRC Council Studies, Welcomme et al. 2006
	Migration timing	
Medium	Spawning areas and key habitats	Fisheries surveys, LEK, MRC
High	Spawning seasons	Larval studies, catch monitoring
	Species replacement, effects of non-native species	
	Swimming behavior of fish	
	Use of protected areas	

Among the data needs, participants from BirdLife International introduced the concept of migration "bottlenecks," which describe areas where multiple flyways converge and many bird species use the habitat (similar to the term "hotspots" used to describe fish habitat). In addition to data needs, a few suggestions that came up during the discussion included ways to improve data collection and echange, such as increased data sharing and better knowledge transfer between communities and scientists.

Several participants also highlighted the need create a list of prioritized species for study as a way of moving scientific efforts from the assemblage to the species level, and that once this list is identified, further research should be conducted to investigate the biology and ecology of these species. The workshop organizers agree and had determined during workshop planning that a prioritization exercise would be a more appropriate activity for a later stage. The discussions about individual species data needs at this workshop were intended to be general in nature; however, one group did come up with a list of key species, which could serve as a starting point for a future discussion about prioritized species (included in Table 2). Their list is a balance between endangered/iconic large migratory species and smaller species important for food security.

Table 2. Migratory fish data needs and data sources for the individual species level.

Level of Current Knowledge	Individual Species Level Data Need	Current Data Sources
	Abundance and trends	catch assessment
	Environment and habitat requirements (e.g., water quality, flow)	

	Home range	
Low	Homing behavior and site specificity	
	Identify key indicator species	
	Identify migratory fish species	MRC
	Identify where species have been lost	
	Key habitats	
	Life cycle	
	Life history	
Low	Migration routes and extent	MRC, LEK (Otolith microchemistry)
	Response to dams	Ministry of Environment report
	Spawning areas	
Low	Species of conservation concern (endangered and threatened)	IUCN red list
	Swimming behavior and speed	
Medium	*Cirrhinus macrolepis*	
	Croaker	
Medium	Giant barb	
Low/Medium	Giant catfish	
Low	Giant stingray	
Low	*Henichorhynchus siamensis*	
Low	Irrawaddy dolphin	
Low	*Mekongina erythrospila*	
Medium	*Pangasius krempfi*	
Medium	*Pangasius* spp.	
High	*Probarbus* spp.	

1.2 What criteria do you consider most important for prioritizing data needs for management?

During this discussion topic, workshop facilitators explained to participants that they would be asked to select which data needs they considered most important to address first, and we wanted to know what kinds of criteria participants would use to prioritize the data needs. The goal of this exercise was to capture the diversity of criteria being used, not to judge or compare the criteria. Below is a compiled list of criteria from all three small discussion groups (list order does not imply

prioritization). These criteria could generally be grouped into ecological concerns (e.g., vulnerability to threats; criteria 1–5) and management-level concerns (e.g., policy implications and financial tradeoffs; criteria 6–11).

1. Level of biological knowledge about the fish(es) (e.g. life cycle)
2. Quality of habitat (for prioritizing which areas to study)
3. Types of threats facing the fish(es)
4. Vulnerability of the fish(es) to extinction
5. Ecological relevance of the fish(es) (conservation status)
6. Social relevance of the fish(es) (importance for food and nutrition)
7. Relevance of the data needs for policy
8. Cost associated with addressing a data need
9. Economic/commercial value of the fish(es)
10. Irreplaceability of fisheries
11. Opportunities for management

In general, participants were concerned about the costs required to address data needs, and thought data needs should be prioritized to benefit nutrition and livelihoods of local people. Some suggested that data collection should be prioritized in a variety of different habitat types (e.g. flooded forest, deep pools, etc.) so that monitoring data are collected for entire species life cycles. They also thought that these criteria could be used to determine which habitat types should be monitored first based on the quality, scarcity, or importance of that habitat type. With regard to studying threats to fish, participants suggested this research should start with understanding threats where there were clear management opportunities to intervene.

Some participants suggested that data needs should be prioritized based on who was doing the research, or the relevant level of management. For example, researchers at the national level have more funding and therefore could undertake larger-scale research projects such as migration pathways. However, data collection is still important at a smaller scale, so local communities could collect data for specific areas. Participants identified that local communities were the most important current source of information and that they should be prioritized as a source of data not only for their knowledge, but also to create buy-in for any future projects. They also highlighted the importance of sharing the results of data collection with local communities, who are often used as a data source but receive no or little information back from researchers about the status of their fisheries.

1.3 Who are the entities (researchers and organizations) that are currently gathering data about migratory fish? Who could be involved in the future?

Participants identified a number of entities that are or could be involved with collecting data on migratory fish. This list is not meant to be comprehensive, and reflects that most of the participants were from Cambodia. Participants highlighted that these various organizations need to work together to maximize their efforts, and that information needs to be shared among different organizations and disciplines (e.g. those studying wetlands or rivers, etc.)

Cambodia

Government:
1. Fisheries Administration
2. Inland Fisheries Research and Development Institute (IFReDI)
3. Tonle Sap Authority

Non-Governmental and Community Organizations
1. 3S Rivers Protection Network (3SPN)
2. Community Fisheries
3. Conservation International (CI)
4. Culture and Environment Preservation Association (CEPA)
5. Fisheries Action Coalition Team (FACT)
6. International Union for Conservation of Nature (IUCN)
7. Mekong River Commission (MRC): Mekong Biodiversity Network (population studies) and Fish Biodiversity Network (species diversity and taxonomy)
8. Natural Heritage Institute (NHI)
9. Scientific Capacity Development Initiative (SciCap)
10. WorldFish
11. World Wide Fund for Nature (WWF)

Universities
1. Prek Leap National College of Agriculture
2. Royal University of Agriculture
3. Royal University of Phnom Penh
4. University of Battambang
5. University of Nevada-Reno (Wonders of the Mekong)

Lao PDR
1. FISHBIO
2. Living Aquatic Resources Research Center (LARReC)
3. National University of Laos

Thailand
1. Ubon Ratchathani University

Vietnam
1. Can Tho University
2. RiA2

Following the Session 1 discussion, the data needs were compiled from each small group into a single master list and presented to all participants. Each participant was then asked to select the three data needs from the consolidated master list that they considered most important for prioritization. These votes were tallied separately for the assemblage and species levels (Tables 3 and 4) and the top data needs formed the starting point for the discussions in Session 2.

Table 3. Compiled list of data needs at the multi-species/assemblage level, and the corresponding number of votes for prioritization.

Multi Species/Assemblage Level Data Needs	Number of Votes
Key habitats and spawning areas	15
Migration routes and distances	14
Migration timing	13
Species life cycles	11
Use of protected areas	8
Spawning seasons	8
Fishing activity/exploitation rates	6
Changes in response to stressors (dams, habitat loss, waste, etc.)	6
Impacts of river flow	5
Knowledge transfer between communities and scientists	5
Migration strategies/functional groups/guilds	5
Food webs	3
Swimming behavior of fish	3
Species replacement, effects of non-native species	2
Migration cues and purpose	1

Table 4. Compiled list of data needs at the individual species level, and the corresponding number of votes for prioritization.

Individual Species Level	Number of Votes
Life-cycle and life history	23
Spawning areas	20
Environment and habitat requirements	18
Migration routes and distance	12
Population abundance and trends	10
Response to dams	9

Swimming behavior	6
Species of concern	6
Home range	5
Recruitment and larval survival	4
Homing behavior	0

Session 2: Techniques and Technology for Monitoring Migratory Fishes

The keynote speaker in this session, Dr. Lee Baumgartner (Charles Sturt University), provided an overview of tools and techniques to quantify freshwater fish migrations, including radio and acoustic telemetry as well as Passive Integrated Transponder (PIT) tags. Other session speakers discussed otolith techniques, including Mr. Vu Vi An (Charles Sturt University), who presented on otolith microchemistry, and Mr. Chhuoy Samol (IFReDI), who presented on using larval otolith analysis to identify spawning grounds for migratory fish. Dr. Nitiwadee Keschumras (Chulalongkorn University) described the application of satellite tags to Mekong giant stingrays, Mr. Dana Lee (FISHBIO) discussed infrared and sonar technologies for use in fish monitoring, and Dr. Vittoria Elliot (Conservation International) described a suite of various tools, ranging from fish catch monitoring to genetic techniques.

The discussions portion of this session included the following three topics, which are described in detail below:
1) What are the best (ideal world) technologies or techniques to fill each of the prioritized knowledge gaps? What are some more accessible alternatives?
2) What are some of the challenges associated with these techniques and how could they be addressed?
3) Where and how are some of these techniques being used already? How could these efforts be coordinated to inform migratory fish management?

2.1 What are the best (ideal world) technologies or techniques to fill each of the prioritized knowledge gaps? What are some more accessible alternatives?

Using the top data needs identified by the group as a starting point, workshop participants brainstormed lists of tools and techniques that could be used to address each data need at the multi-species level (Table 5) and individual species level (Table 6). Although the exercise was initially presented as "ideal techniques" vs. more accessible "alternative techniques," some groups noted that a better distinction might be "more technical" vs. "less technical."

All groups identified that Local Ecological Knowledge (LEK) forms the basis of much of our current understanding about Mekong fishes, and although it is a less technical approach, sometimes it is the only available (and therefore best) technique to use. Even with the adoption of more advanced techniques, scientists will still need to rely upon local knowledge in many cases, as

fishing communities are often able to observe migratory fish more regularly than researchers, and can provide a complimentary perspective. Local knowledge may be able to serve as a starting point that could then be compared with results from the more advanced techniques. Participants also provided examples of how communities could work together with researchers – for example, one researcher in Laos has villagers call him when they see fish starting to migrate past their village. Participants also identified that many of the data needs could be addressed by conducting routine fish sampling, whether through fisheries-dependent (e.g. fisher logbook) or fisheries-independent approaches. Some participants noted that considerable data is available for some of these needs, but is not being used or shared among researchers. It was emphasized that many of these technologies were not sufficient on their own for answering some of the data needs, but that technologies could be combined to maximize their usefulness.

Table 5. Compiled list of techniques and technologies to address data needs at the multi-species/assemblage level.

Multi Species/Assemblage Level		
Data Need	**More Technical Techniques**	**Less Technical Techniques**
Key Habitats and Spawning Areas	• ARIS/Fish finders (hydroacoustics) • GIS • Gonad studies • Larval drift • Mark-recapture studies • Otolith techniques • Radio/acoustic telemetry	• Expert knowledge • Fish sampling/catch monitoring • Larval collection • LEK • Other indicators (i.e. birds) to identify good habitat
Life Cycle & Life History	• Bongo net sampling • Gonad studies and reproductive stage • Otolith techniques + hydrological information • Tagging studies	• Gill net sampling • LEK • Literature review/compile existing information (MRC updated species list) • Seasonal monitoring, fish sampling/catch monitoring
Migration Route & Distances	• Chemical tags • Dai data • Fishway sampling • General mark-recapture techniques • PIT tags • Telemetry	• Citizen science • Expert knowledge • LEK • Phone communication network with villagers
Migration Timing	• Chemical tags • Genetics • PIT tags • Telemetry	• Citizen science • Expert knowledge • General mark-recapture techniques

		• LEK • Phone communication network with villagers
Community Composition	• Indicator species	

Table 6. Compiled list of techniques and technologies to address data needs at the individual species level.

Individual Species Level		
Data Need	**More Technical Techniques**	**Less Technical Techniques**
Life Cycle & Life History	• Aquaculture program • Catch statistics • Larval collections • Otolith techniques • Spawning surveys (markets survey: look for fish w/ eggs; LEK)	• LEK
Environment & Habitat Requirements	• ARIS/video camera • eDNA • Laboratory studies (habitat microcosms in the lab and field) • Larval/fish monitoring & environmental data • Swimming performance (flow studies to look at preference vs. requirements) • Tags (mark-recapture)	• Direct observation • LEK
Population Abundance & Trends	• Fish catch monitoring • Genetic structure • Hydroacoustic monitoring (ARIS) • Long-term monitoring (gill-net monitoring) • Model extinction risk (e.g. BirdLife) • Tags (mark recapture) • VAKI Riverwatcher	• LEK • Otoliths (stock assessment & microchemistry)

2.2 What are some of the challenges associated with these techniques and how could they be addressed?

Participants identified the following challenges associated with migratory fish research:
- Availability of tools
- Big problems require big solutions
- Capacity (human resources)
- Challenging species identification
- Community engagement (need communication, incentives, and education)
- Costs and funding
- Creating infrastructure (e.g., genetics lab)
- Dangerous/difficult sampling environment
- Dynamics of migratory fish biology
- Government support/political will (need innovative communication, donors can lobby)
- Lost/stolen equipment
- Need for coordination or cooperation among multiple organizations
- Need for intensive sampling (e.g. larval sampling)
- Need for project leaders that can coordinate among players and move forward
- Public access to data and educational materials
- Scale of the basin/questions
- Sustaining long-term investment
- Using tools in a trans-boundary context

One of the biggest challenges identified by participants was the cost of various tools, but they also emphasized the lack of capacity and knowledge of many local researchers, who would face difficulties when trying to implement some of the more advanced sampling techniques. In the past, new technologies have been introduced by foreigners that worked well for a short period of time, but as soon as something went wrong, the local researchers did not know how to fix the problem and essentially stopped doing the research. Therefore, capacity building and training would be needed, as well as ongoing support for implementing more advanced technologies.

Another challenge is the scale of the research questions and the need for trans-boundary cooperation. Many of the techniques would be useful on a small scale, but would be extremely challenging on a basin-wide scale that would involve several countries and numerous districts/provinces. Furthermore, research is a low priority in national development plans, and there may not be political will for implementing some of these studies on a large scale. Innovative communication techniques are needed to convey the importance of this research. Someone also noted that project donors may have a better ability to lobby for research support at higher political levels.

A general leader/champion is also needed for any research or monitoring effort to secure long-term funding and provide project coordination and continuity. This would be crucial for long-term implementation and for dealing with the inevitable challenges that would arise. Finally, engaging with communities is critical for the success of many research studies, whether through educating

villagers to return tags for mark-recapture studies, involving them to supervise scientific equipment so it does not get damaged or stolen, or simply helping them understand what tags are when they encountered tagged fish, and that the tags do not pose a threat to health or safety. Incentives are needed to engage communities in research and monitoring work, as well as basic education about how the technology works.

2.3 Where and how are some of these techniques being used already? How could these efforts be coordinated to inform migratory fish management?

Below are a few examples of organizations or individuals using various techniques throughout the Mekong Basin. Countries are listed for institutions not located in Cambodia (AUS = Australia, TH = Thailand, VN = Vietnam)

Technique	Institution
Fish catch monitoring	IFReDI, RiA2 (VN), SciCap, Tonle Sap Authority, WWF
Hydroacoustic monitoring	MRC, Thai Department of Livestock and Fisheries (TH), Ubon Ratchatani University (TH)
Indicator species	IFReDI (Peng Bun Ngor)
Otolith microchemistry	Charles Sturt University (AUS), IFReDI, RiA 2 (VN), Ubon Ratchatani University (TH)
Telemetry	Chulalongkorn University (TH)

Participants noted that many techniques were being used throughout the basin, but there currently is not much coordination between various entities. To coordinate these efforts, some suggested a hierarchy of that starts with a leader or champion of a particular initiative, along with the national-level government and the donor at the top, then carries down through local-level governments and universities working at the province or district level, and ultimately involves fishers and communities at the local level.

Session 3: Developing a Swimway Management Plan

The keynote speaker, Dr. Herman Wanningen (World Fish Migration Foundation), shared experiences and basic steps to develop a Swimway Management Plan, while Dr. Gordon O'Brien (University of Mpumalanga) provided a regional example efforts for swimway management in South Africa. Mr. Yong Ding Li (BirdLife International) described a similar efforts to manage flyways for migratory birds, and Mr. Rous Chanty (National Consultant for the MRC) provided a local example of transboundary fisheries management between Cambodia and Lao PDR.

This discussion portion of this session included the following three topics, which are described in detail below:
1) What are the major fish migration routes for migratory fish assemblages in Cambodia? What are the appropriate geographic scales for management?
2) Who are the management players that should be involved at various scales? What existing efforts are related to a migratory fish management? How could they best be coordinated to maximize effort and minimize overlap?

3) What are potential challenges for migratory fish management? How could these be addressed?

3.1 What are the major fish migration routes for migratory fish assemblages in Cambodia? What are the appropriate geographic scales for management?

Participants used a map of the rivers in Cambodia to identify the following important routes and habitats for migratory fish:

Tonle Sap:
- The Tonle Sap lake is an important habitat for rearing and foraging. There is some spawning in the flooded forest area, mainly blackfish or grayfish species. Other flood plains for rearing are in Kompong Cham
- The Tonle Sap River that connects the Mekong River to the lake is a highly important connection. There are some barriers along this corridor such as the dai fishery.
- There is a Ramsar Site at Boeng Chmer on the Tonle Sap
- Connections to tributaries and floodplains are important migration corridors for fish
- Of the rivers/streams that flow into the Tonle Sap, Steng Sangke and Steng Sen are considered more important. Some blackfish and small/medium sized fishes spawn in these streams and migrate into the Tonle Sap Lake
- The Tonle Sap tributaries were historically important for migrations, but now they all have multiple barriers, such as irrigation structures
- Fires in the flooded forest during the dry season pose some threats

Mekong/3S Basin:
- From October to March, many species migrate from the Tonle Sap up to the Mekong River and 3S Basin (Sekong, Sesan and Srepok rivers) to spawn.
  The 3S Basin was identified as an important spawning area for white fish
- The Sekong River is now more important to keep free-flowing for migratory fish like the giant catfish and Pangasius because of the Lower Sesan II Dam
- Fish also migrate up the Mekong River into Laos, and there is some transboundary management between Cambodia and Laos
- There is spawning around Stung Treng
- The striped river barb spawns in the upper 3S basin
- There are still fish that migrate in the upper watershed of the Sesan River above the dam
- More than a hundred species migrate across Khone Falls.

Lower Mekong/Delta:
- From the Mekong River, fish migrate to the Bassac River and to the Mekong River in Vietnam
- *Pangasius krempfi* and stingrays are examples of fish that migrate to Cambodia from the Mekong Delta (examples of the few diadromous species in the basin)

Participants identified that basin-wide movement of migratory fish is happening year-round (essentially, fish are moving everywhere all the time), and fish are also migrating across borders. However, climate change appears to be influencing the timing of migrations – when there is no rain, migrations are delayed. The Sekong-Mekong-Tonle Sap corridor was identified as particularly important to connect spawning and rearing habitats, especially now that the Srepok and Sesan rivers are dammed. A few important, iconic migratory species include *Probarbus* spp. and giant barb. *Mekongina erythrospila*, *Pangasius* spp. and *Labeo chrysophekadion* are other iconic and valuable species that migrate across Khone Falls

Several publications exist from the MRC and others that describe migrations based on fish catch in the dai fishery, the 3S river system, and the Tonle Sap Lake and its tributaries. The MRC also has a map of some barriers to fish passage, but these maps should be more widely accessible. There are many existing barriers in the tributaries, and more proposed dams at Sambor, along Stung Sen, on the Pursat River, and on the Tonle Sap River. It was noted that a fish passageway exists at Stueng Chinit. A fishway was recently completed at the Lower Sesan II Dam, but participants expressed concerns about its effectiveness.

3.2 Who are the management players who should be involved at various scales? What existing efforts are related to a migratory fish management? How could they best be coordinated to maximize effort and minimize overlap?

Participants identified the following management players at different scales:

Local Level:
- Communities
- NGOs
- Protected area management

Provincial Level:
- Fisheries Administration
- Provincial and municipal governments
- Tonle Sap Authority

National Level:
- Cambodia National Mekong Committee
- Fisheries Administration, IFReDI
- Ministry of Agriculture, Forestry and Fisheries
- Ministry of Mining and Energy
- Ministry of Water Resources

International Level:
- Fisheries Administrations in other Mekong countries
- Mekong River Commission

Others:

- High-level donors (e.g., ADB) and hydropower companies
- Students and young people
- Universities (to contribute research/knowledge)

The Fisheries Administration (FiA) is the only management body for fish at the river-basin level, and there are offices at both national and provincial levels. FIA is in the Ministry of Agriculture and Fisheries, but there are other relevant ministries, such as the Ministry of Environment and Ministry of Water Resources. These ministries also have relevant departments working at the sub-national level, such as the Department of Environment, the Department of Forestry and Fisheries, and the Department of Tourism.

One participant expressed that students and young people were extremely important for these efforts and that they should be incorporated into any existing management efforts, as they would be the ones to carry on this work into the future. This was in keeping with a general sentiment that "everyone" needs to be involved in order to implement successful fisheries management in Cambodia. However, this type of approach would also require a leader to coordinate the effort between all of the various players and to make sure that efforts were not overlapping.

3.3 What are potential challenges for migratory fish management? How could these be addressed?

Participants identified the following challenges to migratory fish management in Cambodia as well as around the Mekong Basin:
- Climate change
- Conflicts of interest among ministries
- Cost and budgeting
- Empowering local communities
- Food security
- Fisheries laws need to be refined
- Hydropower
- Illegal fishing and limited livelihood diversity
- Lack of knowledge about importance of migratory fish / connected habitats
- Lack of overview and leadership
- Political will
- Research-guided policy needed
- Using available data
- Weak environmental law enforcement

A number of threats to fishes also create challenges for management. For example, illegal fishing gears were mentioned, such as poison, dynamite and electric shock. This is a management challenge because of limited human resources and limited law enforcement. Illegal fishing persists because of food security needs and limited livelihood diversity. There are many current barriers to migration, such as irrigation systems around Tonle Sap. With hydropower development

progressing, participants suggested there is a need for fish passage construction, a fund for environment protection, and more government oversight.

Participants noted that one challenge is conflicts of interest among relevant Ministries or Departments. For example, many flooded forests are being converted to agriculture, but this can create tension with tourism, because tourists like to see the flooded forest. There are also overlapping responsibilities between government departments and a lack of coordination, as well as limited funding to go around. To address this, participants suggested that collaboration between line agencies, stakeholders and communities could be strengthened. They also recommended also improving relevant policies and encouraging collaboration between departments.

All groups discussed the need to develop coordinated guidelines for migratory fish management, such as in the form of a master plan. A master plan would be extremely important for providing that guidance and vision for the government, researchers, and others that want to be involved, and keep research and management activities moving forward in a productive way. Some suggestions for the master plan included controlling fishing gear in the open season (the closed season currently has good regulations), and optimizing fisheries management based on the migration period (e.g., stop fishing during the two days at the peak of migration). Participants again recommended using available data to address some of these challenges so that researchers don't continue to collect more data without ever using it.

Some priority actions that were suggested by participants during this session included:
- Coordinate from international to local levels
- Develop a master plan for fisheries management
- Identify a leader to coordinate activities and keep the ball moving forward for migratory fish management
- Improve fishing laws in the open season
- Improve inter-agency communication and coordination
- Improve law enforcement
- Keep Sekong free-flowing
- Keep Sekong-Mekong-Tonle Sap corridor free-flowing
- Protect Tonle Sap River and keep it free-flowing

Session 4: Elements of a Shared Vision for Migratory Fish

This session included the following three topics for discussion, which are described in detail below:
> 1) What are the desired outcomes for managing migratory fish in Cambodia? What does success look like? What are we trying to achieve?
> 2) What types of management tools or approaches could help achieve these outcomes? How might we prioritize these? What are the strengths/weaknesses of each?
> 3) Where do we go from here? What are some next steps and who could be involved?

4.1 What are the desired outcomes for managing migratory fish in Cambodia? What does success look like? What are we trying to achieve?

For this topic, participants were asked to write their ideas for a vision of success for migratory fishes on individual sticky notes. These ideas were then compiled, and the following themes emerged:

- A balance between human and environmental (fish) needs
- Abundant fish to sustain people's livelihoods and food security
- Clean water and a clean environment
- Conservation actions, including increased awareness about sustainability and protecting habitat
- Coordination among multiple stakeholders
- Creating fish passage
- Healthy and abundant populations of migratory fish that can move freely
- Increased research providing data and knowledge to understand life cycles
- Maintain biodiversity
- Protecting migration routes in free-flowing rivers
- Strong governance, including enforcement to prevent illegal fishing and community involvement to manage fish populations

The content from all of the participant contributions is synthesized in Figure 1.

Figure 1. Word cloud of elements of a shared vision contributed by workshop participants.

4.2 What types of management tools or approaches could help achieve these outcomes? How might we prioritize these? What are the strengths/weaknesses of each?

Research: More scientific knowledge and data are needed to help fill the gaps identified in earlier sessions, and the relevant technology and tools should be identified to help answer some of those questions. These needs include improved stock assessments, understanding migration routes to protect them, and a standardized, long-term fish monitoring strategy, including across borders, to monitor the Mekong River, tributaries, and other connected habitats. Valuation is important: the economic, cultural, social, and ecological values of migratory fishes need to be understood.

Data Sharing: Better communication and data sharing are needed at many different levels: between governments and local communities, between fisheries researchers and managers, between various disciplines (outside of fish), etc. Currently, there is often no way to know which people are doing what work and where, so efforts are repeated in many cases. There is also room for data sharing with other disciplines such as researchers studying birds, aquatic reptiles and mammals, and terrestrial ecosystems.

Community Engagement: There is a need to increase public awareness about fish as a limited resource, and the important role of communities in achieving fish sustainability. Communities should share the ownership to solve issues, and any plan for fish management will largely depend on local communities to implement or follow. Livelihood enhancement activities such as aquaculture may be needed to take some pressure off wild fishes. Conservation of fish broodstock and habitats is important for sustainable populations, and community fisheries and freshwater protected areas are one way to achieve this. But participants suggested the process for communities to set up community fisheries should be simplified, building trust between communities and the government is key, and there should be more collaboration between armed forces (police) and communities regarding law enforcement. Generally, participants felt improved communication is needed between stakeholders. Existing networks such as fisheries associations would be key to the success of new management plans, as they are already implementing on-the-ground management with local groups, have been working for years to build trust, and have extensive local knowledge.

Integrate with Existing Management Strategies: The vision for migratory fishes should be integrated into existing systems and fisheries management plans. For example, it could be incorporated into the Fisheries Administration 10-year plan for fish conservation. Workshop participants suggested that the fisheries laws and master plan for the Fisheries Administration should be reviewed and updated, and other ministries, related policies, and strategies should be examined for opportunities to improve fisheries management. There is also an opportunity to link goals for migratory fish to the Sustainable Development Goals, which Cambodia has signed on to. For example, Goal 6.2 is about sustainable water resource management.

4.3 Where do we go from here? What are some next steps and who could be involved?

A good next step would be to create an action plan that includes:
- Priority projects, capacity building, and training
- Priority species, management areas, and management scales
- Clear mission, clear roles, and multi-stakeholder engagement

Once these are determined, existing networks, management strategies, and protected areas in these locations can be identified. This could follow the IUCN hotspot model, whereby areas of importance are identified, and existing efforts and research in these areas are investigated before proceeding with a management plan. Efforts could also include evaluating existing fish passage structures. Ideas to reduce illegal fishing included:

- High-level government involvement
- Government reforms (multi-level, especially in the fisheries law enforcement)
- Increase budget for patrolling
- Use drones for patrolling
- Develop alternative income opportunities for locals
- Organize study tours for government officials and community members to learn how different groups are addressing fish management and conservation

Another next step could be integrating with existing project and management efforts, and working to bring migratory fish into discussions about water management, development, etc. Participants recommended including the private sector in future workshops, since their actions can affect migratory fish. Other pressing next steps include securing funding and finding a champion willing to carry this work forward. Finally, the outputs from this workshop should be disseminated broadly to inform ongoing research and management.

Appendix 1: Workshop Participating Organizations

1. BirdLife International
2. Can Tho University
3. Charles Sturt University
4. Chulalongkorn University
5. Conservation International
6. European Union
7. FISHBIO
8. Fisheries Administration (Battambang, Kampong Chhnang, Kampong Cham, Kampong Thom, Kratie, Siem Reap, Stung Treng)
9. Inland Fisheries Research and Development Institute
10. International Union for Conservation of Nature
11. Lao Department of Livestock and Fisheries
12. Living Aquatic Resources Research Center
13. Mekong River Commission
14. National University of Laos
15. Oxfam
16. Prek Leap National College of Agriculture
17. Research Institute for Aquaculture No2
18. Royal University of Agriculture
19. Royal University of Phnom Penh
20. Tonle Sap Authority
21. Ubon Ratchathani University
22. University of Mpumalanga
23. University of Nevada-Reno
24. USAID
25. Wildlife Conservation Society
26. Wonders of the Mekong
27. World Fish Migration Foundation
28. Young Eco Ambassadors

Appendix 2: Workshop Agenda

Towards a Vision for Managing and Conserving Migratory Fish Species in Cambodia

Hotel Cambodiana, Phnom Penh, Cambodia
17–18 October 2018

Time	Agenda Item	Presentation Topic
Wednesday, 17 October 2018		
7:30-8:30	Registration	
8:30-8:40	Welcome: Ms. Erin Loury (Communications Director, *FISHBIO*)	
8:40-8:50	Opening Speech: H.E. Eng Chea San (D*elegate of the Royal Government of Cambodia in charge of the Fisheries Administration*)	
8:50-9:00	Opening Remarks: Ms. Sang Lee (*USAID Office Director of Food Security & Environment*)	
Plenary Session		
9:00-9:20	Plenary Speaker: Dr. Zeb Hogan (*University of Nevada, Reno*)	Why do we need a vision for migratory fish management?
9:20-9:40	Plenary Spaker: Dr. Herman Wannigen (*World Fish Migration Foundation*)	Connecting Fish, Rivers and People: Improving connectivity for migratory fish from local to global
9:40-9:45	Group Photo	
9:45-10:00	**Coffee Break**	
Session 1: Prioritizing Migratory Fish Data Needs for Cambodia		
10:00-10:20	Keynote Speaker: Dr. Touch Bunthang (*Acting Director, Inland Fisheries Research and Development Institute*)	Prioritizing migratory fish data needs for Cambodia
10:20-10:35	Mr. Chan Sokheng (*Inland Fisheries Research and Development Institute*)	Summary of Fish migration and habitat in Cambodia
10:35-10:50	Dr. So Nam (*Mekong River Commission*)	Impact assessment of water resources development on fish and fisheries in the Lower Mekong Basin
10:50-11:05	Dr. Ngor Peng Bun (*Inland Fisheries Research and Development Institute*)	Seasonal and inter-annual changes in multispecies fish assemblage in regulated and unregulated rivers, Lower Mekong Basin

Time	Agenda Item	Presentation Topic
11:05-12:00	Small Group Discussions	Topic: Identify key migratory fish data needs for Cambodia and how to prioritize them
12:00-12:30	Report Out and Large Group Discussion	
12:30-1:30	**Lunch**	(Compile master list of needs and criteria)
1:30-1:45	Prioritization of Data Needs	Each participant ranks the data needs
Session 2: Techniques and Technology for Monitoring Migratory Fishes		
1:45-2:05	Keynote Speaker: Dr. Lee Baumgartner (*Charles Sturt University*)	Tools and techniques to quantify freshwater fish migrations
2:05-2:20	Mr. Vu Vi An (*Charles Sturt University*)	Otolith microchemistry to infer fish migration
2:20-2:35	Mr. Chhuoy Samol (*Inland Fisheries Research and Development Institute*)	Early life history of Pangasianodon hypophthalmus and Pangasius macronema in Tonle Sap-Lower Mekong River system
2:35-2:50	Dr. Nitiwadee Keschumras (*Chulalongkorn University*)	Tracking of Giant Freshwater Stingray (*Himantura chaophraya/Urogymnus polylepsis*) by using acoustic telemetry in Maeklong River, Thailand
Time	**Agenda Item**	**Presentation Topic**
2:50-3:10	**Coffee Break**	
3:10-3:25	Mr. Dana Lee (*FISHBIO*)	Going beyond visible light: using technology to monitor fish in turbid waters
3:25-3:40	Dr. Vittoria Elliot (*Conservation International* – video presentation)	Monitoring Mekong Fish Migration - from citizen science to DNA
3:40-4:45	Small Group Discussions	Topic: What techniques and technologies are needed to answer the highest priority data needs listed in Session 1?
4:45-5:10	Report Out and Large Group Discussion	
5:10-5:15	Final Remarks for Day 1: Ms. Erin Loury (FISHBIO)	

Thursday, 18 October 2018		
9:00-9:10	Welcome Remarks and Recap of Day 1: Ms. Erin Loury (FISHBIO)	
Session 3: Developing a Swimway Management Plan		
9:10-9:30	Keynote Speaker: Dr. Herman Wanningen (*World Fish Migration Foundation*)	Swimway Management Plans: Basic steps to develop plans and measures to protect and improve swimways of migratory fish
9:30-9:45	Dr. Gordon O'Brien (*University of Mpumalanga*)	Southern Africa legislative perspective on the management of river connectivity and the migratory fishes that require them with the Ecological Reserve
9:45-10:00	Mr. Yong Ding Li (*BirdLife International*)	Bird migration in eastern Asia: lessons and insights for the conservation of migratory taxa
10:00-10:15	Mr. Rous Chanty (*National Consultant*)	Swimway Management Plan: Lessons learnt from the World Bank's transboundary fisheries management between Cambodia and Lao PDR
10:15-10:30	Dr. Gordon O'Brien (*University of Mpumalanga*)	PROBFLO: A Regional Scale Ecological Risk Assessment approach to characterise the E-flows and associated river connectivity requirements for the protection of migratory fishes in Africa
10:30-10:45	**Coffee Break**	
10:45-11:45	Small Group Discussions	Topic: What are the swimways in Cambodia? What organizations and existing efforts might be involved in swimway management?
11:45-12:15	Report Out and Large Group Discussion	
12:15-1:30	**Lunch**	
Session 4: Elements of a Shared Vision		
1:30-2:30	Small Group Discussions	Discuss elements of a vision for managing migratory fish in Cambodia
2:30-3:15	Report Out and Large Group Discussion	Discuss workshop outputs and next steps
3:15-3:30	Final Remarks and Closing Ceremony: Ms. Erin Loury, FISHBIO	
3:30	**Coffee and Snacks**	

Appendix 3. Workshop Photos

Opening remarks by HE Eng Chea San, Director of the Fisheries Administration

Workshop group photo

Workshop small-group discussions

Workshop participants

Participants writing their visions for migratory fish

Facilitator Erin Loury reporting on group discussions

Facilitator Teresa Campbell presenting migration routes

Facilitator Dana Lee reporting on group discussions