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Developing an Environmental Monitoring System to Strengthen Fisheries and Aquaculture Resilience and Improve Early Warning in the Lower Mekong Basin

FAO/NACA Workshop
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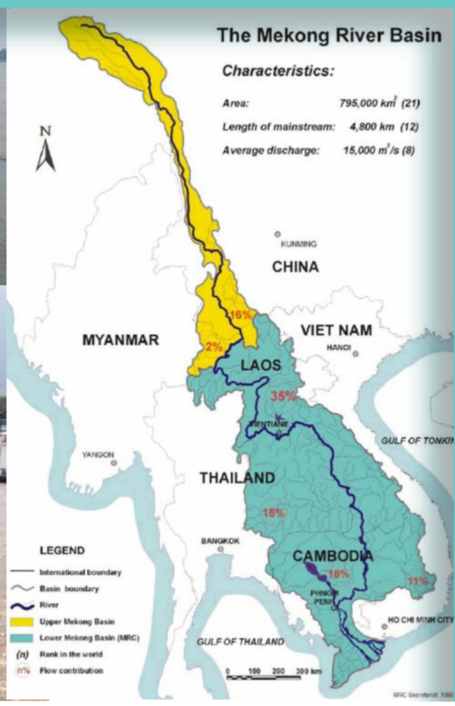

Cover photos:

Top left: Shrimp farms in Thailand, courtesy of Ms D. Soto.
Bottom left: Shrimp farms in Thailand, courtesy of Mr Pedro Bueno.
Left: The Mekong River, Source: Mekong River Commission Secretary.

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Developing an Environmental Monitoring System to Strengthen Fisheries and Aquaculture Resilience and Improve Early Warning in the Lower Mekong Basin

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Preparation of this document

This is the proceedings of the Food and Agriculture Organization of the United Nations (FAO) and the Network of Aquaculture Centres in Asia-Pacific (NACA) Workshop on Developing an Environmental Monitoring System to Strengthen Fisheries and Aquaculture Resilience and Improve Early Warning in the Lower Mekong Basin. It was held in Bangkok, Thailand, on 25–27 March 2015. The workshop was hosted by NACA.

The workshop and workshop report were prepared under the auspices of the project "*Climate Change, Fisheries and Aquaculture: testing a suite of methods for understanding vulnerability, improving adaptability and enabling mitigation (GCP/GLO/322/NOR)*", supported by the Government of Norway.

The document was prepared by Cherdsak Virapat and Simon Wilkinson, NACA, and Doris Soto, Fisheries and Aquaculture Resources Use and Conservation Division, FAO Fisheries and Aquaculture Department, Rome, Italy.

The contributed papers for the workshop are reproduced as submitted by the authors as well as the material included in their respective annexes.

Abstract

These proceedings report the result of a sub-regional consultation on the existence and effectiveness of environmental monitoring systems for fisheries and aquaculture in the Lower Mekong basin. The document also includes a baseline assessment of environmental monitoring systems in Cambodia, Thailand and Vietnam, and the report of a regional workshop to discuss the assessments findings and future steps to improve an environmental monitoring and early warning system that will improve climate change adaptation in fisheries and aquaculture in the area.

The consultation identified main climate change related threats to fisheries and aquaculture and determined the minimum environmental variables and/or associated information that should be collected by a shared environmental monitoring and early warning system in order to support decision-making. Information gaps and pathways to the establishment of a shared monitoring system, information base and environmental data analysis platform were identified. The country assessments also reached out to relevant agencies in the target countries to gather feedback on what environmental issues they considered important and what parameters should be monitored to meet these ends.

The consultation identified a need to try and integrate the available data produced by existing sources and to build on it, where required, to provide a unified environmental monitoring system capable of sharing data and reporting over different geographic scales, from the wider basin level (i.e. between countries) to the local-level advisories of interest to farmers and fishers.

The workshop participants shared assessments and monitoring experiences and identified gaps, needs and policy issues concerning the establishment of an integrated environmental monitoring and early warning system that would better inform and prepare farmers and fishers for hazards associated with climate change and variability and other natural disasters. The secondary purpose of the meeting was to facilitate long-term monitoring of the impacts of climate change on fisheries and aquaculture in the region.

The workshop agreed that generation of reports by the system and timely communication of relevant information to fishers and farmers using appropriate communication channels was a key challenge, as accessibility to different forms of media, the diversity of languages in the region, and literacy skills were all substantial issues for often remote communities.

FAO. 2017. *Developing an Environmental Monitoring System to Strengthen Fisheries and Aquaculture Resilience and Improve Early Warning in the Lower Mekong Basin. Bangkok, Thailand, 25–27 March 2015*, by Virapat, C., Wilkinson, S. and Soto, D. FAO Fisheries and Aquaculture Proceedings No. 45. Rome, Italy.

Contents

Abbreviations and acronyms

BOD	biological oxygen demand
CCTV	closed-circuit television
CFR	community fish refuge
COD	chemical oxygen demand
DO	dissolved oxygen
FCR	food conversion ratio
FIRF	Marine and Inland Fisheries Branch
HAB	harmful algal bloom
IOI	International Ocean Institute
LMB	Lower Mekong Basin
MaFreDI	Marine Fisheries Research and Development Institute, Cambodia
MRC	Mekong River Commission
NACA	Network of Aquaculture Centres in Asia-Pacific
NCDM	Nepal Center for Disaster Management
RAP	Regional Office for Asia and the Pacific
SMS	short message service
TAO	Tambon Administrative Organization
TSS	total suspended solids
WWF	World Wildlife Fund

1. OPENING OF THE WORKSHOP

The welcome address was given by Dr Cherdsak Virapat, Director-General, Network of Aquaculture Centres in Asia-Pacific. Opening addresses were given by Mr Adnan Qureshi, Chief Administrative Officer, Regional Office for Asia and the Pacific, FAO, and Dr Waraporn Prompoj, Deputy Director-General, Department of Fisheries, Thailand.

The workshop was held at the Centara Grand at Central Plaza Ladprao Hotel, Bangkok, Thailand, 25–27 March 2015. The workshop was sponsored by FAO, the International Ocean Institute (IOI), the Electricity Generating Authority of Thailand and the Thai Life Insurance Co. Ltd.

1.1 Introduction of participants

The workshop was attended by 40 people from six countries, international organizations, development agencies and non-governmental organizations (NGOs). The list of participants is in Annex 1.

1.2 Overview of workshop objectives and expected outputs

The objectives are to convene a subregional stakeholder consultation to discuss the present state of environmental monitoring systems in the Mekong Basin, to share assessments and monitoring experiences, and to identify gaps, needs and policy issues concerning the establishment of a shared, integrated environmental monitoring and early warning system. The expected outcomes of the consultation were:

- The meeting should agree on the main climate change related threats to fisheries and aquaculture (including diseases), and will agree on the minimum environmental variables and/or associated information that should be collected and integrated to provide relevant feedback for decision-making.
- It is expected that the meeting will make a major contribution to identify the current state of environmental monitoring systems in the Mekong Delta, including gaps and the pathway to a common/shared monitoring system, information base and analysis platform. Such a system should allow aquaculture farmers and fishers to be better informed and prepared and could help in preventing main losses to the sector.
- To produce a workshop report, including the finding and recommendations, with a focus on policymaking and a proposal for implementing an integrated environmental monitoring and warning system.

The agenda is in Annex 2.

2. BASELINE ASSESSMENT AND PRESENTATIONS SESSION

Dr Doris Soto gave a presentation on *the relevance of environmental monitoring systems to increase resiliency in fisheries and aquaculture and addressing the major climate change threats in the Mekong Basin*.

Dr Elisabeth Conrad and Prof. Louis Cassar presented a draft report of the *Baseline assessment of existing environmental monitoring and early warning systems relevant to fisheries and aquaculture in the Mekong Basin* (Paper 1). The project teams of Cambodia, Thailand and Viet Nam presented the results of national baseline survey assessments they had conducted of existing environmental monitoring and early warning systems relevant to fisheries and aquaculture in the Lower Mekong Basin (Papers 2–4). A brief discussion was held after each presentation. The major points raised were:

- The questionnaire had been designed using online submission tools so that it could be filled in and collated easily. Planning of data collection had been delegated to the teams from each country. Data were collected from: (i) fishers and farmers; (ii) government agencies; and (iii) other stakeholders such as civil groups and NGOs.

- It would have been useful to include a socio-economist in the questionnaire design and to incorporate more socio-economic and market data, for example, farmgate prices and farmer satisfaction with such, as these may have provided more insights into possible support interventions. However, trade-offs had to be made in the interests of keeping the questionnaire a reasonable length for stakeholders and focused on the task at hand.
- The difficulty in differentiating between natural seasonal variations and the effects of climate change was noted. It was difficult to attribute individual observations to climate change. A long-term approach to environmental monitoring was required in order to establish clear trends.
- As flooding is an annual event in much of the lower Mekong Basin, warning needs are largely concerned with timing and height. Marginal areas that do not experience flooding every year may be less well prepared than those areas where it is routine.
- Trust was a substantial issue. The information generated by an environmental monitoring or early warning system needed to be of high quality and accuracy and reach stakeholders in a timely manner in order to be useful. Otherwise, stakeholders may not trust the source or ignore valid warnings in future.
- Environmental monitoring and early warning systems needed to address risk management and risk communication. There was a need to communicate risk to different stakeholder groups, from farmers and fishers to government policy-makers and political leaders, as the latter often had control over the technical management of water resources.
- Illegal fishing and illegal fishing practices (for example, the use of pesticides) were noted as a shared problem within the Mekong Basin.
- There are many systems in place to monitor various aspects of the environment, but they are operated by a diverse range of agencies and designed for a variety of purposes. There is thus a need to improve data sharing between systems and agencies in order to build a more consolidated picture, both nationally and within the wider basin. Collating information from multiple sources was particularly important in trying to observe climate change impacts occurring over longer time scales.
- Communicating the output of environmental monitoring systems back to farmers was a complex issue. While Lower Mekong Basin countries still had large extension networks, provincial or district level officers were generally responsible for livestock and agriculture as well as aquaculture.
- Farmer clusters or collectives were noted as one potentially useful way to facilitate communications with large numbers of small-scale farmers, particularly where the extension service is limited.

Additional presentations were given by China, the Mekong River Commission (MRC), Dr David Lymer, FAO Marine and Inland Fisheries Branch (FIRF), and Mr Miao Weimin, FAO Regional Office for Asia and the Pacific (RAP), with a brief period for discussion. The main points raised were:

- Otolith chemistry could be used to monitor fish migration patterns. However, this was not yet being conducted in the Mekong River.
- A severe drought in China from 2009 to 2012 had been observed to correspond to a decline in fish catches in the Cambodian stretch of the Mekong River.
- China has established a network for joint management, environmental monitoring and fish conservation via its provincial fishery environment monitoring centres and provincial environmental monitoring stations. These monitor a wide range of water quality parameters including various contaminants, in some cases using biological indicators such as contaminant levels in freshwater bivalves.
- As all countries along the Mekong River had their own environmental monitoring systems, it was noted that there would be considerable value in coordinating

efforts to jointly monitor key parameters and to share data, particularly with regards to producing an efficient early warning system and to monitoring the long-term effects of climate change.

- The MRC has a wide network for disseminating information, working with national line ministries in each member country, via its newsletter and through translations of key information conducted by each member country, which also played a key role in disseminating information through their own channels.

3. SYNTHESIS OF THE ASSESSMENT OF CURRENT MONITORING SYSTEMS RELEVANT TO FISHERIES AND AQUACULTURE AND GAP ANALYSIS IN THE LOWER MEKONG BASIN

Dr Elisabeth Conrad and Prof. Louis Cassar presented a synthesis of the assessment of current monitoring systems relevant to fisheries and aquaculture and gap analysis in the Lower Mekong Basin. The major points raised were:

- A multidisciplinary approach would be required to establish a consolidated environmental monitoring system. An individual's perspective in dealing with impacts is heavily influenced by one's training.
- In establishing an environmental monitoring system, it would be important to carefully consider the available resources and build on existing systems where possible rather than to duplicate. Geographical differences needed to be considered and it was important to focus on goals that were realistically achievable within existing resource constraints.
- It would be important to ensure that there was broad representation of stakeholders from all sectors and to solicit opinions from a broad range of sources, focusing on facts and avoiding politicization of issues.
- The system should empower local people to participate in the planning and management of resources. The involvement of stakeholders, particularly fishers and farmers in data collection, was highly desirable and indigenous knowledge should also be considered. It was noted that scientists, in particular, may find it difficult to communicate with local people in the field and thus indigenous knowledge may not be collected.
- Governance issues should be considered in the design of any monitoring system, including communication of the benefits and results to stakeholders. This would help ensure that stakeholders understood and valued the system and were encouraged to contribute; if stakeholders lose faith in the system or in the information generated by it, the system will fall apart.
- With regards to science, it is necessary to quantify information, where possible, using indicators to monitor the various components of the environmental monitoring system with milestones, aims and objectives that could be tracked. This would provide a "yardstick" against which to measure performance. The system could make use of traditional indicators of environmental quality, plus biomarker species that provide indications of environmental change.
- It was noted that projects often fail because the issues and problems have been poorly defined and analysed, and the concepts that have been put forward have been inadequately translated into development goals. Conversely, well-designed projects incorporating social, economic and environmental dimensions and baseline assessments of these variables generally do better. Projects must be implementable within the resource constraints and context.
- The environmental monitoring system should be designed with the livelihoods implications of change in mind, as the system was intended to serve the needs of fishers and farmers. There was a need to think about exactly what aspects this environmental monitoring system will contribute to, for example, perhaps a focus on disaster mitigation and recovery.

Comments on the synthesis from participants were as follows:

- Failure of projects often occurred due to a lack of resources and a lack of understanding of the benefits by stakeholders, including at the government level. Having enough resources to sustain an environmental monitoring system over a long period of time would be difficult under conventional project-based budget cycles. Long-term investment from government would be required.
- At the local level, technical people may have difficulties communicating with local communities. Extension support is needed to help them understand the local issues and also to help establish linkages with communities. There was a need to pursue an integrated approach with coordination between agencies.
- MRC would begin a restructure in 2016, and its monitoring systems would be progressively decentralized and handed over to member countries for implementation over the next few years, with MRC itself ceasing work in this area by 2020. However, flood planning would remain in-house due to its importance.
- There is a need to clearly define the goals of the environmental monitoring system and to ensure that the data collected clearly benefited stakeholders, as data collection involved a cost. Existing monitoring systems and data sets should be tapped into as far as possible.
- The system should be designed to provide insight into both short-term fluctuations required for advising farmers and fishers on their daily activities and to observe slow-onset climate change impacts.
- Historical data sets, some going back for decades, were available for many variables such as river levels, flow and temperature from national bureaus of meteorology and irrigation departments as well as the MRC. It would be useful to request access to historical data sets and also to request agencies collecting environmental data to make the data accessible on the Internet via a machine-readable interface so that data sets could be automatically harvested and shared between systems.
- A distinction should be made between short-term climate variability and long-term climate change, as this influences the design of the monitoring system. It was noted that these issues are of interest to different stakeholder groups; for example, farmers and fishers would need information relevant to their daily activities, while policy-makers would be more concerned with strategic issues and longterm planning.
- Government authorities understand that they need to do something about climate change, but they often do not have a clear idea about how they should address it. There was a need to focus on projects that were practical and implementable given operational constraints.
- Environmental risks varied between locations, and it would be useful to focus on sensitive areas. For example, coastal areas are susceptible to erosion and sea level rise. Sea level, in particular, and salinity are very important factors for fisheries. Changes in environmental parameters such as temperature may also influence the behaviour of fishers, causing them to go out to fish in different locations or at different times based on what they know.
- Similarly, fisheries and open aquaculture systems are more vulnerable than closed systems (e.g. ponds), as they are exposed to the prevailing water chemistry and environmental conditions, whereas pond systems have some degree of isolation.
- Interpretation of data would be a key issue. Institutions need to interpret the data collected by the system for the benefit of stakeholders. Communicating the information to stakeholders in a form and language that they understand is essential, and communication channels need to be built into the design.
- It would be worthwhile considering the use of social and bioindicators, as well as tools such as remote sensing, in the design of the environmental monitoring system.

4. WORKING GROUP SESSION

Participants formed two working groups, one addressing fisheries and the other aquaculture. The groups were tasked with:

- Identifying the main threats that posed the greatest risk to the sector, considering past experiences and vulnerability aspects, risks to fisheries and aquaculture, and related food security and livelihoods.
- Identifying minimum variables or indicators that should be collected in relation to specific threats and that should be collected and integrated in order to provide relevant information for decision-making.
- Identifying who should collect such information at the government, community, and farm or individual levels, and how the collection and provision of information could be supported.
- Proposing a system/mechanism to build the database, analyse the information and generate feedback at a national level and at a regional level in the Lower Mekong Basin.
- Proposing a financing mechanism to provide human and monetary resources.

The working groups presented a summary of their discussions in plenary, followed by a joint discussion. The reports of the working group follow.

4.1 Working Group I: Aquaculture

Main threats and minimum variables or indicators

The main threats identified for aquaculture are summarized in Table 1. It was noted that different kinds of threats may cause impacts over different time scales. An effective environmental monitoring system would need to monitor both threats and impacts.

Who should be collecting the data

Agencies identified as potential sources for collecting data (i.e. they have existing data sets and monitoring programmes, or are best placed to collect additional information) are summarized in Table 2.

System/mechanism to build the database

General principles for providing effective information services were identified. The information must be:

- serving the needs of the end user;
- accurate, timely and authoritative/credible;
- comprehensible (suitable form, language and jargon for the target stakeholders); and
- cost effective and maintained over the long term.

Some information is already published online by government agencies in Thailand and Viet Nam (e.g. weather and hydrology warnings, river flow and height forecasts, current reservoir capacities and fill data). Some historical data are also available. However, the full data set (possibly spanning decades) may not be available online or in machine readable format.

A central mechanism (possibly involving computer models and automatic interpretation and reporting) is needed for interpreting data and providing feedback to farmers and fishers in each participating country. National institutions are currently collecting information, but it is unclear if they are all interpreting it for farmers. The institutions that collect environmental data may not necessarily be involved in aquaculture or fisheries. There is a need to conduct vulnerability assessments as to who needs to be warned, by whom and how.

Meteorological departments and other agencies have good communication channels to publish weather warnings and similar in the mainstream media. However, they may not be interpreting the information specifically for fishers and farmers. These

TABLE 1
Major threats, indicators of threat and impact

Threats	Physical/chemical	Biological	Socio-economic	Threat indicators	Impact indicators
Floods and droughts	Large change in water quality (increased turbidity, nutrient load, temperature, salinity, pollution, supply problems)	Reproductive Disease risk Mortality Growth rate Algal blooms and eutrophication Temperature stress	Infrastructure, property damage Crop loss/escapees Shortened culture period Job/livelihood loss Food security Conflict over water management Logistical interruptions (feed and seed supplies) Pumping costs	Rainfall River flow and level Reservoir storage capacity/level Inundation area Turbidity Algal density Nutrients Salinity	Infrastructure damage Water quality Turbidity Disease Mortality Algal blooms Loss of infrastructure Crop loss Job/livelihood loss Food insecurity Number of conflicts Logistical interruptions (road blocked, etc.) Production costs Food conversion ratio (FCR) Escapees Loss of life Impact on women, children, elderly and infirm (e.g. livelihoods, nutrition and more)
Extreme temperature fluctuations	O_2 levels Salinity Stratification	Harmful algal blooms Temperature stress Mortality Disease Natural food availability Cage fouling	Broodstock/crop loss Shortened culture period Job/livelihood loss Food insecurity Higher insurance costs	Temperature (air, water) Nutrients (conductivity, etc.)	Water quality Disease Mortality Algal blooms Crop loss Production cost (e.g. aeration, pumping cost) FCR
Unusual water level fluctuations (e.g. river, reservoir levels and flow)	Bank erosion Sedimentation Water quality (turbidity, temp, etc.)	Stress Disease Escapees		Water level Flow	Water quality Turbidity Salinity Disease Mortality Algal blooms Crop loss Job/livelihood loss Food insecurity Number of conflicts Production cost FCR
Saline intrusion into coastal estuaries (sea level rise, reduced flow levels)	Chemical and/or water-quality parameters	Mortality Stress Disease Algal blooms	Loss of farming area/sites Conflict with other users of water Low production	Salinity	Water quality Turbidity Disease Mortality Algal blooms Crop loss Job/livelihood loss Food insecurity Number of conflicts Production cost FCR
Extreme climatic events (storms, wind, wave amplitude)	Large change in water quality (increased turbidity, nutrient load, lower temperature) Pollution	Disease risk Mortality Algal blooms Escapees	Infrastructure/property damage Crop loss Job/livelihood loss Loss of life Food security Logistical interruptions (feed and seed supplies)	Forecasts Water level (reservoirs, rivers)	Water quality Turbidity Disease Mortality Algal blooms Crop loss Job/livelihood loss Food insecurity Infrastructure loss/damage Loss of life Impact on women, children, elderly and infirm (e.g. livelihoods, nutrition and more)

TABLE 2
Agencies with existing monitoring programmes or best placed to collect additional data

<table>
<tr><th>Threat indicators</th><th>Who (government, communities, farmers and fishers, NGOs)</th></tr>
<tr><td>Rainfall</td><td>Meteorological authorities (national, local)</td></tr>
<tr><td>River flow</td><td>Meteorological authorities (national, local) – publish current, mean and forecast river flows – Viet Nam – www.nchmf.gov.vn
Department of Water Resources, Hydrographic Department, Hydro and Agro Informatics Institute (Thailand)
Ministry of Water Resources and Meteorology (national), National Fisheries Administration (provincial) (Cambodia)</td></tr>
<tr><td>Water level (rivers, lakes, coastal, reservoir storage)</td><td>Mekong River Commission – collates data provided by riparian countries?
Meteorological authorities – publish river current height and forecasts (Viet Nam)
Department of Water Resources, Hydrographic Department, Hydro and Agro Informatics Institute, individual water management authorities (Thailand)
Ministry of Water Resources and Meteorology (national), National Fisheries Administration (provincial/cantonment) (Cambodia)
Role for local communities</td></tr>
<tr><td>Inundation area</td><td>Mekong River Commission
Ministry of Agriculture and Rural Development (Directorate of Irrigation and Water Resources)
Department of Land Development, Royal Irrigation Department, Hydro and Agro Informatics Institute – including risk management systems (Thailand)
Role for local communities</td></tr>
<tr><td>Air/water temperature</td><td>Meteorological authorities (air, possibly sea surface temp)
+ Ministry of Agriculture and Rural Development + provincial offices – water temperature (Viet Nam)
Hydro and Agro Informatics Institute/National Electronics and Computer Technology Center (NECTEC) – field server and school weather station projects (Thailand)
www.thaiwater.net – river temperatures
Combination of satellite and hand measurement
Ministry of Water Resources and Meteorology (national), National Fisheries Administration (provincial/cantonment) (Cambodia)
Role for local communities and farms (but maybe in pond)</td></tr>
<tr><td>Algal abundance</td><td>Provincial fisheries offices (Thailand)
Inland Fisheries Research and Development Institute (Cambodia)
Role for local communities and farmers, Secchi disk, etc.</td></tr>
<tr><td>Reservoir storage/ capacity (volume and surface area)</td><td>Department of Irrigation, Hydro and Agro Informatics Institute (Web site provides current and maximum storage levels, including historical data) (Thailand) – www.thaiwater.net
Ministry of Natural Resources and Environment (Viet Nam)
Ministry of Water Resources and Meteorology, National Fisheries Administration (Cambodia)</td></tr>
<tr><td>Turbidity</td><td>Role for local communities, farmers</td></tr>
<tr><td>Nutrient load</td><td>Environmental ministries
Can we ask agencies already collecting routine water quality data to collect additional parameters?</td></tr>
<tr><td>Salinity</td><td>Role for local communities, farmers?</td></tr>
<tr><td>Disease</td><td>Farmers
NACA/OIE/FAO aquatic animal disease focal points (national level reporting, regional system)
National fisheries and aquaculture departments
Private sector (diagnostic labs, animal health companies)</td></tr>
<tr><td>Food insecurity</td><td rowspan="7">Farmers and local communities</td></tr>
<tr><td>Job/livelihood loss</td></tr>
<tr><td>Crop loss</td></tr>
<tr><td>Loss of infrastructure</td></tr>
<tr><td>Algal bloom</td></tr>
<tr><td>Mortality</td></tr>
<tr><td>Number of conflicts</td></tr>
<tr><td>Logistical interruptions (road blocked, etc.)</td><td rowspan="4">Provincial and national governments</td></tr>
<tr><td>Escapees</td></tr>
<tr><td>Loss of life</td></tr>
<tr><td>Impact on women, children, elderly and infirm (e.g. livelihoods, nutrition and more)</td></tr>
</table>

existing communication channels could, however, be used to convey warnings without inventing anything new. For example, the Australian Bureau of Meteorology published sheep grazer warnings and agricultural frost alerts as part of its regular local level weather forecasts. It may be useful to explore, including aquaculture and fisheries alerts, through such existing channels.

Distributed sensor networks also offer opportunities for cheap, automated and real-time data collection. For example, the oyster industry in Tasmania must be temporarily closed to harvesting when rainfall exceeds a certain level for food safety reasons. Sensor data are relayed to a central collection point where a computer model interprets the results and issues advisories to the fishery manager as to which areas need to be closed and for how long. Once the criteria or a model for making decisions have been established, online data can be interpreted by machines to deliver fast advisory services at low cost. Cell phones can also collect and relay a lot of data via applications.

Data collection and reporting need to be addressed at the local, national and regional levels. Requirements will vary.

- A country-level coordinating agency must be determined, most likely the fisheries agency. This agency will compile information and interpret it, and share it with stakeholders. However, currently, fisheries departments do not have much role to communicate with other agencies. There is a need to build these links.
- A national level coordinating agency, usually a department of fisheries, will collate and interpret local data (with involvement of technical organizations as required, for example, research institutes may be needed for disease issues) for distribution to local agencies, and also regionally, as appropriate.
- Local agencies have a responsibility to collect/collate data (including farmer input) and feed the data to the national level coordinating agency.
- Involving stakeholders (farmers, fishers) in data collection could help them to engage more actively and have ownership of the system. Farmers are the main target-end users, but also a potentially valuable source of data.
- There is a need to establish a common standard for the data collected.
- Existing data sets and data collection, for example, by bureaus of meteorology, should be investigated for sharing. Additional data collection requirements need to be regularized and standardized.

Who should pay

Governments for national level data; possibly a small payment from farmers is possible for information that is relevant to them (perhaps through farmer associations/clusters).

4.2 Working Group II: Fisheries

Main threats

The main threats were perceived to be:

- Changes in water level (more generally, changes in the hydrological cycle, which includes water level changes, drought, rainfall, seasonal changes, as well as sudden changes and glacial melting).
- Water temperature variability (change can be generated by sudden water flows or floods).
- Dissolved oxygen (particularly in drought periods; algal bloom related).
- Salinity (especially important for summer fish-migration patterns); influenced by storms, storm surges.

The above threats are considered to be climate related. Other issues were:

- Pollution, related to human activities (discharges), becomes more serious in drought conditions when not enough water is available to flush away the pollutants; also relevant in (heavy) precipitation that can generate surface runoff of pollutants into the river.

- Dissolved oxygen and salinity are not directly driven by climate, but by a combination of temperature and changes in the hydrological cycle.
- Threats are not necessarily limited to extreme or out of the norm values since seasonal variations also play a very important role in the Mekong River Basin fisheries.
- The main threat to inland capture fisheries is hydropower development and other climate adaptation schemes such as flooding mitigation schemes.

Minimum variables or indicators

- It was suggested to include not only criteria for "measurement" but also for "observation and reporting"; the latter would provide the fishers with a greater role in this type of monitoring system.
- There was considerable debate concerning which specific type of information would actually be useful for fishers.
- It was agreed that with fisheries, the time and space parameters become increasingly important.

Measurement criteria

- salinity (not relevant to the entire lower basin, mainly the areas near the coast);
- nutrients (related to algal blooms);
- water level changes;
- temperature;
- species composition, fish catch and recruitment patterns; and
- identify critical (essential) habitats, e.g. deep/shallow pool areas within the Lower Mekong Basin.

Observation/reporting criteria

- extreme meteorological events;
- fish disease and deaths; and
- obvious pollution events/sources, e.g. algal blooms, discharge outlets.

Who should be collecting the data

- end users for crowdsourced data;
- institutions for quality control; this issue will not be further explored below; and
- the proposed monitoring system is not meant to replace the existing institutional environmental and fisheries monitoring system but complements it.

How can the data be collected

- using a smartphone application, e.g. Mobile4D;
- field sensors supported by smartphone; and
- direct field observation/reporting, e.g. on fish mortality or mass fish kills.

How can the information gathering be made available

- purchasing a limited number of smartphones; and
- training on operating the smartphone system/field sensors.

System/mechanism to build the database

- programming of existing software to adjust to this project; and
- data quality control.

Institutions (national, regional and networking)

- Regional and national institutions.

How feedback and early warning is provided

- automatically; and
- via central data storage/filter/interpretation system.

Financing mechanism and cost

- pilot phase application;
- maintaining a central data storage/filter/interpretation system;
- cost of programming of existing software to adjust to this project; and
- cost of data quality control.

Who should pay

- Government supported.

5. PLENARY DISCUSSION

The following describe the highlights of the discussion:

- The need to focus on those parameters that are of practical value to the end users (farmers and fishers), rather than those that may be largely of academic interest. Data may need to be interpreted differently to serve the needs of different stakeholder groups.
- Gender aspects should be included in the system, as environmental impacts often affect men and women in different ways. There are substantial differences in occupations between the sexes that could be affected differently. Similarly, the impact on children, the elderly and infirm should be considered.
- Smartphones generally come with a range of integrated sensors, and with the use of apps can collect and relay data over the mobile phone network to collection points. Smartphones can also help overcome language problems through the use of pictograms and pretranslated text templates. Smartphones can provide a direct channel to end users for both data collection and communication. However, while their availability is rapidly accelerating, they are still by no means available to or suitable for everyone.
- As an alternative to smartphones and apps, ultra-low-cost programmable micro-controllers (essentially the kind of computer that operates a hotel door lock) are now available off the shelf for commercial and hobbyist development, starting from around US$15 (e.g. www.arduino.cc). A surprisingly wide range of compatible environmental sensors is available to allow them to log everything from meteorological parameters to gas concentrations and radiation levels (e.g. www.adafruit.com/category/35). Similarly, the Hydro and Agro Informatics Institute (Thailand) has been developing “field servers” for agricultural applications, which are tiny computers that can be connected to sensors and placed in the field in weatherproof boxes for long periods of time, drawing on solar power and relaying data back via the mobile phone network. This enables data from a distributed network of stations to be gathered and processed automatically in real time with minimal human intervention. Similar devices are being used in small-scale fisheries management for vessel tracking and monitoring environmental parameters.
- At the other end of the technological spectrum, simple devices such as rain gauges may be sufficient for some locations and some stakeholder groups.
- Data gathered from end users need to be subjected to quality control or oversight. One way to minimize the work involved is to subject data to range checks to test that the data conforms to reasonable values. Outlying records can be flagged for manual examination or discarded as spurious depending on the value.
- There was a need to follow standards when collecting and sharing data in order to facilitate sharing and interoperability, including with computer systems. There

were likely to be significant differences between fisheries and aquaculture in terms of what kinds of data were required to meet the needs of fishers and farmers.

- Early warning systems needed to be robust, reliable, timely and operate automatically, where appropriate, in order to avoid unnecessary delays caused by waiting for human intervention. The type of warnings an early warning system should provide needed to be carefully considered, in addition to the time frame that the warnings needed to be communicated within.
- SMS messages are still a useful way to communicate with end users, although sudden public emergencies could overload mobile phone networks, so that the length of the warning period is important. Commercial bulk SMS delivery services are available, which are capable of delivering massive batches locally and globally (e.g. clickatell.com). However, participants had observed even these services to have occasional outages and downtime for maintenance. Warning systems needed to have multiple levels of redundancy to ensure 100 percent uptime.
- The Red Cross uses smartphone applications to help households in many areas communicate their needs.
- It is important to position the system as a knowledge bank or broker. Social media is another channel that could help connect to people and could be helpful in building an online community of end users.
- There is a need to "brand" the environmental monitoring system and for all stakeholders to contribute to raising awareness of it. One way to do this would be for all participants in the consultation to prepare a small post or article for their own Facebook page to link their own networks into the endeavour. Other services such as LINE were popular in some countries. As it is generally popular with younger people or children, simple devices such as rain gauges are suitable for use by local communities.
- Real-time systems are in place for flood monitoring in Thailand and Viet Nam, but it is not clear if adequate communication mechanisms are in place to communicate with fishers and farmers. Warnings may be sent to different levels of government (provincial, district, etc.), but there is still a communication gap between fishers and farmers (many of whom are small scale and in remote locations) and the government. In Cambodia, although flood forecasting and warning services are available, there is no means of mitigation.
- MRC advised that water level information was available on the MRC Web site, although not all riparian countries were currently sharing their full data sets. It would be useful, for example, to have dry season water-level information from China, as this was of use to downstream countries.
- A number of agencies publish current environmental information on their Web sites. However, online data sets are often limited to recent records rather than the full data set, which have to be manually requested from the agency that owns it. There is a need to: (i) encourage agencies to publish their full data sets; (ii) transform the data into a machine readable format where the data could be automatically harvested, so that machines could retrieve and combine the data for analysis with other data sets; and (iii) standardize the format of the data for easy analysis.

6. ROUND-TABLE DISCUSSION OF THE MAIN FINDINGS

Dr Doris Soto summarized the main points of the discussion and issues that had been raised during the meeting:

- Early warning could mean different things, ranging from large-scale life or property threatening events such as floods and storms to issues that may impact fisheries, crops and livelihoods seasonally or over the long term.
- The way forward for implementation of an environmental monitoring system for

the Lower Mekong Basin would be a pilot project involving Cambodia, Thailand and Viet Nam. The project would develop a data analysis and interpretation platform to collect and share relevant environmental data. The project would also need a regional component to address issues of transboundary significance, such as water use, funding and synergy between countries, disseminating information and upscaling the project to the regional level.

- A basin-wide environmental monitoring system would require collaboration between local and national institutions, with national coordination being undertaken by a lead agency. There would also be a need for collaboration between countries in information collection and sharing. There was also clearly a need to involve farmers and fishers.
- While the consultation has generated some ideas about specific recommendations to increase the resilience of farmers, it would be important to understand the linkages between environmental events and impacts.
- It is uncertain at this stage as to what level of information on climate change would be perceived as useful by farmers and fishers. There is a need for consultations with these stakeholders. The pilot project would select focal areas or "hotspots" as a first step to assess the needs of local people in particular areas and to conduct a cost-benefit analysis to understand the economic value of the monitoring system.
- Fishers and farmers may not know all the information resources that were available to them, in part because of language, literacy and information access barriers. Communication with these stakeholder groups needs to be an integral part of the design of an environmental monitoring system.
- People involved in data collection would need training to ensure that they generate high-quality data. Fish farmers were likely more familiar with environmental monitoring than their fisher counterparts due to increasing regulatory requirements in aquaculture.
- A communication strategy should be part of the project design in order to reach out to stakeholders and share the output of the system. Smartphones are a potentially useful tool for both information collection and dissemination at the individual farmer/fisher level, but obviously not for everyone. Traditional means and channels of communication remain relevant and useful.
- There would be a need to demonstrate the system's benefit to farmers and fishers to help secure long-term funding for the system. The environmental monitoring system would therefore need to be evaluated after several years against predefined indicators and targets.

The main points in the discussion of the presentation were as follows:

- The proposed environmental monitoring system also had significant potential ecosystem benefits and applications that could improve environmental performance.
- Analysing centrally data gathered from across multiple jurisdictions could be complicated, since the organizations collecting the data should also have a role in their analysis and interpretation.
- There may be need to have a number of sub-projects within the pilot; for example, exploring communications options in one area, or institutions to assess the best mechanisms for transferring or sharing data in another.
- Lack of coordination between organizations currently collecting environmental data is a key issue, as is providing feedback to farmers and fishers from these agencies.
- The proposed system may be thought of as an environmental monitoring system with an early warning component. It may be useful to collect more biological information, particularly on the fisheries side such as shifts in catches and species

compositions (including presence and absence), market surveys and consumption studies. Fish migration and recruitment could be key variables to monitor, for example, the condition of stocks in deep water pools. The project will need to assess what information is already being collected by various agencies, negotiate access and identify gaps.

- The pilot should be very focused on the parameters that are collected, focusing on the key variables of relevance to farmers and fishers, and considering the practical measures that could be taken to mitigate impacts. As farmers and fishers were not involved in the workshop, this group must be incorporated into the pilot project. An early warning system in particular needs to work within the local context.
- Sustaining the monitoring system over the long term would be challenging, but is necessary due to the nature of the issue and to effectively contribute to reduce vulnerability and increase adaptation.
- Although much information is currently being gathered and produced, there are persistent issues that include not reaching the right people, even technical experts, due to gaps in communications and a lack of coordination between agencies. There was a need for a tripartite approach to data collection and dissemination involving scientists, governments and communities.
- The recent trend for gathering and analysing "big data" and "linked open data" demonstrates the usefulness of making full data sets available online and openly for others to use and interpret in novel ways. Agencies collecting environmental data should endeavour to publish the data online. It would be ideal to make the data machine readable to allow automatic harvesting and interpretation with algorithms.
- The behaviour of young fishers is very different to that of older generations in the way they interact with monitoring programmes and information. They may be more willing to monitor and report bioindicators such as fish kills and algal blooms.
- It was noted that a workshop on climate change adaptation options and actions will be held in 2016 by FAO (date and venue to be confirmed). A discussion on early warning systems could be included.
- The quality of the data collected was seen as a key concern, as was the interpretation and outreach back to the farmers and fishers; it is a two-way, preferably interactive, process. The local, national and regional context and aspects of the project would need careful consideration.

7. CONCLUSION, WAYS FORWARD AND CLOSING

The Chair noted that participants had reached consensus on some complex issues relating to both information and institutional arrangements. He congratulated the participants for making the meeting a success and looked forward to working collaboratively to progress the issue. He thanked FAO and sponsors for making the workshop possible, and to the national and institutional representatives for contributing their valuable time, expertise and perspectives to the proceedings. He said the report of the meeting will contain the proceedings, the baseline assessment reports, and the recommendations of the workshop. A second output would be a concept note or project proposal to develop a pilot environmental monitoring system with a view to a long-term implementation period (i.e. ten years at least) and evaluation process.

ANNEX 1

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ANNEX 2

Agenda

WEDNESDAY, 25 MARCH 2015

08.30–09.00	**Registration**
09.00–09.20	**I. Opening Session:**
	Welcome address by Dr Cherdsak Virapat, Director-General, Network of Aquaculture Centres in Asia-Pacific (NACA)
	Opening address by Mr Adnan Quereshi, Chief Administrative Officer, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand
	Opening address by Dr Waraporn Prompoj, Deputy Director-General of Thailand's Department of Fisheries
09.20–09.45	Introduction to participants
09.45–10.15	Group photo and coffee break
10.15–10.20	Introduction to the workshop by Dr Cherdsak Virapat, NACA
10.20–10.45	Dr Doris Soto, FAO
	The relevance of environmental monitoring systems to increase resiliency in fisheries and aquaculture; addressing the major climate change threats in the Mekong Delta
10.45–11.15	**II. Baseline Assessment and Presentations Session:**
	Baseline Assessments of Existing Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture in the Lower Mekong basin
11.15–11.30	Dr Elisabeth Conrad and Prof. Louis F. Cassar, Institute of Earth Systems, University of Malta
11.30–12.15	Presentation on Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture in Cambodia
12.15–12.30	Discussion
12.30–14.00	Lunch
14.00–15.00	Presentation on Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture in Thailand
15.00–15.30	Coffee break
15.30–16.15	Presentation on Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture in Viet Nam
16.15–16.30	Discussion
16.30–16.45	Presentation by China
16.45–17.00	Presentation by Mekong River Commission
17.00–17.15	Presentation by Dr David Lymer, FIRF FAO
17.15–17.30	Presentation by Mr Miao Weimin, FAO RAP
18.00–20.00	Reception

THURSDAY, 26 MARCH 2015

09.00–10.00	Synthesis of the Assessment of Current Monitoring Systems Relevant to Fisheries and Aquaculture and Gap Analysis in the Lower Mekong basin
	Dr Elisabeth Conrad, Institute of Earth Systems, University of Malta
	Prof. Louis F. Cassar, Institute of Earth Systems, University of Malta
	Dr Werner Ekau, Centre for Tropical Marine Ecology, Germany
	Associate Prof. Tavida Kamolvej, Associate Dean for Academic Affairs, School of Political Science, Thammasat University, Thailand
	Associate Prof. Wong Poh Poh, School of Social Sciences, University of Adelaide, Australia
	Prof. Anthony Stephen Micallef, Euro-Mediterranean Centre on Insular Coastal Dynamics, University of Malta
	Mr Theerawat Samphawamana, Programme Officer, Mekong River Commission
	Dr Rawee Viriyatum, WWF Greater Mekong
10.00–10.30	Discussion
10.30–11.00	Coffee Break
11.00–12.30	**III. Working Group Session:**
	Working Group Discussion on gaps and the pathway/policy guidance/ recommendations to a common/shared monitoring system and information base that allow aquaculture farmers and fishers to be better prepared and prevent main losses to the sector
	Working Group I: Aquaculture
	Working Group II: Fisheries
12.30–13.30	Lunch
13.30–15.30	Working Group Discussion (continued)
15.00–15.30	Coffee break
15.30–17.30	Working Group Discussion (continued)
18.00–20.00	Dinner

FRIDAY, 27 MARCH 2015

09.00–09.30	Working Group Presentations
	Working Group I: Aquaculture
09.30–09.45	Discussion
09.45–10.15	Working Group II: Fisheries
10.15–10.30	Discussion
10.30–11.00	Coffee break
11.00–12.00	General discussion
12.00–13.30	Lunch
13.30–15.00	**IV. Round Table Discussion of the Main Findings**
15.00–15.30	Coffee break
15.30–16.00	**V. Conclusion, Ways Forward and Closing**
	By Dr Doris Soto, FAO, and Dr Cherdsak Virapat, NACA

PAPER 1

The Regional Assessment Report

Baseline Assessment of Existing Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture in the Mekong Delta

REPORT
February 2015

Dr Elisabeth Conrad and Prof. Louis F. Cassar
(Independent Consultants)

Professional affiliation:
Institute of Earth Systems, University of Malta

on behalf of

the Network of Aquaculture Centres in Asia-Pacific (NACA)

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Executive summary

Aquatic organisms are intimately connected to and affected by environmental conditions in their surroundings; such conditions are determined by parameters including temperature, salinity, oxygen, acidity, alkalinity, productivity, water circulation and general water quality. Environmental monitoring systems provide information about changes in such parameters to fishers and fish farmers, and therefore play a critically important role in ensuring sustainable harvesting and production of fish.

This report summarizes the results of a survey examining the current state of environmental monitoring systems in the Lower Mekong Basin (with a focus on Thailand, Cambodia and Viet Nam) and the potential for future development of such systems. The survey considered two-way information flows: (i) communication of information about changes in environmental parameters from authorities to fishers and fish farmers; and (ii) communication of baseline information from fishers and fish farmers to authorities, for this to then be incorporated into monitoring systems. The survey was answered by 240 respondents from private, public, non-governmental, academic and intergovernmental sectors.

There appears to be some, albeit limited, awareness of existing national and regional environmental monitoring systems that provide information to fishers and fish farmers. However, there are evident differences between the three countries of the lower delta. A number of challenges to effective pan-regional collaboration in the implementation of such systems were identified by respondents, including differences in coordination and communication mechanisms, inadequacies in legal and policy frameworks, and the lack of involvement of upstream countries in such collaborations within the lower Mekong. Respondents also provided feedback on the perceived utility of a range of different monitoring parameters, further indicating the frequency with which these should be monitored, and suitable media for communicating this information (notably radio, television, telephone and through extension officers).

There was some awareness of mechanisms for fishers and fish farmers to provide baseline environmental information to authorities, albeit limited. While feedback was provided concerning the utility of monitoring of a range of environmental parameters, several practical difficulties to such reporting of information by fishers and fish farmers were noted; these included limited access to the Internet/mass media, time and resource constraints, unwillingness to provide such information to authorities (for a variety of reasons), fear or mistrust of authorities, and poor awareness of the value of environmental monitoring. Respondents further identified related capacity-building needs.

These results thus indicate that, while there is some awareness of and appreciation for the important role of environmental monitoring systems, there are key challenges that need to be overcome for effective implementation, both at the grassroots level (among fishing and fish farming communities) and at the broader regional level (across the various countries of the Lower Mekong Basin).

1. INTRODUCTION

1.1 Background to the assessment

Aquatic organisms are intimately connected to and affected by environmental conditions in their surroundings; such conditions are determined by parameters including temperature, salinity, oxygen, acidity, alkalinity, productivity, water circulation and general water quality. There are many examples of these effects. Shifts in temperature may increase the risk of disease or even trigger disease outbreaks in farmed animals. Sudden water movements or overturns may bring anoxic water to the surface or trigger toxic algal blooms. Changes in monsoonal patterns can generate different freshwater runoff and discharge patterns, impacting on fish production. Changes in a variety of environmental variables can thus adversely affect farmed fish and drive away wild stocks that would normally be captured by coastal fishers. While wild fish may be able to escape adverse environmental conditions by migrating to other locations, farmed organisms frequently cannot do so.

In more developed countries, aquaculture operations normally have to comply with regulatory requirements for environmental monitoring in order to assess and manage impacts of aquaculture on the environment. However, such environmental monitoring systems rarely take into account the converse scenario of the potential impacts of adverse environmental conditions and natural disasters on aquaculture; notable exceptions are systems that monitor potential red tides or other environmental conditions that can affect production of filter feeders (notably shellfish)[1] and fish in cages (including some examples in the case of salmon) (De Silva and Soto, 2009). Aquatic monitoring systems of this sort are even rarer in the case of fisheries, especially inland fisheries. Thus, although fisheries and aquaculture are sensitive to climatic variability (including to long-term changes), there are very few cases of integrated monitoring systems that provide such information and interpret it in a form that is useful to fishers and farmers for making decisions. Even though information on meteorological conditions may reach fishers and farmers, and they may have some experience interpreting this information in terms of potential consequences for their livelihoods, simple information concerning environmental variables collected on an ongoing basis could serve as a very useful decision-making tool, given the need for fisheries and fish farming operations to be prepared to deal with such environmental variation.

In general, environmental monitoring systems should follow a risk-based approach that recognizes that increased risk requires increased monitoring efforts. The Food and Agriculture Organization of the United Nations (FAO) is promoting, at pilot level, the development and implementation of environmental monitoring (of parameters relating to aquatic environments, meteorology, target species and farming systems) and early warning systems to improve fishers' and farmers' preparedness and resilience to climatic variability and climate change that also involve local communities (fishers and fish farmers).

1.2 Assessment scope

The Lower Mekong Basin (LMB) (Figure 1), which broadly incorporates regions of the Lao People's Democratic Republic, Thailand, Cambodia and Viet Nam, supports large fisheries and aquaculture industries that are important from both food security and livelihood perspectives. Over 60 million people (12 million households) live in the Lower Mekong Basin, of whom over 80 percent rely directly on the river system for their food and livelihoods (Baran and Myschowoda, 2009; ICEM, 2010). Fish is the main source of dietary protein (MRC, 2005), and most of these households would thus be affected by any change in fish availability (Orr *et al.*, 2012). However, fish production from this area is under increasing threat from a variety of sources, including both environmental factors (that also incorporate climate variability and change), as well as developments for hydropower and/or damming to address climate change threats.

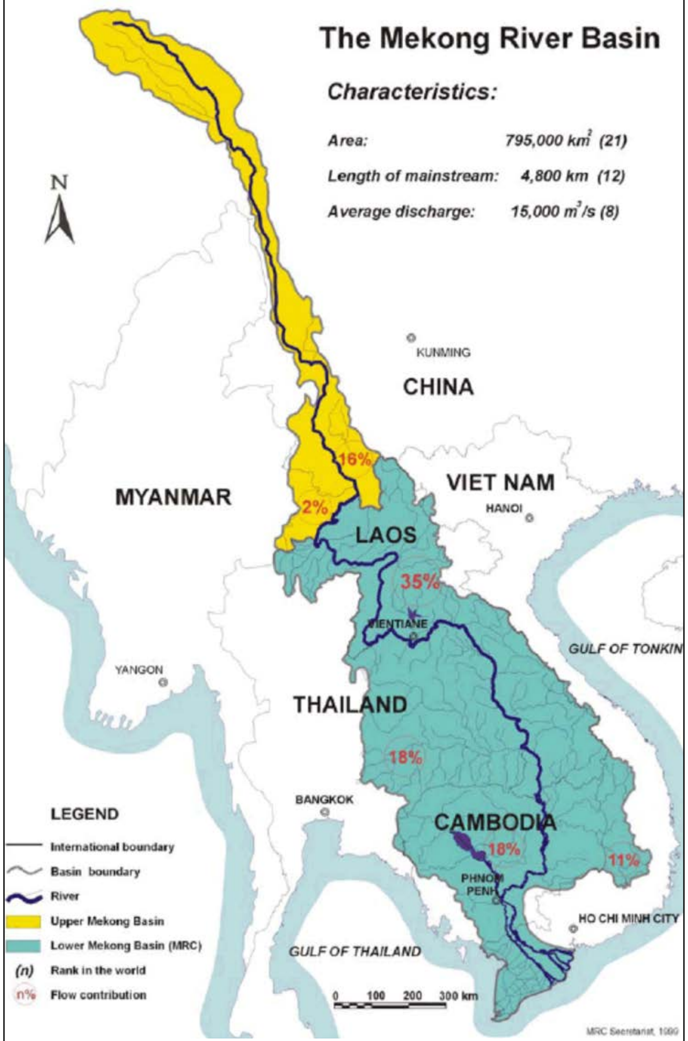
Taking the above into account, this baseline assessment constitutes the first element of a three-pronged initiative to improve risk preparedness in this region, as follows:

[1] See the harmful algal bloom monitoring programme in Southern California (www.sccoos.org/data/habs/about.php), the Gulf of Mexico (http://habsos.noaa.gov), and southern Chile (www.ifop.cl/mr/index.php).

(i) Assessment of the current situation of climate-related environmental monitoring and warning systems for fisheries and aquaculture in the Mekong Delta.
(ii) Implementation and testing of a platform for open access to environmental information and an early warning system that is accessible by local stakeholders. This platform will integrate data from many existing sources.
(iii) Implementation of a training programme for fishers, farmers and managers. Such training will include awareness-raising of the advantages of environmental monitoring systems, providing a mechanism for stakeholders to share local knowledge with the system, and providing an understanding of climatic variability and climate change.

This assessment focuses on identifying the current state of monitoring systems in three LMB countries: Thailand, Cambodia and Viet Nam.

FIGURE 1
The Mekong River (countries of the Lower Mekong Basin shown in blue)



Source: Mekong River Commission Secretary (1999).

2. METHODOLOGY

2.1 Introduction

This baseline assessment was conducted through a questionnaire survey, and intended to determine:

- whether there are any existing environmental monitoring and warning systems currently available across the region and within individual countries of the LMB;
- any parameters currently being monitored within such existing systems relevant to fisheries and aquaculture;
- parameters that should be included within future monitoring systems;
- the regularity with which different parameters should be monitored;
- suitable media for communicating environmental monitoring information;
- constraints that may limit the successful implementation of environmental monitoring systems;
- key needs for successful implementation of environmental monitoring systems; and
- similarities and/or differences in the above across the three target countries of the LMB.

The survey considered information flows in two directions: from national/regional authorities to fishers and farmers, and vice versa. National/regional authorities are generally responsible for providing information in a consolidated and easily interpretable form to those working in fisheries and aquaculture. Conversely, given their close contact with environmental systems on a daily basis, fishers and farmers may be best placed to provide direct data concerning observed environmental changes, which can in turn feed into wider-scale monitoring systems. The target audience for this survey thus included respondents from a range of sectors, including those working directly as fishers or fish farmers, or in other related capacities within the private sector, government officials and officials from intergovernmental departments, members of nongovernmental organizations (NGOs), and academics with expertise relating to fisheries and fish farming.

2.2 Survey overview

Based on the objectives outlined in Section 2.1, the survey was subdivided into the following four main sections – (a full copy of the questionnaire survey is provided in Annex 1):

Demographics

- Respondent information
  - Country
  - Sector of operation

Provision of information from national environmental monitoring systems to fisheries and aquaculture operations

- knowledge of any existing national environmental monitoring systems providing information to fisheries and aquaculture operations;
- knowledge of any existing regional (Lower Mekong Basin) environmental monitoring systems providing information to fisheries and aquaculture operations (including any that are based on panregional collaboration);
- perceived utility of monitoring specified environmental parameters and related monitoring time frames;
- perceived utility of different communication media;
- perceived constraints and challenges; and
- knowledge of any negative impacts arising from changes in environmental conditions.

Provision of information from fisheries and aquaculture operations to national environmental monitoring systems

- knowledge of any existing systems for fishers and farmers to feed information into national environmental monitoring systems;
- knowledge of any existing systems for fishers and farmers to feed information into regional (LMB) environmental monitoring systems;
- perceived utility of providing feedback on specified environmental parameters and related monitoring time frames;
- data collection methods and techniques;
- perceived utility of different communication media; and
- perceived constraints and challenges.

Miscellaneous

- Capacity-building needs and recommendations.

2.3 Survey dissemination and collection of responses

The report was made available as an online survey using Qualtrics software. The link to the survey was disseminated to relevant agencies and individuals from within three of the LMB countries (Cambodia, Thailand and Viet Nam), with respondents identified by the Network of Aquaculture Centres in Asia-Pacific (NACA); the survey was then further disseminated by identified respondents (i.e. snowball sampling). The survey was made available over a three-month period (mid-November 2014 to mid-February 2015). The response dropout rate over this period was 7 percent.

While the sampling methodology does not allow for a representative sample of fishers and farmers from across the LMB to be obtained, it nevertheless provides a useful snapshot of views and concerns. It must be borne in mind that there are several (likely prohibitive) constraints to obtaining a representative and statistically significant sample of fishers and farmers from across the LMB; these constraints include the large size of the geographical area in question, the large population of fishers and farmers, access difficulties and literacy limitations, all of which would result in significantly high costs for obtaining a representative sample. For purposes of this assessment, a representative sample was not considered necessary, as responses provided by a smaller group of respondents can nevertheless provide very useful input for the development of environmental monitoring systems in the region.

2.4 Survey analysis

Survey responses were analysed using analytical tools provided by both Qualtrics software and by the Statistical Package for the Social Sciences (IBM SPSS Statistics 22). Where possible, data were analysed quantitatively through frequency counts and related parameters (including mean and median values); answers to open-ended questions were analysed through thematic coding.

2.5 Limitations

It should be noted that the data gathered through this survey are subject to a number of limitations, including the following:

- It is likely that the survey disproportionately represents the views of literate members of fishing and fish farming communities and of those with Internet literacy/access; this conversely means that the views of fishers and fish farming communities with lower literacy levels or that are more remote may be underrepresented.
- The administration of this survey in the English language may mean that questions may not have been fully understood by respondents not fluent in English; in fact, a small number of responses to open-ended questions were unclear and/or did not seem to correspond to the question set. These are not considered in the results sections below.

3. RESULTS

3.1 Overview of responses obtained

3.1.1 Country of origin/operation

A total of 265 responses to the questionnaire survey were obtained over the sampling period; of these, 26 did not report the country, 15 were partial responses in other ways and 225. The majority of respondents (54 percent) were involved in fisheries and aquaculture operations in Thailand, with smaller proportions originating from or working in Cambodia (26 percent) and Viet Nam (24 percent), and to a lesser extent, the Lao People's Democratic Republic (14 percent) – totals exceed 100 percent due to the fact that a number of respondents worked within more than one country (Table 1). It should be noted that, unlike in the case of the other three countries, there were no attempts to specifically seek out respondents from the Lao People's Democratic Republic – all but three respondents who indicated that they work there therefore also operated in one of the other countries of the LMB. A detailed breakdown of the country of origin/operation of respondents is given in Table 1.

In addition, 26 respondents did not specify a country, and 4 respondents noted that they work in a total of three countries. Although these are not included in the totals in the table, the details are:

- 2 respondents: Thailand, Cambodia and Viet Nam
- 1 respondent: Thailand, Viet Nam and the Lao People's Democratic Republic
- 1 respondent: Thailand, Cambodia and the Lao People's Democratic Republic

TABLE 1
Breakdown of respondents by country of origin/operation. The matrix below shows respondents who operate within a single country (values shown in bold), as well as those indicating that they work within two countries (values shown in italics)

	Thailand	Cambodia	Viet Nam	Lao PDR	Total
Thailand	**82**	*3*	*1*	*25*	**111**
Cambodia	*3*	**49**	-	-	**52**
Viet Nam	*1*	-	**47**	-	**48**
Lao People's Democratic Republic	*25*	-	-	**3**	**28**
Total	**111**	**52**	**48**	**28**	**239**

3.1.2 Sector of operation

The majority of respondents (63 percent) were from the private sector, working in fisheries and aquaculture operations; 27 percent of respondents were from government departments, 8 percent from academia, 4 percent from non-governmental organizations, and 1 percent from intergovernmental organizations. These proportions varied somewhat at the level of individual countries, as shown in Table 2. A number of respondents did not specify their sector of work.

TABLE 2
Breakdown of respondents by sector* and country of origin

	Academia	Private sector	Government	NGOs	Inter-governmental departments	Total
Thailand	7	44	26	5	0	82
Cambodia	2	33	18	4	1	58
Viet Nam	3	30	14	0	0	47
Lao People's Democratic Republic	0	1	1	0	1	3
Multiple countries	5	26	6	0	0	37
Total	17	133	65	9	3	227

* Respondents indicating that they work within more than one sector are counted within each relevant category in the table (i.e. multiple counting).

Only two academic respondents specified that they work in aquaculture, with none of the other nine respondents providing details of their academic discipline; however, since this survey was disseminated to those working in the fields of aquaculture and fisheries, it is assumed that all academics would have related areas of expertise. Private-sector respondents included both fishers and fish farmers, as well as respondents who did not specify which category they fall into. Indicatively, there were approximately 79 respondents who specified that they are fishers and 38 respondents who indicated that they are fish farmers. One other respondent identified himself/herself as a food entrepreneur. Respondents from government departments specified that they work in a variety of sectors, including fisheries, aquaculture, education, community development, and agricultural and rural development; there were also respondents representing municipality or provincial departments as well as village leaders. Non-governmental respondents included representatives of educational, community development and wildlife conservation organizations. No further details were provided by any of the respondents who indicated that they work for inter-agency organizations.

3.2 Current state of environmental monitoring systems communicating information from authorities to fishers and fish farmers

3.2.1 Knowledge of any existing national environmental monitoring systems

Of the 214 respondents who answered the question asking whether they are aware of any national environmental monitoring systems that communicate information to fishers and fish farmers, 50 percent answered yes, 31 percent answered no, and 20 percent of respondents were unsure. The majority of those who responded "yes" (63 percent) were from Thailand; 49 percent of Viet Nam respondents and 25 percent of Cambodian respondents knew of existing environmental monitoring systems within their countries (Table 3). Conversely, and as could be expected given these results, the majority of respondents having no knowledge of such systems were from Cambodia (56 percent).

TABLE 3

Knowledge of any currently existing national environmental monitoring systems among respondents. "Yes" indicates that respondents are aware of at least one such system, while "no" indicates that respondents do not know of the existence of any such systems. Percentages show the proportion of respondents within each category for each country

	Yes	No	Unsure
	% of respondents		
Thailand (n=115)	62.6	20.9	16.5
Cambodia (n=55)	25.5	56.4	18.2
Viet Nam (n=51)	49.0	25.5	25.5

3.2.2 Parameters included within existing national environmental monitoring systems

Respondents who were aware of existing national environmental monitoring systems (i.e. those who answered yes in Table 3) were asked to indicate which parameters are being monitored within these systems; results are shown in Table 4. In general, the most commonly monitored parameters were water temperature, oxygen levels, salinity and pH. Least commonly measured parameters were tides and currents.

However, there were significant differences between the various countries, as can be noted from the table. Most commonly measured parameters in Thailand (cited by 83.3 percent of respondents aware of monitoring systems in the country) were water temperature and oxygen levels; close to this range, pH, harmful algal blooms (HABs) and extraordinary climatic events were referred to by 80.56 percent of respondents, while over 80 percent of respondents also referred to monitoring of water colour, currents and tides. In Cambodia, the most commonly measured parameter was water temperature, but this was highlighted by just 50 percent of the 14 respondents aware of monitoring systems in the country. All other parameters were cited by less than half of respondents from Cambodia. Meantime, the vast majority of respondents for Viet Nam (96 percent) highlighted water temperature, salinity and oxygen level monitoring. Least commonly noted parameters were tides and currents (cited by 28 percent and 36 percent of respondents, respectively). However, it should be noted that, since this analysis is limited to those respondents aware of existing monitoring systems, sample sizes for Cambodia and Viet Nam are somewhat small; results for these countries should therefore be interpreted with due caution.

Several "other" parameters were noted by respondents; common to all three countries was turbidity. Respondents from Thailand also referred to monitoring of water transparency and sedimentation and monitoring of fish diseases. Meanwhile, respondents from Viet Nam highlighted a range of additional parameters, including chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), nitrite (NO_2^-), nitrate (NO_3^-). ammonia (NH_3), phosphate (PO_4), and heavy metals content.

TABLE 4
Parameters currently being monitored within existing national environmental monitoring systems. Values are percentages of those respondents knowing of existing environmental monitoring systems having highlighted each parameter

	Thailand (n=72)	Cambodia (n=14)	Viet Nam (n=25)
	% of respondents		
Water temperature	83.3	50.0	96
Salinity	79.2	35.7	96
Harmful algal blooms	81.9	35.7	76
Water colour	80.6	35.7	60
Currents	80.6	42.9	36
Tides	80.6	35.7	28
Oxygen levels	83.3	42.9	96
Extraordinary climatic events	81.9	42.9	44
pH	81.9	42.9	88
Water level	86.1	42.9	48
Other parameters	58.3	35.7	40

3.2.3 *Knowledge of any existing regional environmental monitoring systems*

In addition to being asked whether they are aware of any monitoring systems within their country, respondents were also asked whether they are aware of any monitoring systems that cover the wider region of the LMB. Of the 219 respondents who answered the question, 32 percent answered yes, 48 percent answered no, and 45 percent of respondents were unsure. While there were some differences across the three different countries (Table 5), it is of note that "no" answers outnumbered answers in the affirmative in all cases, with this being most marked in the case of Cambodia.

TABLE 5
Knowledge of any currently existing regional (LMB) environmental monitoring systems among respondents. "Yes" indicates that respondents are aware of at least one such system, while "no" indicates that respondents do not know of the existence of any such systems. Percentages show the proportion of respondents within each category for each country

	Yes	No	Unsure
	% of respondents		
Thailand (n=115)	36.5	42.6	20.9
Cambodia (n=53)	18.9	66.0	15.1
Viet Nam (n=51)	33.3	41.2	25.5

3.2.4 *Parameters included within existing regional environmental monitoring systems*

Respondents who were aware of existing regional (LMB) environmental monitoring systems (i.e. those who answered yes in Table 5) were further asked to indicate which parameters are being monitored within these existing systems; results are shown in Table 6. In general, the most commonly monitored parameters were water level and HABs, followed by water colour; water temperature, pH and oxygen levels were also commonly cited.

As in the case of national monitoring systems, there were a number of differences between respondents from different countries. Respondents from Thailand most commonly cited water temperature, oxygen levels and pH. As noted above, however, the percentage responses for respondents from Cambodia and Viet Nam should be interpreted with caution, given the small size of *n* in these cases; nevertheless, some differences are evident, as can be seen in Table 6.

Parameters other than those listed in Table 6 were also noted by respondents; these are similar to those noted for national environmental monitoring systems, commonly including turbidity, water transparency, sedimentation, COD, BOD, nitrite, nitrate and phosphate. Additional parameters referred to by respondents were ammonium (NH_4) and hydrogen sulphide (H_2S).

TABLE 6

Parameters currently being monitored within existing regional environmental monitoring systems. Values are percentages of respondents knowing of existing environmental monitoring systems having highlighted each parameter

	Thailand (n=42)	Cambodia (n=10)	Viet Nam (n=17)
	% of respondents		
Water temperature	81.0	30.0	94.1
Salinity	73.8	30.0	94.1
Harmful algal blooms	76.2	66.7	76.5
Water colour	78.6	66.7	65.7
Currents	76.2	66.7	35.3
Tides	76.2	30.0	58.8
Oxygen levels	81.0	30.0	94.1
Extraordinary climatic events	76.2	66.7	35.3
pH	81.0	30.0	94.1
Water level	83.3	66.7	70.6
Other parameters	54.8	100	41.2

3.2.5 Regional collaboration

Respondents were asked whether they are aware of any collaborations across countries of the LMB to provide information through an environmental monitoring system for fisheries and aquaculture. A total of 210 respondents answered the question; of these, just 20 percent were aware of regional collaboration. Answers in the negative outnumbered answers in the affirmative in the case of all three countries. Most commonly cited examples of such regional collaboration were the Mekong River Commission and the Greater Mekong Committee. Some respondents referred to national committees and agencies that could potentially participate in regional collaboration, but that are not examples of the latter *per se.* A total of 55 percent of respondents were not aware of any regional collaboration, while a further 25 percent were unsure. The breakdown of responses by country of respondents is given in Table 7.

TABLE 7

Knowledge of any region-wide collaborations for environmental monitoring in the LMB among respondents. "Yes" indicates that respondents are aware of at least one such collaboration, while "no" indicates that respondents do not know of the existence of any such collaborations. Percentages show the proportion of respondents within each category for each country

	Yes	No	Unsure
	% of respondents		
Thailand	32.2	48.7	19.1
Cambodia	15.4	55.8	28.8
Viet Nam	2.0	58.8	39.2

Respondents were further asked to identify any challenges to regional collaboration (Table 8). A total of 14 respondents said they could not identify any challenges, while a further 15 were not sure. Challenges identified by other respondents are shown in Table 8. As can be noted, these have been broadly classified into five categories based on thematic coding of open-ended responses: (i) differences between countries of the LMB; (ii) issues resulting from the activities of non-LMB countries (primarily China); (iii) resource and implementation challenges; (iv) communication issues; and (v) issues relating to the poor current state of the Mekong River. The issue most commonly cited by respondents was the influence of upstream activities on downstream LMB countries, with damming in China frequently cited as an example. Another frequently highlighted issue was lack of resources, with respondents referring to a variety of aspects including lack of financial resources, lack of personnel, lack of training of personnel and lack of technological capacities. Respondents also criticized the perceived lack of effective outreach from authorities/monitoring agencies to fishing and fish farming communities; on a larger scale, communication/coordination issues between LMB countries were seen to limit the potential for effective regional collaboration.

TABLE 8

Identified challenges/issues that currently limit collaboration across the LMB. An indication of the number of respondents making reference to each issue is also provided

Challenge/issue	Cited by (No. of respondents)
Differences between countries of the LMB	
Coordination and communication issues across countries	6
Inadequacies of legal/policy frameworks	5
The large geographical area of the LMB	4
Differences in legal systems across LMB countries	3
Political influences, including regional issues that are not directly related (e.g. immigration, narcotics)	3
Differences in natural and/or infrastructure conditions across countries	2
Lack of standards for fish culture	2
Differences in levels of education, social norms and cultures	1
Lack of uniformity in environmental monitoring systems	1
Issues resulting from the activities of non-LMB countries	
Activities in China (including dam construction) and/or other upstream countries	14
Lack of resources (including financial, human and technological)	7
China’s lack of involvement in the Mekong River Commission	2
Ineffective intra-agency cooperation	2
Lack of continuity in data collection	1
Lack of effective cooperation between authorities and fishers and fish farmers	1
Lack of interest in environmental monitoring among fishers and fish farmers	1
Low levels of education among fishers and fish farmers	1
Lack of sophisticated monitoring equipment	1
Resource and implementation challenges	
Communication issues	
Lack of effective outreach	7
Lack of provision of information by governments	3
Lack of systems for information exchange	3
Lack of provision of real-time information	2
Lack of direct involvement of affected organizations	1
Issues relating to the poor current state of the Mekong River	
Unsustainable activities on the river (e.g. mining, deforestation)	2
Poor water quality	2
Chemical contamination of river	1

3.3 Considerations for future monitoring systems

3.3.1 Perceived utility of different monitoring parameters

In order to identify which monitoring parameters are perceived to be most useful, respondents were asked to assess a list of given parameters using a five-point scale (ranging from a score of 1 for "very useful" to a score of 5 for "not useful at all"). Mean and median values for each parameter are shown in Table 9; as can be noted, all parameters were considered to be significantly important, with all mean values above the midpoint of this range, and with the lowest median score being 2 (i.e. "useful").

TABLE 9
Mean and median scores for the perceived utility of different monitoring parameters. Scores range from 1 (very useful) to 5 (not useful at all)

	Mean value	Median value
Water temperature	1.6	1
Salinity	2.1	2
Harmful algal blooms	2.3	2
Water colour	1.7	2
Currents	1.6	1
Tides	1.6	1
Oxygen levels	1.3	1
Extraordinary climatic events	1.6	1
pH	1.6	1
Water level	1.5	1

Detailed results for the three individual countries are given in Tables 10 to 12. Several differences can be noted. In the case of Thailand, the most useful monitoring parameter (based on the highest percentage of "very useful" responses) was considered to be oxygen levels; other parameters with high scores within this "very useful" category were water level (presumably because of the country's recent history of flooding incidents), tides, currents, extraordinary climatic events and water temperature. The parameters perceived to be least useful were salinity and HABs. In the case of Cambodia, the most useful parameters were perceived to be oxygen levels, pH and water temperature, while the least useful parameters were HABs and tides. In the case of Viet Nam, most useful monitoring parameters were perceived to be extraordinary climatic events and oxygen levels; however, the former was also considered to be of no use at all by 9 percent of respondents. As in the case of Thailand and Viet Nam, several respondents appeared to have doubts concerning the utility of monitoring HABs, with 13 percent of respondents considering this parameter to be "not very useful" or "not useful at all".

TABLE 10
Perceived utility of different monitoring parameters: Thailand

	Very useful	Useful	Neutral	Not very useful	Not useful at all	Mean	Median
	% of respondents						
Water temperature	60.9	30.9	7.3	0.9	0	1.5	1
Salinity	34.3	22.9	17.1	8.6	17.1	2.5	2
Harmful algal blooms	36.7	26.6	11.9	8.3	16.5	2.4	2
Water colour	48.6	38.5	11.9	0.9	0	1.7	2
Currents	63.2	29.2	6.6	0.9	0	1.5	1
Tides	65.1	28.3	3.8	1.9	0.9	1.5	1
Oxygen levels	74.8	18	6.3	0.9	0	1.3	1
Extraordinary climatic events	61.5	31.2	3.7	2.8	0.9	1.5	1
pH	52.3	32.1	10.1	3.7	1.8	1.7/2	2/1
Water level	65.7	28.7	4.6	0.9	0	1.7	1

TABLE 11
Perceived utility of different monitoring parameters: Cambodia

	Very useful	Useful	Neutral	Not very useful	Not useful at all	Mean	Median
	% of respondents						
Water temperature	79.6	12.2	6.1	2	0	1.3	1
Salinity	72.3	14.9	10.6	2.1	0	1.4	1
Harmful algal blooms	62.9	22.9	8.6	5.7	0	1.6	1
Water colour	72	16	12	0	0	1.4	1
Currents	74	16	8	2	0	1.4	1
Tides	69.2	12.8	12.8	2.6	2.6	1.6	1
Oxygen levels	85.7	8.2	4.1	2	0	1.2	1
Extraordinary climatic events	56.3	31.3	12.5	0	0	1.6	1
pH	80.4	13	6.5	0	0	1.3	1
Water level	72.5	22.5	5	0	0	1.3	1

TABLE 12
Perceived utility of different monitoring parameters: Viet Nam

	Very useful	Useful	Neutral	Not very useful	Not useful at all	Mean	Median
	% of respondents						
Water temperature	20	60	15.6	2.2	2.2	2.1	2
Salinity	26.7	44.4	24.4	4.4	0	2.1	2
Harmful algal blooms	23.7	39.5	23.7	7.9	5.3	2.3	2
Water colour	19	38.1	35.7	7.1	0	2.3	2
Currents	19.6	43.5	30.4	4.3	2.2	2.3	2
Tides	34.7	57.1	6.1	2	0	1.8	2
Oxygen levels	58.3	36.1	5.6	0	0	1.5	1
Extraordinary climatic events	64.4	17.8	6.7	2.2	8.9	1.7	1
pH	38.5	48.7	10.3	2.6	0	1.8	2
Water level	39.1	43.5	17.4	0	0	1.8	2

3.3.2 Perceptions regarding required frequency of monitoring

Respondents were asked to consider the frequency with which different parameters would ideally be monitored, choosing from three options: (i) in real time (score of 1); (ii) daily (score of 2); or (iii) weekly (score of 3). Mean and median responses are shown in Table 13. As can be noted, parameters with lowest scores (i.e. those which respondents would like monitored more frequently) are extraordinary climatic events, water level, pH, currents, water temperature and tides. The first two of these could both potentially rapidly contribute to disaster conditions, and the need for real-time data in this regard is therefore evident.

Detailed results for the three individual countries are given in Tables 14 to 16. In the case of Thailand, parameters that were most frequently considered to require real-time monitoring were extraordinary climatic events, currents and water level. Conversely, salinity and HABs were considered to require less frequent (weekly) monitoring. In the case of Cambodia, there were split views regarding HABs – 43 percent felt that this required real-time monitoring, but 39 percent felt that weekly monitoring would suffice. The unclear results in the case of this and other parameters may be due to the small sample size representing this country, and results should therefore be interpreted with caution. Results for Viet Nam were somewhat similar to those for Thailand, with extraordinary climatic events again seen to require real-time monitoring, and salinity and HABs seen to require less frequent monitoring.

TABLE 13

Mean and median scores for perceptions regarding the frequency with which different parameters should be monitored. Scores range from 1 (in real time) to 2 (daily) to 3 (weekly)

	Mean	Median
Water temperature	1.9	2
Salinity	2.3	2
Harmful algal blooms	2.0	2
Water colour	2.0	2
Currents	1.9	2
Tides	1.9	2
Oxygen levels	1.8	2
Extraordinary climatic events	1.7	1
pH	1.9	2
Water level	1.8	2

TABLE 14

Perceived required frequency of monitoring of different parameters: Thailand

	In real time	Daily	Weekly
	% of respondents		
Water temperature	44.1	26.1	29.7
Salinity	30.3	13.1	56.6
Harmful algal blooms	44.9	12.1	43.0
Water colour	44.4	21.3	34.3
Currents	47.3	29.1	23.6
Tides	43.9	30.8	25.2
Oxygen levels	42.7	34.5	22.7
Extraordinary climatic events	55.1	23.4	21.5
pH	38.5	30.3	31.2
Water level	49.5	30.3	20.2

TABLE 15

Perceived required frequency of monitoring of different parameters: Cambodia

	In real time	Daily	Weekly
	% of respondents		
Water temperature	27.5	52.5	20.0
Salinity	26.3	31.6	42.1
Harmful algal blooms	42.9	17.9	39.3
Water colour	25.6	33.3	41.0
Currents	37.5	30.0	32.5
Tides	24.1	48.3	27.6
Oxygen levels	27.8	58.3	13.9
Extraordinary climatic events	33.3	26.7	40.0
pH	25.7	57.1	17.1
Water level	39.5	28.9	31.6

Other parameters that respondents felt would be useful included a range of chemical and biological water quality parameters (levels of nitrite, ammonia, ammonium, organic matter, hydrogen sulphide, BOD, organic matter content, sedimentation); data relating to environmental events in the wider region (e.g. forest fires, the spread of disease and parasites, and discharges of wastewater from industry); and data relating to the operation of dams (and related water discharges) upstream. Several of

TABLE 16
Perceived required frequency of monitoring of different parameters: Viet Nam

	In real time	Daily	Weekly
	% of respondents		
Water temperature	8.9	73.3	17.8
Salinity	7.1	45.2	47.6
Harmful algal blooms	10.5	44.7	44.7
Water colour	2.4	70.7	26.8
Currents	4.3	57.4	38.3
Tides	6.1	63.3	30.6
Oxygen levels	29.7	54.1	16.2
Extraordinary climatic events	54.3	30.4	15.2
pH	12.5	65.0	22.5
Water level	10.6	66.0	23.4

the chemical and biological water quality parameters listed here were indicated to be already included in a number of national/regional environmental monitoring systems (see Section 3.2); however, it is not clear whether such monitoring occurs across all regions and LMB countries, and whether any monitoring and related communication of information is currently taking place with regard to environmental events and river operations upstream.

3.3.3 Communication media

Respondents were asked to evaluate different communication media in terms of their perceived utility for communicating information on environmental parameters to fishers and fish farmers. A 10-point scale was used, with a score of 1 indicating that the medium is not suitable for this purpose, and a score of 10 indicating very high suitability. Overall scores are given in Table 17, with scores for individual countries given in Table 18. Overall, radio and television were considered to be very suitable media, as was communication through extension officers. However, in all cases, use of email was considered to be a poor option, likely because of the lack of email access or Internet literacy among fishing and fish farming communities. Several respondents

TABLE 17
Perceived utility of different communication media on a scale of 1 to 10, where 1 indicates that the medium is not useful, and a score of 10 indicating very high suitability: mean and median scores

	Mean	Median
Radio	8.2	9
Television	8.4	9
Email	3.9	3
Extension officers	8.0	9

TABLE 18
erceived utility of different communication media on a scale of 1 to 10, where 1 indicates that the medium is not useful, and a score of 10 indicating very high suitability: mean scores for the three countries

	Thailand	Cambodia	Viet Nam
Radio	8.0	9.0	7.9
Television	8.5	8.8	7.9
Email	4.4	3.0	3.0
Extension officers	8.6	9.1	5.6

also indicated that telephones (particularly cell phones) would be ideal media for communication, notably as a channel for delivery of warning messages via short message service (SMS), in addition to email, or on smartphones or push alerts. Both domestic and international companies exist that provide Web interfaces for mass delivery of SMS that could conceivably support an early warning system.

3.4 Provision of information from fishers and fish farmers to authorities: current state of environmental monitoring systems

3.4.1 Knowledge of any existing national environmental monitoring systems

Respondents were asked whether fisheries and aquaculture operations in their country provided information to authorities to feed into a national environmental monitoring system (which would then in turn provide information to fishers and fish farmers). Of the 211 respondents who answered the question, 38 percent answered yes, 33 percent answered no, and 29 percent of respondents were unsure. The most responses in the affirmative came from respondents from Thailand (Table 19), with 52 percent of them answering "yes". Nevertheless, it should be noted that over 36 percent and 38 percent of respondents from Thailand and Cambodia, respectively, were not aware of any such provision of information. In the case of Viet Nam, most respondents (57 percent) were unsure.

TABLE 19
Knowledge of whether fisheries and aquaculture operations provide information to feed into national environmental monitoring systems. Percentages show the proportion of respondents within each category for each country

	Yes	No	Unsure	Total
	% of respondents			
Thailand (n=115)	52.2	35.7	12.2	100
Cambodia (n=53)	20.8	37.7	41.5	100
Viet Nam (n=51)	25.5	17.7	56.9	100

Respondents were also asked to indicate which parameters fishers and fish farmers currently provide information on; results are shown in Table 20. Overall, the most commonly highlighted parameter was disease (cited by 70 respondents), but there were no major differences between the number of citations of each parameter.

TABLE 20
Parameters on which fishers and fish farmers currently provide information. Values are percentages of respondents with knowledge of such information provision systems having highlighted each parameter

	Thailand (n=60)	Cambodia (n=11)	Viet Nam (n=13)
	% of respondents		
Catch composition	93.3	45.5	15.4
Condition of farmed species	88.3	45.5	76.9
Disease	95.0	45.5	92.3
Fish mortalities	92.0	45.5	46.1
Pests	90.0	45.5	84.6

3.4.2 Knowledge of any existing regional environmental monitoring systems

Respondents were asked whether fisheries and aquaculture operations in their country provided information to authorities to feed into a regional environmental monitoring system (which would then in turn provide information to fishers and fish farmers). Of the 210 respondents who answered the question, the majority (40.48 percent) answered in the negative, with 34 percent of respondents unsure, and with just 25 percent of answers in the affirmative. Negative responses outnumbered positive responses in the case of all countries (Table 21). In this case, however, it is possible that fishers and fish farmers provide information, but are not aware of how this is eventually used, and they rarely receive feedback in either national or regional systems.

TABLE 21
Knowledge of whether fisheries and aquaculture operations provide information to feed into regional environmental monitoring systems. Percentages show the proportion of respondents within each category for each country

	Yes	No	Unsure	Total
	% of respondents			
Thailand (n=114)	31.6	48.3	20.2	100
Cambodia (n=52)	17.3	36.5	46.2	100
Viet Nam (n=51)	19.6	27.5	52.9	100

Respondents were also asked to indicate which parameters fishers and fish farmers provide information on (for regional monitoring systems). Most commonly cited were the condition of farmed species and disease. Results for individual countries are shown in Table 22; however, given the small sample sizes (particularly in the case of Cambodia and Viet Nam), these results should be interpreted with caution.

TABLE 22
Parameters on which fishers and fish farmers currently provide information. Values are percentages of respondents with knowledge of such information provision systems having highlighted each parameter

	Thailand (n=36)	Cambodia (n=9)	Viet Nam (n=10)
	% of respondents		
Catch composition	97.2	44.4	20
Condition of farmed species	97.2	44.4	90
Disease	97.2	44.4	90
Fish mortalities	97.2	44.4	60
Pests	94.4	33.3	70

3.5 Considerations for future monitoring systems

3.5.1 Perceived utility of different monitoring parameters

In order to identify what information fishers and fish farmers could most usefully provide, respondents were asked to assess a list of given parameters using a five-point scale (ranging from a score of 1 for “very useful” to a score of 5 for “not useful at all”) in terms of their utility. Mean and median values for each parameter are shown in Table 23. As can be noted, the median value was 1 (corresponding to “very useful”), with similarly low mean values within the range of 1.43–1.7; this would appear to indicate that all parameters listed are considered to be very useful to useful.

Tables 24 to 26 provide a breakdown of responses by country of respondent. While the majority of respondents in all countries considered the parameters listed to be very useful or useful, some differences can nevertheless be noted. For example, disease was considered to be a very useful parameter by the greatest percentage of respondents from Thailand and was also considered to be the most useful parameter in the case of Viet Nam. In the case of Cambodia, however, percentage responses for fish mortalities and pests were slightly higher. These differences are minor, however, and caution should be exerted when interpreting results.

TABLE 23
Mean and median scores for the perceived utility of different monitoring parameters. Scores range from 1 (very useful) to 5 (not useful at all)

	Mean value	Median value
Catch composition	1.7	1
Condition of farmed species	1.7	1
Disease	1.4	1
Fish mortalities	1.5	1
Pests	1.6	1

TABLE 24
Perceived utility of different monitoring parameters: Thailand

	Very useful	Useful	Neutral	Not very useful	Not useful at all	Mean	Median
	% of respondents						
Catch composition	44.0	37.6	11.0	4.6	2.8	1.8	2
Condition of farmed species	41.9	48.6	4.8	0	4.8	1.8	2
Disease	72.1	18.9	8.1	0	0.9	1.4	1
Fish mortalities	61.3	26.1	8.1	2.7	1.8	1.6	1
Pests	68.5	20.7	6.3	2.7	1.8	1.5	1

TABLE 25
Perceived utility of different monitoring parameters: Cambodia

	Very useful	Useful	Neutral	Not very useful	Not useful at all	Mean	Median
	% of respondents						
Catch composition	74.5	23.4	2.1	0	0	1.3	1
Condition of farmed species	78.4	19.6	2.0	0	0	1.2	1
Disease	84.3	9.8	5.9	0	0	1.2	1
Fish mortalities	88.0	10.0	2.0	0	0	1.1	1
Pests	85.4	6.3	6.3	2.1	0	1.3	1

TABLE 26
Perceived utility of different monitoring parameters: Viet Nam

	Very useful	Useful	Neutral	Not very useful	Not useful at all	Mean	Median
	% of respondents						
Catch composition	34.3	40.0	20.0	5.7	0	2.0	2
Condition of farmed species	34.9	46.5	16.3	0	2.3	1.9	2
Disease	47.7	31.8	15.9	2.3	2.3	1.8	2
Fish mortalities	34.1	43.2	20.5	0	2.3	1.9	2
Pests	20.0	47.5	30.0	2.5	0	2.2	2

Other aspects that respondents felt would be usefully monitored by fishers and fish farmers included environmental impacts and seasonal observations; clear further details were, however, not provided. With reference to the former, it should be noted that, at several points, respondents remarked on poor environmental quality of the LMB and related concerns for the future of fisheries and fish farming.

3.5.2 Perceptions regarding frequency of monitoring

Respondents were asked to consider the frequency with which different parameters would ideally be monitored by fishers and fish farmers, choosing from five options: (i) in real time (score of 1); (ii) daily (score of 2); (iii) weekly (score of 3); (iv) monthly (score of 4); or less often than monthly (score of 5). Mean and median responses are shown in Table 27. As can be noted, the median score is 2 (representing daily monitoring), with mean scores ranging between 2.06–2.53, thus indicating that the mean preference of respondents is for daily to weekly monitoring of all listed parameters.

TABLE 27

Mean and median scores for perceptions regarding the frequency with which different parameters should be monitored. Scores range from 1 (in real time) to 5 (less often than monthly)

	Mean	Median
Catch composition	2.5	2
Condition of farmed species	2.5	2
Disease	2.1	2
Fish mortalities	2.3	2
Pests	2.3	2

Detailed results for the three individual countries are given in Tables 28 to 30. In the case of Thailand, the preference for all parameters was for real-time monitoring; however, 36.7 percent and 38.1 percent of respondents felt that catch composition and condition of farmed species, respectively, should only be monitored on a monthly or less frequent basis. In the case of Cambodia, the majority preference was for realtime monitoring of pests, daily monitoring of catch composition, disease and fish mortalities, and weekly monitoring of the condition of farmed species. In the case of Viet Nam, the majority preference was for all parameters to be monitored on a daily basis, with the exception of pests, for which the preferred option was weekly monitoring.

TABLE 28

Perceived required frequency of monitoring of different parameters: Thailand

	In real time	Daily	Weekly	Monthly	Less often than monthly
	% of respondents				
Catch composition	44.0	7.3	11.9	22.0	14.7
Condition of farmed species	34.3	11.4	16.2	26.7	11.4
Disease	49.1	12.5	17.0	17.9	3.6
Fish mortalities	39.3	19.6	15.2	19.6	6.3
Pests	43.2	13.5	17.1	18.9	7.2

TABLE 29

Perceived required frequency of monitoring of different parameters: Cambodia

	In real time	Daily	Weekly	Monthly	Less often than monthly
	% of respondents				
Catch composition	17.1	46.3	19.5	14.6	2.4
Condition of farmed species	11.4	36.4	38.6	13.6	0
Disease	21.7	47.8	23.9	6.5	0
Fish mortalities	22.7	40.9	31.8	4.5	0
Pests	37.2	23.3	34.9	2.3	2.3

TABLE 30
Perceived required frequency of monitoring of different parameters: Viet Nam

	In real time	Daily	Weekly	Monthly	Less often than monthly
	% of respondents				
Catch composition	17.1	45.7	5.7	25.7	5.7
Condition of farmed species	22.0	51.2	14.6	12.2	0
Disease	33.3	46.2	20.5	0	0
Fish mortalities	4.9	68.3	24.4	2.4	0
Pests	5.3	34.2	47.4	7.9	5.3

3.5.3 Monitoring methods

Respondents were asked to provide details concerning methods currently in use to collect data concerning parameters indicated in the above tables (i.e. catch composition, condition of farmed species, fish mortalities and pests). Results are shown in Table 31, with these based on thematic coding of open-ended responses. Several of the categories are not clearly distinct and there may therefore be overlap; however, no further refinement was possible based on the responses provided. As can be seen, a range of methods appears to be employed for such monitoring, but there is little standardization; some methods also raise concerns as to the validity and reliability of data being collected. A priority for future work in this area would thus need to be clear guidance for monitoring and provision of related infrastructure/equipment/training, as necessary.

TABLE 31
Methods cited as being currently in use for monitoring different parameters

Parameter	Cited by (No. of respondents)
Catch composition	
Using fish finders/locators or other navigation instruments	12
Taking daily notes/records	11
Based on cage, hook records	8
Catch monitoring, classification and counting	6
Based on experience	5
Through surveys and questionnaires	5
Through fish surveys	4
Do not know	3
Through household/fishers/farmer interviews	2
Based on records maintained by fisheries departments	1
Based on daily estimates	1
Through meetings	1
Condition of farmed species	
Observations of catch/samples	40
Through surveys	9
Based on farmer logbooks	3
Laboratory analysis	2
Checking feeding sites	2
Through household/fisher/farmer interviews	2
Checking water quality	1
Based on catch and weight when sold	1
Based on developed guidelines	1
Do not know	1

TABLE 31 (CONTINUED)

Parameter	Cited by (No. of respondents)
Fish mortalities	
Daily observation	33
Counting	3
Estimation based on samples	3
Through surveys	3
Through household/fisher/farmer interviews	3
Inspection at fishery departments	2
Do not know	2
Using stock assessment methods	1
Pests	
Observation and recording	49
Through surveys	5
Through household/fisher/farmer interviews	3
Through laboratory analysis	3
By checking water quality	1
By notifying officers	1
Through government inspections	1
Do not know	1

3.5.4 Communication media

Respondents were asked to evaluate the overall utility of three different communication media on a scale of 1 to 10, where 1 indicates that the medium is not suitable, while 10 indicates very high suitability. Results are shown in Tables 32 and 33. The most suitable means for farmers to communicate monitoring information was perceived to be through extension officers; this was the case both overall, as also for each of the three countries. The least suitable medium was considered to be email. As noted in section 3.5.5, this latter finding is related to poor Internet access/literacy among fishing and fish farming communities. Telephone was also noted to be a suitable means of communication by a number of respondents; however, it was also observed that some individuals may not have access to a telephone set.

TABLE 32
Perceived utility of different communication media on a scale of 1 to 10, where 1 indicates that the medium is not useful, and a score of 10 indicating very high suitability: mean and median scores

	Mean	Median
Paper reporting	6.8	7
Email	3.9	3
Extension officer	8.1	1

TABLE 33
Perceived utility of different communication media on a scale of 1 to 10, where 1 indicates that the medium is not useful, and a score of 10 indicating very high suitability: mean scores for the three countries

	Thailand	Cambodia	Viet Nam
Paper reporting	6.9	8.1	5.2
Email	4.3	3.9	3.3
Extension officer	8.5	9.3	6.1

3.5.5 Challenges

Respondents were asked to identify any challenges to the effective reporting of baseline environmental information by fishers and fish farmers. Several concerns were raised (Table 34). The aspects most frequently highlighted were: (i) limited access to email/ mass media; (ii) time, financial and resource constraints; (iii) unwillingness to provide such environmental information; (iv) lack of awareness of or appreciation of the value of environmental monitoring; and (v) absence of data recording systems. Respondents frequently noted that fishers and fish farmers have little time for such monitoring and limited means for providing information, given the remote location and poor connectivity of several such communities. It was further noted that some fishing and fish farming communities may be reluctant to communicate information for a variety of reasons, including fear of public officials and a desire to withhold catch information for taxation reasons. The low level of education of some fishers and fish farmers was also noted to be a constraint, as were language differences. Several of the responses suggest that there may be a need to improve relationships between fishers and fish farmers and extension officers, at least in some regions and communities.

TABLE 34
Identified challenges to effective reporting of baseline environmental information by fishers and fish farmers

Parameter	Cited by (No. of respondents)
No email access/Internet literacy	26
Time, financial and resource constraints	17
Unwillingness to report	15
No awareness of environmental monitoring	15
No data recording system in place	13
Fear of officials among farmers	9
Low levels of education	9
Lack of clarity/understanding about monitoring surveys	7
Lack of guidance/coordination	6
Mismatch between timeline of environmental change/analysis	5
No telephone	3
Distance to provide information in person	3
Limited government officers	3
Literacy limitations	2
Language differences	2
No focal agency to receive information	2
Reporting delays	1
Non-uniform communication systems	1
No trust in data receivers	1
Not knowing who to provide information to	1

3.6 Capacity-building needs and recommendations

Respondents highlighted several capacity-building needs, also putting forward a number of recommendations. Key needs relate to resources; they include: (i) financial resources, including through appropriate funding; (ii) access to technology, particularly to instrumentation for environmental monitoring; and (iii) access to communication resources. Also identified were public communication and relations needs; these included the need to develop awareness of the environmental effects of aquaculture and of the value of environmental monitoring among fishing and farming communities. Respondents also recommended that mass media be used to develop more widespread awareness of the valuable contribution being made by fishing and fish farming communities. Furthermore, it was noted that the position of village and community leaders could be better mobilized to encourage cooperation and mutual support. Respondents also noted that, at institutional level, there is a need for more effective cooperation and coordination and for data integration.

Respondents also put forward recommendations to tackle socio-economic dimensions of fisherier and fish farming, notably relating to implementation of livelihood improvement programmes. It was also noted that support should be provided to enable alternative occupations where fishing and fish farming has become difficult, and that better support should be provided to fishers and fish farmers to enable successful operation of these industries. Specific recommendations put forward included reducing the costs of required inputs, implementation of fish stocking programmes, and provision of fish finders and locators. Given the dangers posed by disaster events/conditions, the need to have support systems in place to alert fishers and fish farmers should the need arise was also highlighted; the development of early warning systems where these are lacking should therefore be a priority.

A final group of recommendations reflected concerns about the future of fishing and fish farming industries in the LMB given the poor environmental conditions. The points raised included the need for better law enforcement and curtailing of illegal activities, the need to limit environmental pressures (through, for example, treatment of wastewater), the need for more effective protection of wild fish stock, and the need for proactive measures (such as enhanced production of fingerlings and fish stocking in rivers) to ensure a viable future for these industries.

4. KEY FINDINGS

The results mentioned above indicate the following key findings:

- There is some awareness of existing national/regional monitoring systems; however, this is limited and does not appear to extend to all key stakeholders. Moreover, there appear to be differences in parameters monitored within these systems between the different countries of the LMB.
- Respondents identified several challenges to effective pan-regional collaboration in the provision of environmental information; these included the large geographical area of the LMB, differences in coordination/communication mechanisms between countries, issues resulting from the activities of non-LMB countries (notably China), and resource and implementation challenges. Several respondents noted that policy and/or legal frameworks were currently inadequate for facilitating such large-scale regional collaboration.
- Feedback provided by respondents on the perceived utility of different monitoring parameters indicates that several parameters are considered to be very important or important by the vast majority of respondents; such parameters included water temperature, salinity, extraordinary climatic events, water colour, currents, tides, oxygen levels, pH, water level and harmful algal blooms. However, key differences between countries were also noted, often corresponding to the recent environmental history of those countries; respondents from Thailand, for example, which has been negatively affected by flooding in recent years, placed particular emphasis on parameters such as water level. Respondents also indicated a range of other chemical and biological water quality parameters that they would like to see monitored, together with data relating to upstream activities (notably dam operation). Furthermore, respondents also provided their views on the frequency with which information on the various parameters should be provided.
- While radio and television are considered to be suitable media for communicating information to fishers and fish farmers, email and Internet sources are generally unsuitable because of poor Internet literacy or access among communities.

Telephone was also considered to be a suitable medium, as was communication through extension officers. Nevertheless, it should be noted that respondents also had some concerns about the relationship between officers and fishers/fish farmers (as discussed below), and the limited number of such extension officers was also noted.

- Respondents had some, but limited, awareness of mechanisms for fishers and fish farmers to provide baseline information to feed into environmental monitoring systems. While it was seen to be useful for fishers and fish farmers to provide information on a range of parameters (including catch composition, condition of farmed species, disease, fish mortalities and pests), respondents noted several limitations to effective reporting of such information. These included poor access to the Internet or to other suitable media for reporting information, disinterest and mistrust of authorities, failure to appreciate the value of such environmental monitoring systems, and time and resource constraints.
- Respondents also provided feedback on ways in which environmental parameters are currently monitored by fishers and fish farmers; while a range of methods was indicated, the majority are broadly based on direct observation, with little evident standardization of approaches. For effective implementation of such a reporting system, it would appear that clearer guidance would need to be provided to fishers and fish farmers, and suitable aid would need to be provided by trained officials. However, effective implementation would also be dependent on fostering an understanding of the value of environmental monitoring among all concerns, and on constructive working relationships between key stakeholders.

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ANNEX 1

QUESTIONNAIRE

Q1. This survey forms part of an initiative to facilitate the development of an environmental monitoring system to strengthen the resilience of fisheries and aquaculture operations and to improve early warning in the Lower Mekong Basin. Your feedback will provide valuable information that will help in implementing this initiative. This survey should not take you longer than 15 minutes to complete.

Q2. Please select your country; if you are involved professionally in work relating to fisheries/aquaculture operations in more than one country, please check all that apply.

❑ Viet Nam (1)
❑ Thailand (2)
❑ Cambodia (3)
❑ Other (4) ______________________________

Q3. Please indicate the sector(s) in which you work (select from the following options); if you wish, please provide further details in the space provided.

❑ Academia (1) ______________________________
❑ Private-sector fisheries and aquaculture operations (2) ______________
❑ Governmental departments (3) ______________________
❑ Non-governmental organizations (4) __________________
❑ Intergovernmental organizations (5) __________________

Q4. Are there any environmental monitoring systems that provide information to fisheries/aquaculture operations in your country?

❑ Yes (1)
❑ No (2)
❑ Not sure (3)

Q5. On which of these parameters do the environmental monitoring systems in your country provide information to fisheries/aquaculture? Tick all that apply.

❑ Water temperature (1)
❑ Salinity (2)
❑ Harmful algal blooms (HABs) (3)
❑ Water colour (4)
❑ Currents (5)
❑ Tides (6)
❑ Oxygen levels (7)
❑ Extraordinary climatic events (8)
❑ pH (9)
❑ Water level (10)
❑ Other (11) ______________________________

Q6. Are you aware of any environmental monitoring systems which provide information to fisheries/aquaculture operations in the wider area of the Lower Mekong basin?

❑ Yes (1)
❑ No (2)
❑ Not sure (3)

Q7. On which of these parameters do the environmental monitoring systems in the Lower Mekong basin provide information to fisheries/aquaculture? Tick all that apply.

- ❑ Water temperature (1)
- ❑ Salinity (2)
- ❑ Harmful algal blooms (HABs) (3)
- ❑ Water color (4)
- ❑ Currents (5)
- ❑ Tides (6)
- ❑ Oxygen levels (7)
- ❑ Extraordinary climatic events (8)
- ❑ pH (9)
- ❑ Water level (10)
- ❑ Other (11) ____________________

Q8. Are you aware of any collaborations across countries of the Lower Mekong Basin to provide information through an environmental monitoring system (for fisheries/aquaculture)?

- ❑ Yes (please provide details) (1) ____________________
- ❑ No (2)
- ❑ Not sure (3)

Q9. Are there any reasons that you are aware of why it may be difficult to establish a collaboration across countries of the Lower Mekong Basin to develop an environmental monitoring system for fisheries/aquaculture?

____
____
____
____
____

Q10. Please indicate how useful you think it would be to provide fisheries/aquaculture operations with information on the following parameters:

	Very useful (1)	**Useful (2)**	**Neutral (3)**	**Not very useful (4)**	**Not useful at all (5)**
Water temperature (1)					
Salinity (2)					
Harmful algal blooms (HABs) (3)					
Water colour (4)					
Currents (5)					
Tides (6)					
Oxygen levels (7)					
pH (8)					
Water level (9)					
Extraordinary climatic events (10)					
Other (please specify) (11)					
Other (please specify) (12)					
Other (please specify) (13)					

Q11. How regularly do you think that information about the following environmental parameters should be provided to fisheries/aquaculture operations?

	In real time (1)	Daily (2)	Weekly (3)
Water temperature (1)			
Salinity (2)			
Harmful algal blooms (HABs) (3)			
Water colour (4)			
Currents (5)			
Tides (6)			
Oxygen levels (7)			
pH (12)			
Water level (13)			
Extraordinary climatic events (8)			
Other (please specify) (9)			
Other (please specify) (10)			
Other (please specify) (11)			

Q12. Please indicate how suitable you think that the following media are for providing information to fishers/aquaculture operators. 1 indicates that the medium is not suitable, while 10 indicates very high suitability.

______ Radio (1)
______ Television (2)
______ Email (3)
______ Extension officers (4)

Q13. Are you aware of any incidents in the Lower Mekong Basin region where fisheries/aquaculture operations were negatively impacted by changes in environmental conditions? Please give details below.

Q14. Are you aware of whether fisheries/aquaculture operations in your country provide any information to feed into an environmental monitoring system that in turn provides information to the same operations?

❑ Yes (1)
❑ No (2)
❑ Not sure (3)

Q15. On which of these parameters do fisheries/aquaculture operations in your country provide information? Tick all that apply.

❑ Catch composition (1)
❑ Condition of farmed species (2)
❑ Disease (3)
❑ Fish mortalities (4)
❑ Pests (5)
❑ Other (6) ____

Q16. Are you aware of whether fisheries/aquaculture operations in the wider area of the Lower Mekong Basin provide any information to feed into an environmental monitoring system that in turn provides information to the same operations?

❑ Yes (1)
❑ No (2)
❑ Not sure (3)

Q17. On which of these parameters do fisheries/aquaculture operations in the Lower Mekong Basin provide information? Tick all that apply.

❑ Catch composition (1)
❑ Condition of farmed species (2)
❑ Disease (3)
❑ Fish mortalities (4)
❑ Pests (5)
❑ Other (6) ____________________

Q18. Please indicate how useful you think it would be for fisheries/aquaculture operations to provide feedback on the following aspects of their operations:

	Very useful (1)	**Useful (2)**	**Neutral (3)**	**Not very useful (4)**	**Not useful at all (5)**
Catch composition (1)					
Condition of farmed species (2)					
Disease (3)					
Fish mortalities (4)					
Pests (5)					
Other (6)					

Q19. How regularly do you think that information about the following should be provided by fisheries/aquaculture operations?

	In real time (1)	**Daily (2)**	**Weekly (3)**	**Monthly (4)**	**Less often than monthly (5)**
Catch composition (1)					
Condition of farmed species (2)					
Disease (3)					
Fish mortalities (4)					
Pests (5)					
Other (6)					

Q20. Please indicate which methods and/or instruments are used to collect data for each of the following, as applicable:
Catch composition (1)
Condition of farmed species (2)
Fish mortalities (3)
Pests (4)
Other (5) ____________________

Q21. Please indicate how suitable you think that the following media are for fishers/aquaculture operators to provide information on aspects of their operations. 1 indicates that the medium is not suitable, while 10 indicates very high suitability.

______ Paper reporting (1)
______ Email (2)
______ Extension officers (3)

Q22. Are there any difficulties that you are aware of that may make it difficult for fishers/aquaculture operators to provide information of this sort?

Q23. Do you have any specific needs and/or recommendations regarding future capacity building in your region/country? Please provide details below.

PAPER 2

Cambodia Country Report

Fisheries Administration

Network of Aquaculture Centres in Asia Pacific

In-country Baseline Assessment of Existing Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture (Including Climatic Aspects) in Cambodia

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1. BACKGROUND

1.1 Current status of the fisheries sector in Cambodia

Since ancient times, rice and fish have been integral staple foods of the daily diets of Cambodians, and fish has been described as crucial and priceless. Because Cambodia's geography is dominated by the Mekong River, which is more than 500 kilometres in length, and the Tonle Sap Great Lake is its heart, the country is rich in natural resources of all kinds, especially fisheries.

Cambodia's fisheries play a very important role in contributing to employment opportunities for about 6 million people (total Cambodian population is 15 million) working full- and part-time in fisheries and fisheries-related activities, and contributes to people's livelihoods and national food security and adds approximately US$1.5 billion per year to the economy, corresponding to around 8–12% of total gross domestic product.

Today, about 500 inland fish species and 520 marine fish species are known in Cambodia. The total annual freshwater and marine capture fisheries production is estimated at about 700 000–800 000 tonnes, of which the annual yield of inland fisheries is approximately 500 000–600 000 tonnes; the country ranks fourth worldwide in inland fish production after China, India and Bangladesh. The annual marine capture fisheries production is estimated at 100 000–150 000 tonnes, and annual aquaculture production adds some 90 000–100 000 tonnes. Fish consumption in Cambodia is 63 kg per person/year, with fish providing 81.5 percent of animal protein intake.

At present, multiple factors, such as population growth, climate change and overfishing, are likely to have potential impacts on fisheries resources. In recent years, the Royal Government of Cambodia reformed the fisheries sector by abolishing all fishing lots and transferring management to communities in order to conserve those areas and use them in a sustainable manner to contribute to poverty reduction.

Since the fisheries policy reform of 2000–2015 was adopted 15 years ago, the Fisheries Administration has worked tirelessly on the implementation of policy reforms to achieve success and best achievements, including aquaculture development, fishery management and community fisheries development, conservation of fisheries resources, improving fisheries conservation and protected areas, protection of flooded and mangrove forests, development of community fish refuges, processing and quality control of fishery products, and planning, research and extension services.

The Rectangular Strategy–Phase III, the National Strategic Development Plan 2014–2018 and the Strategic Planning Framework for Fisheries 2010–2019 have promoted fisheries production for local consumption and for export through: (i) inland and marine fisheries; (ii) inland and marine aquaculture; and (iii) post-harvest and trade.

The Royal Government of Cambodia allows the operation of Dai fisheries to harvest small migratory fish, which are either fermented or made into fish paste to supply remote rural people in other provinces. During the past 15 years, total fish production has been increasing, and inland fish production has been higher than marine fish catches. However, the trend of capture fisheries has only slightly changed as compared with the continued increase in the development of aquaculture. Per capita, the average Cambodian fish consumption is 63 kg per year, of which inland fish comprises 44 kg, marine fish 17 kg and aquaculture 1.3 kg, which represents 81.5 percent of animal protein intake. Cambodian consumption of fish paste is around 5.2 kg/year, fermented fish 4.8 kg/year, smoked fish 8.3 kg/year, salt-dried fish 9.3 kg/year, and fish sauce 4.5 litres/year.

Cambodians are currently aware of the declining fisheries resources and are changing their attitude from depending on natural fish to cultured fish. This has made fish culture activities increase remarkably, including the quantity of fingerlings produced, the number of hatcheries, as well as the increased number of community fish refuges established every year.

A community fish refuge (CFR) is a type of protection or conservation area generally established in a rice paddy field flooded during the wet season and far away from natural waterbodies, which holds water all year round. CFRs are important for providing a huge contribution to increase fisheries resources and rice field fisheries production. At present, 820 CFRs have been established, with the aim of creating one CFR for every commune throughout the country. Recently, it has been reported that there are 63 000 households participating in aquaculture activities and trained by the Fisheries Administration, among which 154 people are model fish farmers and local aquaculture extensionists.

The fish species cultured so far are sea bass, grouper, blood cockle, silver barb, *Pangasius*, climbing perch, walking catfish, giant gourami, tilapia, silver carp, fresh water eel, and fresh water prawn. Currently, the production of aquaculture is now up to 90 000 tonnes (or 12 percent of total fish production), of which 90 percent is from inland aquaculture and 10 percent from mariculture.

The Royal Government of Cambodia has considered aquaculture an important fish replenishment strategy for daily food consumption in Cambodia, particularly for smallholder aquaculture farmers using a low-cost input farming strategy, which may be vulnerable to predicted global climate change impacts.

1.2 Survey aim and objectives

The general objective of this country assessment is more focused on the current situation regarding climate-related environmental monitoring and warning systems for fisheries and aquaculture in Cambodia. In order to address this general objective, there is a need to address these specific objectives:

- To conduct a desk review on the available information related to the current situation regarding climate-related environmental monitoring and warning systems for fisheries and aquaculture in Cambodia.
- To identify the current situation regarding climate-related environmental monitoring and warning systems for fisheries and aquaculture in Cambodia based on the responses of the stakeholders.
- To identify problems and issues regarding climate-related environmental monitoring and early warning systems.
- To provide any specific needs and recommendations regarding future capacity building, including at the regional level.

1.2.1 Survey locations

The survey was conducted in six provinces, namely Kampong Chhnang, Kampong Cham, Kandal, Siem Reap, Thbong Khmon and Prey Veng, and the capital, Phnom Penh.

1.2.2 Sample size

In total, 47 respondents were interviewed in the six provinces and Phnom Penh, as summarized in Table 1.

TABLE 1
Summary of field work of Cambodia

	No. of respondents
Kampong Cham	8
Kampong Chhnang	11
Kandal	2
Phnom Penh	13
Prey Veng	10
Siem Reap	1
Thbong Khmom	2
Total	47

1.2.3 Survey tool

The questionnaire form was designed by the Network of Aquaculture Centres in Asia-Pacific (NACA) experts, and focuses on three main groups of respondents: (i) fishers; (ii) fish farmers; and (iii) fisheries/aquaculture experts and stakeholders.

1.2.4 Data processing and analysing

After the opinion survey was conducted, the data of 47 questionnaires were checked and verified for errors and missing points. The data were entered into the SPSS software for analysis. The database was cleaned and checked for the second time for errors before analysis. Two different statistical programmes were applied for analysing the data, namely EXCEL and SPSS. Most of the results are descriptive statistics and presented in percentages of the ideas and perceptions of fishers, fish farmers and fisheries/aquaculture experts and stakeholders who responded to the interviewers.

2. OVERVIEW OF RESPONSES OBTAINED

Based on the Cambodian team's observation and interviews regarding incidents in the Lower Mekong Basin, where fisheries and aquaculture operations were negatively impacted by changes in environmental conditions, fishers and fish farmers mostly could not answer the question (41 percent and 27 percent, respectively). Most respondents said that climate change has seriously impacted biodiversity; it has decreased species composition, increased fish disease outbreaks, and natural hazards such as floods and droughts are occurring more often. Natural hazards such as floods, droughts and storms are likely to become more prevalent and more intense, and water resources are likely to have changes in availability, quantity and quality.

The fishers' group noted biodiversity decrease (6 percent), low water quality (29) and fish disease outbreaks (24 percent) as the main effects. Fish farmers were mostly focused on low water quality (40 percent) and fish disease outbreaks (33 percent). The fisheries/aquaculture experts and stakeholders were also specific on natural hazards (27 percent) and biodiversity (20 percent) and the impact on water quality (13 percent).

When asked if Cambodia had environmental monitoring systems relevant to fisheries and aquaculture, 19.1 percent of 47 respondent interviewed answered "yes". Most respondents, however, did not know such systems were available (68.1 percent), and 12.8 percent responded "not sure" (Figure 1 and Annex 1). The fisheries/aquaculture experts and stakeholders were most aware of these systems (60 percent of 15 respondents), with 20 percent unsure and 20 percent unaware of such systems. The fishers' group had little awareness of such systems, answering unsure (94.1 percent) and no (5.9 percent). The fish farmers' group response was 86.7 percent, responding that they did not know of such systems, and 13.3 percent said they were unsure.

Similar responses were obtained regarding awareness of any environmental monitoring system relevant to fisheries and aquaculture operations in the wider area of the Lower Mekong Basin. Of the 47 respondents interviewed from all stakeholder groups, 19.1 percent were aware of such systems, while 63.8 percent were unaware of such systems, and 17.0 percent were not sure (Figure 2 and Annex 2). By group, the fisheries/ aquaculture experts' and stakeholders' group was the most aware (60 percent of 15 respondents interviewed), while 13.3 percent were not aware and 26.7 percent were not sure. In the fishers' group, 88.2 percent were unaware and 11.8 percent unsure, and in the fish farmers' group 86.7 percent were unaware and 13.3 percent unsure.

The reasons why it may be difficult to establish collaboration across countries of the Lower Mekong Basin to develop an environmental monitoring system for fisheries and aquaculture were collected from respondents, who provided additional suggestions on the issue. They said the main difficulties were: (i) lack of human resources; (ii) lack of a network; (iii) lack of information; (iv) lack of funding support; (v) different environmental conditions; (vi) different economic conditions; and (vii) different political issues. Concerning the respondents' perceptions to indicate the usefulness of various water quality parameters to fisheries and aquaculture operations, more than 80 percent of respondents interviewed noted that the water parameters were useful or very useful (Figure 4), and less than 20 percent did not understand their function. Three parameters, namely harmful algal blooms, tides and extraordinary climatic events, were not clearly understood by all respondents interviewed.

Owing to a lack of technical knowledge on environmental management issues such as water quality control, the 47 respondents noted that they do not know which parameters should be collected for regular environmental monitoring. More than 30 percent of the 47 respondents could not answer for water temperature, salinity, water colour, oxygen level, pH and water level; more than 50 percent could not answer for harmful algal blooms and tides; and more than 75 percent could not answer for extraordinary climatic events. Some respondents indicated that monitoring should be conducted in real time, some daily and some weekly for an appropriate monitoring frequency for all parameters; respondents, however, did not have much confidence in this, except for the aquaculture experts and stakeholders. Interestingly, nearly all the respondents indicated that radio, television and extension officers were highly suitable media for providing information to fishers and farmers, at 87.2 percent, 87.2 percent and 85.0 percent, respectively (Figure 6). Providing information to fishers and farmers via the email medium was not considered a good option, as most of them either could not use or did not have access to the Internet.

Focusing on the intention to assess whether fisheries and aquaculture operations in Cambodia are providing any information to feed into an environmental monitoring system that in turn provides information to the same operations, only 14.9 percent of the 47 respondents interviewed were aware of such practices, 40.4 percent were not aware and 44.7 percent were not sure (Figure 7). The respondents who were aware of this information came almost entirely from the fisheries/aquaculture experts' and other stakeholders' group, with 46.7 percent of 15 respondents interviewed aware, 40 percent not aware, and 13.3 percent not sure. The fishers' and fish farmers' groups were not aware (52.9 and 26.7 percent, respectively) and not sure (47.1 percent and 73.3 percent, respectively).

Based on interviews, most of the respondents were not sure or not aware if fisheries and aquaculture operations in the wider area of the Lower Mekong Basin provide any information to feed into an environmental monitoring system that in turn provides reports to the same operations (56.5 percent and 34.8 percent, respectively) (Figure 8 and Annex 8). Only a small number of respondents (8.7 percent of 47 respondents) were aware of such practices, and most of them came from the fisheries/aquaculture experts' and stakeholders' group, of which 28.6 percent of 15 respondents interviewed were aware, 35.7 percent not aware and 35.7 percent not sure. The fishers' and fish farmers' groups were generally not aware (47.1 percent and 20 percent, respectively) or not sure (52.9 percent and 80 percent, respectively).

On the issue of how useful respondents think it would be for fisheries and aquaculture operations to provide feedback on the parameters that are collected (catch composition, condition of farmed species, disease, fish mortalities and pests, Figure 9), 80 percent of respondents considered these factors useful or very useful for fisheries and aquaculture, while less than 12 percent did not understand their function.

With regard to the frequency of monitoring, respondents did not have a clear preference (Figure 10), with a high percentage of respondents in all groups indicating that they do not know how frequently monitoring should be undertaken; although, in order, daily checking was the most common, followed by weekly and then real time. Very few respondents selected monthly as an appropriate frequency to monitor. More than 15 percent were not sure. The fisheries and aquaculture experts indicated that they could understand the issue, but were not confident in their preferences.

The respondents commented on the usefulness of methods and registries for collecting data for four parameters (see Table 3). They noted that observation methods were suitable for monitoring catch composition (13 percent), condition of farmed species (53 percent), fish mortalities (36 percent) and pests (58 percent). The use of other methods such as household interviews, logbooks, records and laboratories were supported by a small number of respondents. However, a large proportion of respondents gave no answer for suitable methods for catch composition (60 percent), condition of farmed species (37 percent), fish mortalities (34 percent) and pests (28 percent). This appears to be related to technical knowledge, as their experience was limited with regard to these factors.

Figure 11 shows the proportion of respondents who answered or did not answer regarding their knowledge and experience of the parameters of catch composition, condition of farmed species, fish mortalities and pests. Figure 12 presents the respondents' views on suitable media for accessing information. Most of the respondents reported that newspaper reporting and extension officers are highly suitable media for fishers and farmers to access information (77 percent and 93.5 percent, respectively). Providing information via email was not deemed to be appropriate, as many people in these groups either could not use or had no access to the Internet.

There are a number of constraints that make it difficult for fishers and farmers to provide feedback; 71 percent of 17 fishers, 33 percent of 15 fish farmers, and 27 percent of 15 experts and stakeholders could not answer the question on environmental monitoring, and this suggests that they were not clear on the purpose of establishing environmental monitoring and warning systems (see Table 3). As already mentioned, most respondents were not aware of environmental monitoring and warning systems work in Cambodia. The difficulties for respondents included low education, poor communication (extension services), lack of networks (new technology), and lack of computer and Internet literacy for more than 40 percent of farmers, 17 percent of fishers, and 13 percent of experts and stakeholders.

In the context of environmental monitoring and early warning system relevant to fisheries and aquaculture in Cambodia, respondents reported specific needs and recommendations for further development of the fisheries and aquaculture sector. These are to: improve human resources; provide training on disease prevention and water quality control; establish an environment monitoring and warning system; provide technical support; provide water quality control; provide financial support or credit policy to farmers and fishers; improve wild fish stocks; and improve awareness of the environment. These issues may be broadly categorized as the improvement of fisheries and aquaculture extension, upgrading technical know-how, and improving financial support.

With regard to small-scale fisheries and aquaculture, Cambodia lacks appropriate extension systems both in terms of human resources and organizational structure. The inadequate technical knowledge in managing these sectors has been primarily attributed to inappropriate extension services. The absence of a fully operational fisheries and aquaculture extension system has constrained fishers and fish farmers from realizing their full potential and the contribution that the sector could offer. There is an urgent need to reorganize a traditional extension system into a new structure that involves fishers and fish farmers in participatory technology design and transfer. Extension programmes should aim at meeting fisher and farmer needs and taking account of their field conditions. The local areas for extension programmes should cover environmental management, water quality controls and fish disease controls rather than providing too much emphasis on promoting special aquatic products.

It is clear that the lack of technical know-how is a major constraint for the development of fisheries and aquaculture. Educational attainment and farming experience have impressive impacts on the level of income for fishers and aquaculture farmers as well as on other farming enterprises. Thus, provision of training opportunities for fishers and fish farmers is important. Training programmes should aim to upgrade skills on environmental management, fish disease controls and water quality. Environmental monitoring and early warning systems for fisheries and aquaculture are new concepts for Cambodia. However, Cambodia has joint collaboration through the research and monitoring programme of the Mekong River Commission (MRC), and provides scientific data (water quality, fish abundance, deep pools, Dai catch, fish larvae and biological monitoring) that are crucial resources to consider for such a system and to improve ongoing research and intervention to prevent losses for fishers and fish farmers in the country. To date, most interventions have focused on fisheries habitat management and small-scale aquaculture development for the poor and development programmes to promote livelihoods, and thus environmental monitoring and early warning systems relevant to fisheries and aquaculture are not yet widespread throughout Cambodia. There are many cases of incidental negative impacts on fisheries and aquaculture, but there is no framework in place for developing indicators for fisheries and aquaculture system health. Cambodia has not produced a framework for developing a monitoring system to respond to environmental change.

The development of fisheries as well as aquaculture needs financial support for materials improvement and operations. Most fishers and farmers lacked sufficient financing for farm operations. Thus, provision of finance for farmers, particularly the poor, is important.

3. CURRENT ENVIRONMENTAL MONITORING SYSTEMS: NATIONAL AND REGIONAL

- Water Quality Monitoring Network in the Lower Mekong Basin
- National Perspectives on Transboundary Flood Issues
- Nationally Perceived Transboundary Flood Issues
- National Frameworks for Disaster Management and Regional Cooperation on Flood Management
- Deep Pools Fishery Monitoring (MRC programme)
- Cambodia Dai Fishery Monitoring
- Fish Larvae Monitoring Programme in the Lower Mekong Basin
- Biomonitoring in the Lower Mekong Basin
- Freshwater Dolphin Conservation in Kratie and Strung Treng Province (Cambodia)
- Fish Abundance and Diversity Monitoring Programmes (Small-scale Artisanal Fisheries)

4. RESULTS OF THE SURVEY

4.1 Recording of information and communication from national authorities to fishers and fish farmer operators

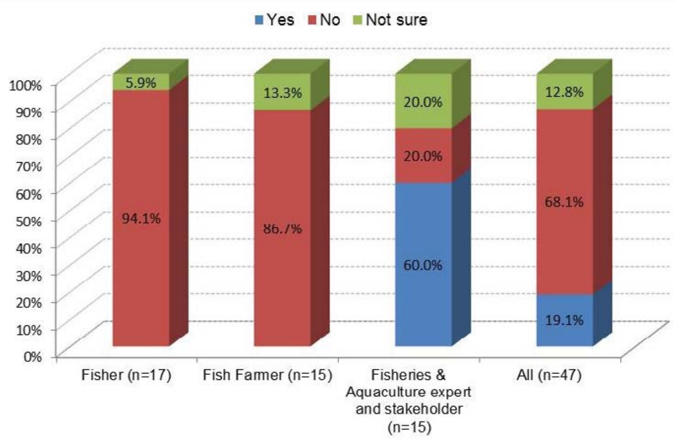
4.1.1 Perceived main threats potentially related to climate variability and/or climate

Are you aware of any incidents in the Lower Mekong Basin region where fisheries and aquaculture operations were negatively impacted by changes in environmental conditions?

Most fishers and farmers could not answer this question (41 percent and 27 percent, respectively). Most of them thought that the changes have seriously impacted on biodiversity – decreased species composition and increased fish disease outbreaks – and that natural hazards such as floods and droughts are occurring more often. Natural hazards such as floods, droughts and storms are likely to become more prevalent and more intense, and water resources are also likely to have changes in availability, quantity and quality.

The fishers noted the biodiversity decrease (6 percent), low water quality (29 percent), and fish disease outbreak (24 percent); fish farmers mostly focused on low water quality (40 percent) and fish disease outbreaks (33 percent); the experts and stakeholders reported natural hazards (27 percent), biodiversity (20 percent) and water quality impacted (13 percent).

FIGURE 1
Percentage of respondents who know of any environmental monitoring systems that provide information to fisheries and aquaculture in Cambodia



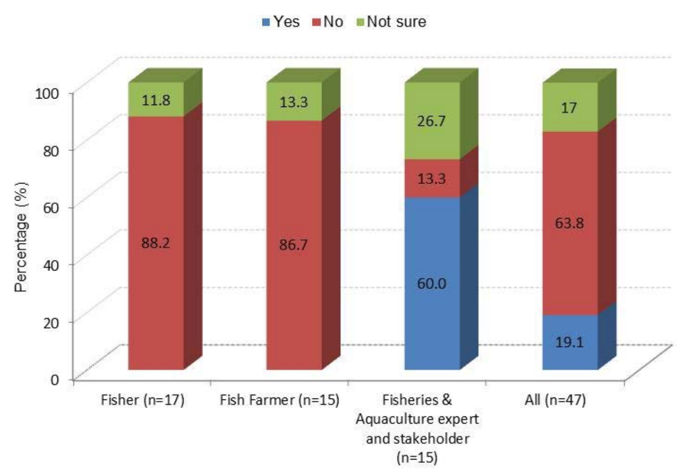
Are there any environmental monitoring systems that provide information to fisheries and aquaculture operations in your country?

Of the 47 respondents, 19.1 percent were aware of environmental monitoring systems that provide information to fishers and farmers; however, most (68.1 percent) were unaware of such systems and 12.8 percent were unsure (Figure 1 and Annex 1). By group, 60 percent (15 respondents) of the fisheries/aquaculture experts' and stakeholders' group said that they were most likely aware of the systems, while 20 percent did not know and 20 percent were unsure. The fishers' group predominantly did not know of such systems (94.1 percent) or were unsure (5.9 percent). The fish farmers' group, responded similarly, with 86.7 percent unaware and 13.3 percent unsure.

Are you aware of any environmental monitoring systems that provide information to fisheries and aquaculture operations in the wider area of the Lower Mekong Basin?

Of the 47 respondents, 19.1 percent reported "yes", indicating that they were aware of such systems, although 63.8 percent were unaware and 17 percent were unsure (Figure 2 and Annex 2). By group, the fisheries and aquaculture expert and stakeholder group were most likely to answer that they were aware of such systems (60 percent of 15 respondents), while 13.3 percent were not aware and 26.7 percent were not sure. The fishers' and fish farmers' groups were mainly not aware (88.2 percent and 86.7 percent, respectively) or unsure (11.8 percent and 13.3 percent, respectively.)

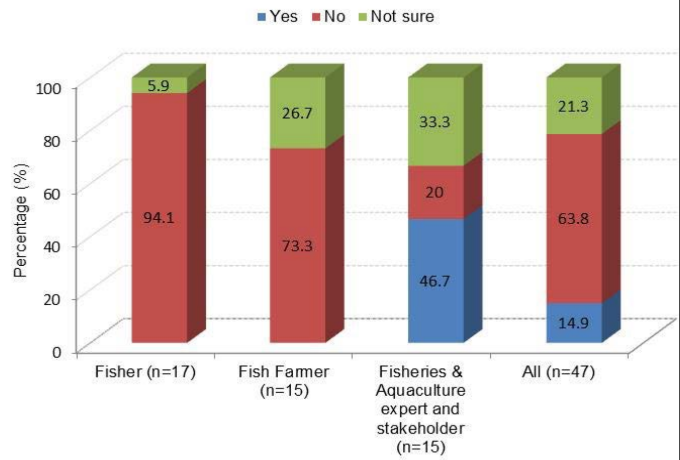
FIGURE 2
Percentage of respondents who are aware of any environmental monitoring systems that provide information to fisheries and aquaculture in the wider area of the Lower Mekong Basin



Are you aware of any collaboration across countries of the Lower Mekong Basin that provides information through an environmental monitoring system for fisheries and aquaculture?

Figure 3 and Annex 3 show that only 14.9 percent of 47 respondents interviewed were aware of collaboration between countries

FIGURE 3
Awareness of any collaboration across countries of the Lower Mekong Basin that provides information through an environmental monitoring system for fisheries and aquaculture



of the Lower Mekong Basin who provided information through an environmental monitoring system for fisheries and aquaculture (Viet Nam), 63.8 percent were not aware, and 21.3 percent were not sure. The respondents who were aware of this information mainly came from the fisheries/aquaculture experts' and stakeholders' group, from which 46.7 percent of the 15 respondents interviewed were aware, followed by 20 percent not aware, and 33.3 percent not sure. The fishers' and fish farmers' group were predominantly not aware (94.1 and 73.3 percent, respectively) and not sure 5.9 percent and 26.7 percent, respectively.

Are there any reasons that you are aware of why it may be difficult to establish collaboration across countries of the Lower Mekong Basin to develop an environmental monitoring system for fisheries and aquaculture?

Most respondents (68 percent) reported that they had no opinion on this question (100 percent of fishers and 68 percent of fish farmers). The reasons why it may be difficult to establish collaboration and develop an environment monitoring system for fisheries and aquaculture were collected from the respondents. The suggestions were: (i) lack of human resources; (ii) lack of networks; (iii) lack of information; (iv) lack of funding support; (v) different environmental conditions; (vi) different economic conditions; and (vii) different political issues.

4.1.2 Perceived relevance of different environmental parameters (including biological and physico-chemical observations, and recording) and analysis and interpretation of the information

Please indicate how useful you think it would be to provide fisheries and aquaculture operations with information on the following parameters.

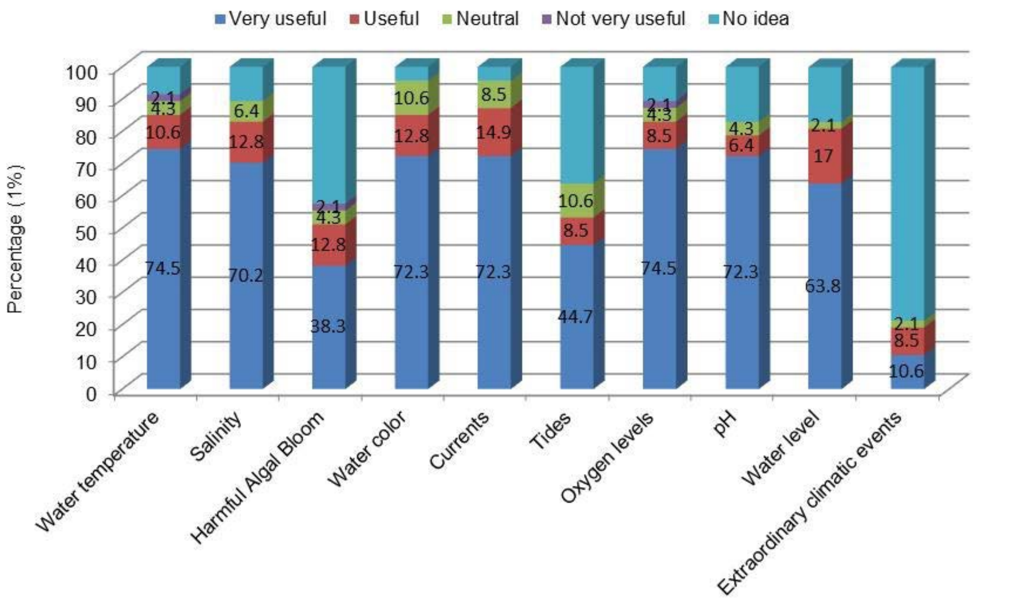
Figure 4 shows that more than 80 percent of respondents considered the parameters to be useful or very useful, and less than 20 percent did not understand their function. However, only three parameters, namely harmful algal blooms, red tides and extraordinary climatic events, were not clearly understood by all respondents interviewed. Annex 4 illustrates the understanding of fishers, fish farmers and fisheries/aquaculture experts and stakeholders on these water parameters.

4.1.3 Time frames

How regularly do you think that information about the following environmental parameters should be provided to fisheries and aquaculture operations?

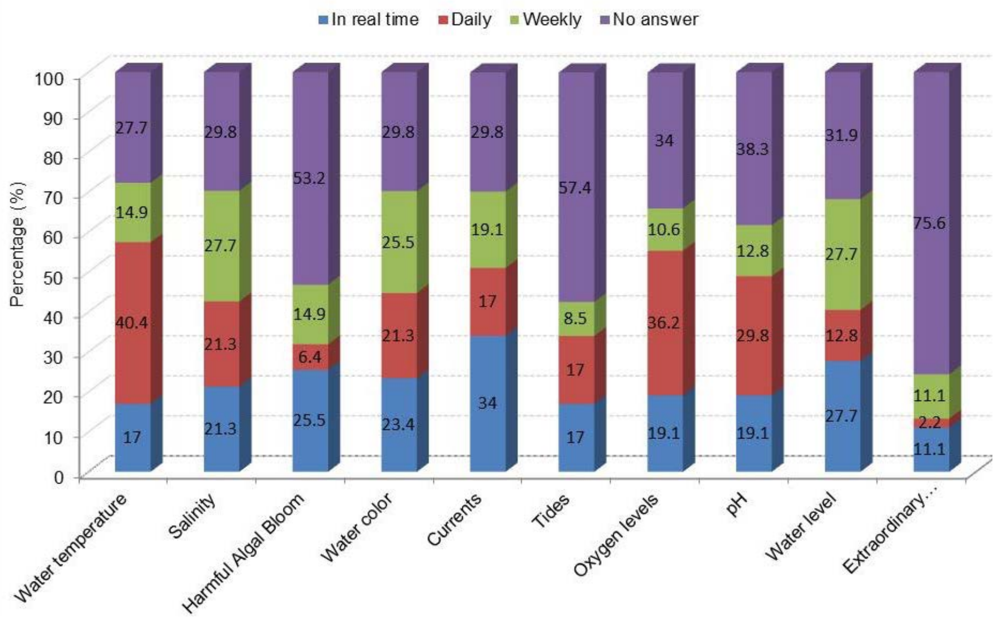
Because respondents lacked technical knowledge on environmental management issues such as water quality control, they did not show a clear preference (Figure 5). A high percentage of respondents across all three groups said that they did not know

FIGURE 4
Usefulness of providing water parameters information to fisheries and aquaculture operations



which parameters should be regularly collected for a monitoring programme. More than 30 percent of 47 respondents could not answer with regard to water temperature, salinity, water colour, oxygen level, pH and water level; more than 50 percent could not answer for harmful algal bloom and tides; and more than 75 percent for extraordinary climatic events. Some respondents selected real time as the appropriate frequency for monitoring while others chose daily or weekly monitoring for all parameters, but respondents did not have high confidence, except for aquaculture

FIGURE 5
Time period monitoring of environmental parameters to fisheries and aquaculture operations



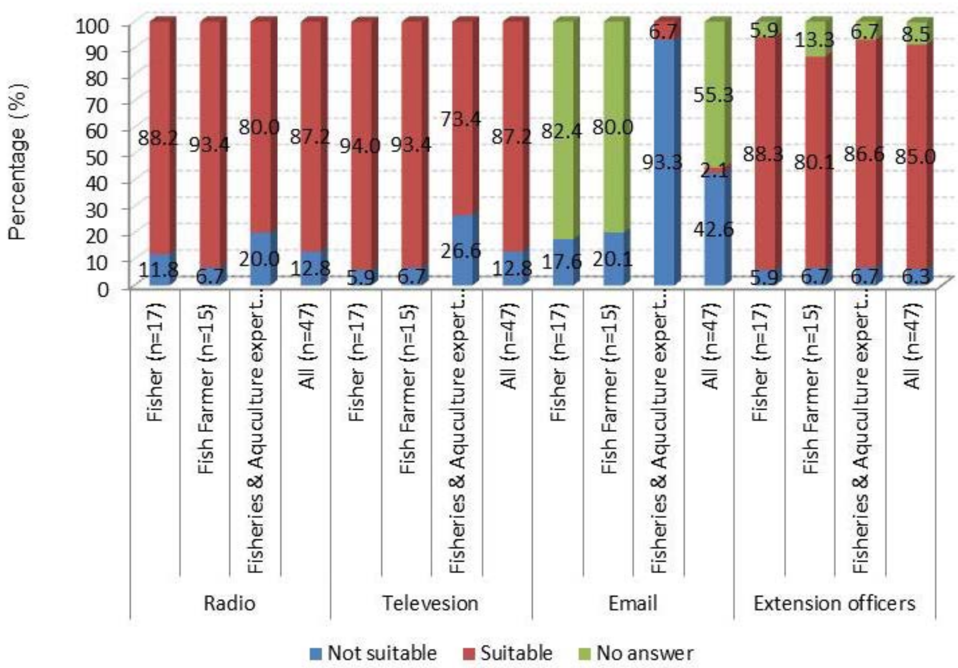
experts and stakeholders. Annex 5 illustrates the understanding of fishers, fish farmers, and fisheries/aquaculture experts and stakeholders on time period monitoring for environmental parameters.

4.1.4 Communication media and pathways

Please indicate how suitable you think that the following media are for providing information to fishers and aquaculture operators.

Nearly all 47 respondents said that radio (87.2 percent), television (87.2 percent) and extension officers (85 percent) were suitable media for providing information to fishers and farmers (Figure 6 and Annex 6). Email was not seen as a useful way to provide information to these groups as most of the respondents either could not access or could not use the Internet.

FIGURE 6
Media suitable for providing information to fishers and aquaculture operators



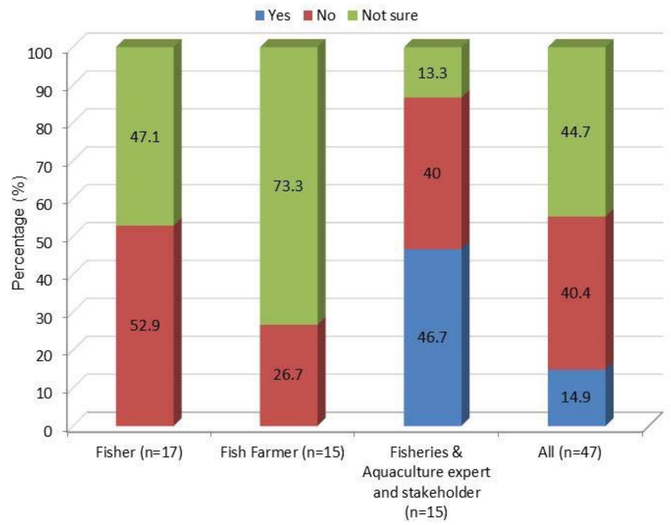
4.2 Recording of information and communication from fishers and fish farmer operators to national authorities

4.2.1 Perceived main threats potentially related to climate variability and/or climate change

Are you aware of whether fisheries and aquaculture operations in your country provide any information to feed into an environmental monitoring system that in turn provides information to the same operations?

Figure 7 and Annex 7 show that only 14.9 percent of 47 respondents interviewed were aware of whether fisheries and aquaculture operations in Cambodia provide any information to feed into an environmental monitoring system; 40.4 percent were not aware, and 44.7 percent were not sure. The respondents who were aware of this information mainly came from the fisheries/aquaculture experts' and stakeholders' group, of which 46.7 percent of 15 respondents interviewed were aware, 40 percent were not aware, and 13.3 percent not sure. The fishers' group were mainly not aware (52.9 percent) and not sure (47.1 percent), while the fish farmers' group were mainly not sure (73.3 percent) and unaware (26.7 percent).

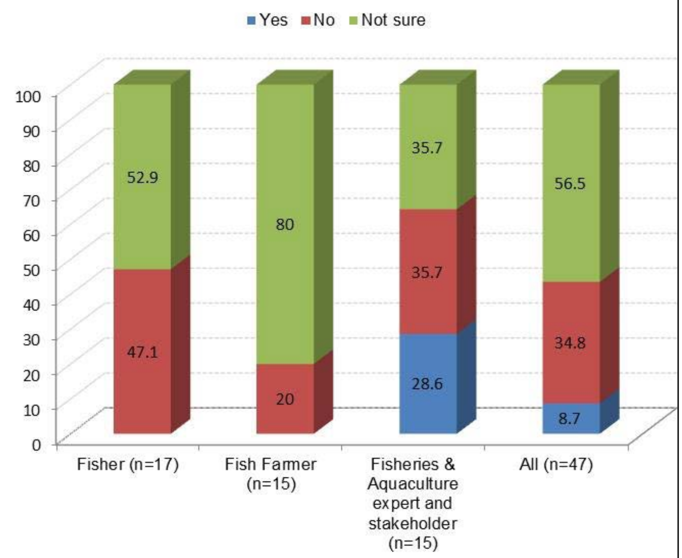
FIGURE 7
Awareness of whether fisheries and aquaculture operations in Cambodia provide information to feed into an environmental monitoring system



Are you aware of whether fisheries and aquaculture operations in the wider area of the Lower Mekong Basin provide any information to feed into an environmental monitoring system that in turn provides information to the same operations?

Figure 8 and Annex 8 show that most of the respondents interviewed were not sure (56.5 percent) or did not know (34.8 percent) whether the operations in the Lower Mekong Basin provide any information to feed into an environmental monitoring system. Only 8.7 percent of the 47 respondents were aware of such cases, and almost all of them came from the fisheries/aquaculture experts' and stakeholders' group, of which 28.6 percent of 15 respondents interviewed were aware, 35.7 percent were not aware, and 35.7 percent were not sure. The fishers' group were mainly not sure (52.9 percent) and not aware (47.1 percent), while the fish farmers' group were mainly not sure (80 percent) and unaware (20 percent).

FIGURE 8
Awareness of whether fisheries and aquaculture operations in the Lower Mekong Basin provide information to feed into environmental monitoring systems



Please indicate how useful you think it would be for fisheries and aquaculture operations to provide feedback on the following aspects of their operations.

Regarding the usefulness of parameters such as catch composition, condition of farmed species, disease, fish mortalities and pest aspects to provide feedback on fisheries and aquaculture, Figure 9 shows that most (80 percent) of the respondents interviewed considered these factors to be useful or very useful for fisheries and aquaculture. Less than 12 percent did not understand the relevance of such parameters. Annex 9 illustrates the opinion of fishers, fish farmers, and fisheries/aquaculture experts and stakeholders on all aspects.

FIGURE 9
Usefulness of parameters to provide feedback on fisheries and aquaculture operations

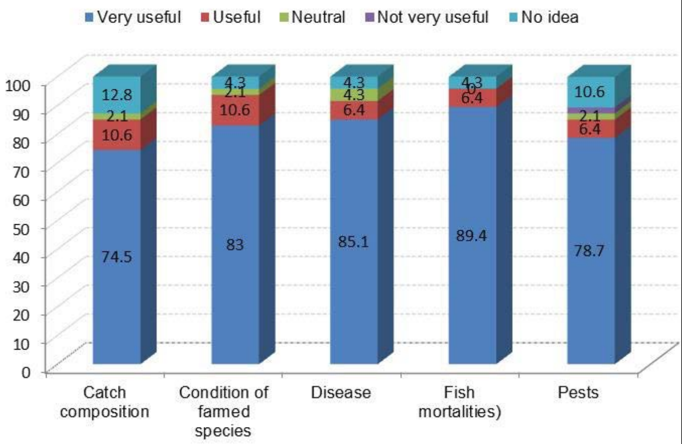
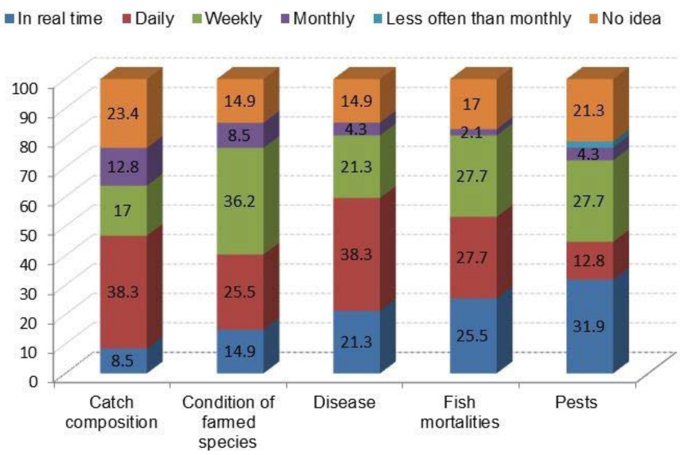


FIGURE 10
The frequency of monitoring environmental parameters for fisheries management



4.2.2 Perceived relevance of different environmental parameters

How regularly do you think that information about the following should be provided by fisheries and aquaculture operations?

In total, 47 respondents across all survey groups did not express a clear preference for the frequency of monitoring environmental parameters (Figure 10). A high percentage of respondents across all survey groups said that they do not know how frequently parameters should be monitored; but daily monitoring was the most frequently selected option, followed by weekly and in real time. A very small number of respondents selected monthly, while more than 15 percent were not sure. The fisheries and aquaculture expert group understood the issue, but were not confident in their opinion. Annex 10 illustrates the understanding of fishers, fish farmers, and fisheries/aquaculture experts and stakeholders on the frequency of monitoring environmental parameters for fisheries management.

4.2.3 Data collection and observation recording methodologies

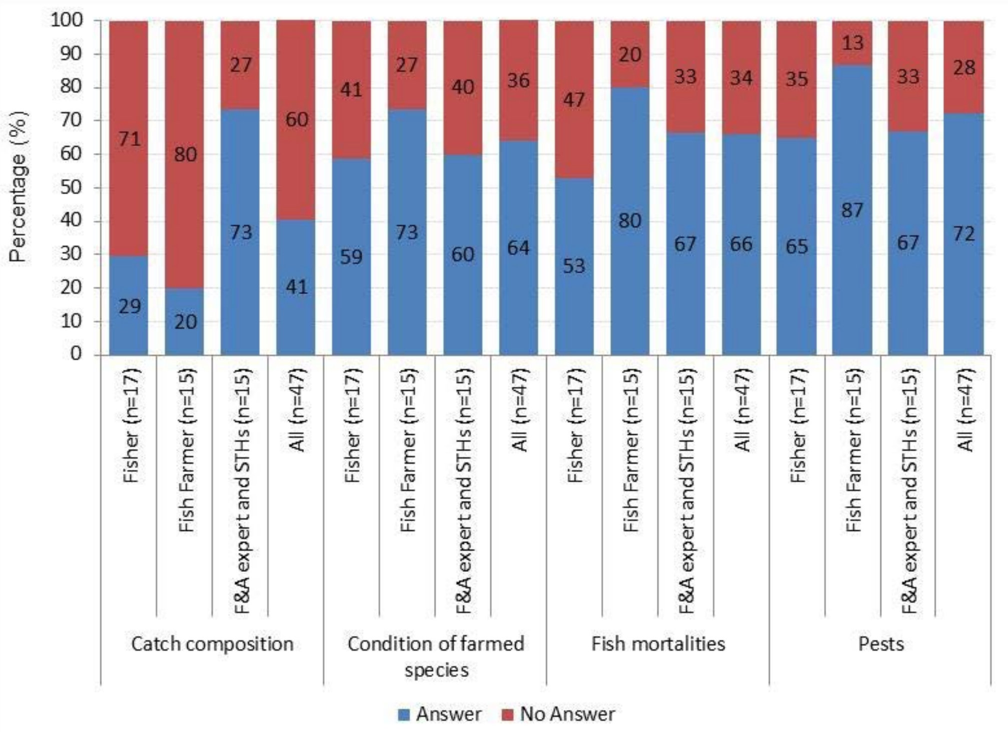
Please indicate which methods and/or instruments are used to collect data for each of the following, as applicable.

The methods and registries used to collect data for catch composition, condition of farmed species, fish mortalities and pests, and the combined responses of all 47 respondents across all survey groups, are summarized in Table 2.

TABLE 2
Usefulness of methods and registries for collecting data

Catch composition	Condition of farmed species	Fish mortalities	Pests
• Household interview (6%) • Observation (13%) • Using logbook (15%) • Records (6%) • No answer (60%)	• Household interview (4%) • Observation (53%) • Using logbook (4%) • Records (2%) • No answer (37%)	• Household interview (7%) • Observation (36%) • Using logbook (17%) • Records (6%) • No answer (34%)	• Household interview (6%) • Observation (58%) • Using logbook (2%) • Laboratory checking (4%) • Records (2%) • No answer (28%)

FIGURE 11
Respondents who answered and did not answer regarding their knowledge and experience of the parameters



Most respondents noted that direct observation methods are suitable. From all respondents interviewed, this choice represents approximately 13 percent of responses for catch composition; 53 percent for condition of farmed species; 36 percent for fish mortalities; and 58 percent for pests. This was followed by the usefulness of other methods such as household interviews, logbooks, records and laboratories, which account for small amounts of responses.

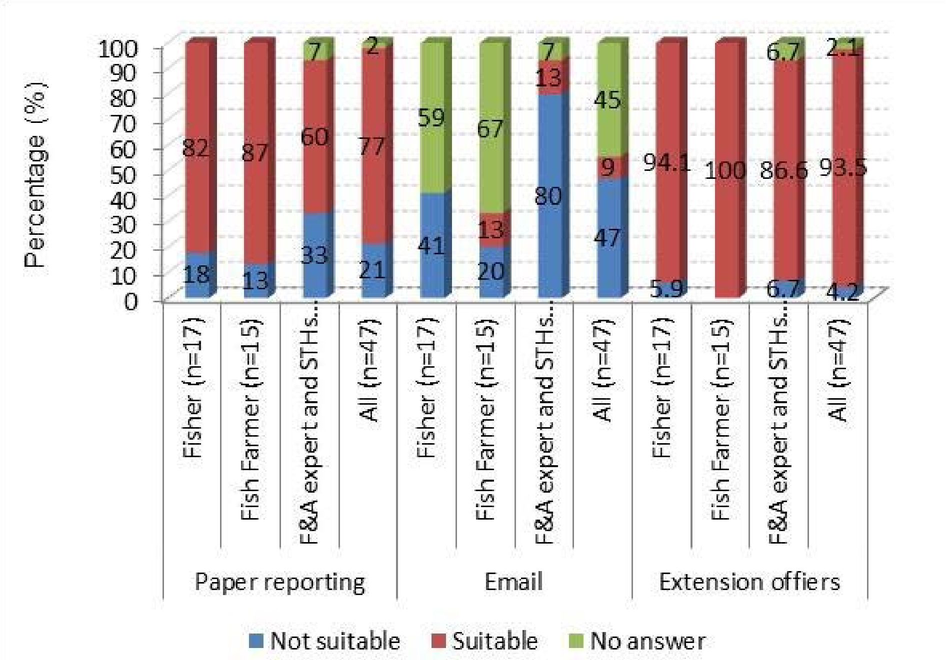
Figure 11 shows the respondents who answered and did not answer regarding their knowledge and experience of the parameters. A high proportion of respondents had no response (60 percent for catch composition, 36 percent for condition of farmed species, 34 percent for fish mortalities, and 28 percent for pests). This appears to be related to the technical knowledge and experience of respondents, meaning that their knowledge and experience are still limited in these fields.

4.2.4 Communication media and pathways

Please indicate how suitable you think that the following media are for fishers and aquaculture operators to provide information on aspects of their operations. 1 indicates that the medium is not suitable, while 10 indicates very high suitability

In total, nearly all respondents across all survey groups indicated that paper reporting and extension officers are highly suitable channels for communicating with fishers and aquaculture operators to provide information on aspects of their operations (77 percent and 93.5 percent, respectively; Figure 12 and Annex 11). Email was not considered a suitable channel, as most fishers and fish farmers either did not have access to or could not use the Internet.

FIGURE 12
Media channels for fishers and aquaculture operators to provide information on aspects of operations



5. CONSTRAINTS AND CHALLENGES

Are there any difficulties that you are aware of that may make it difficult for fishers and aquaculture operators to provide information of this sort.

In total, 71 percent of fishers, 33 percent of fish farmers, and 27 percent of experts and stakeholders could not answer this question as they are still not clear about the nature and role of environmental monitoring and warning systems in Cambodia.

The main difficulties anticipated in establishing appropriate environmental monitoring and warning systems to support fishers and farmers were low education levels, poor communication channels (notably the limited supply of extension services), lack of networks (for new technology), and lack of computer literacy and Internet access. The opinion of each group with regard to the main constraints are summarized in Table 3.

TABLE 3
Main constraints of environmental monitoring and warning systems to support fishers and farmers

Fishers (n=17)	Fish farmers (n=15)	Fisheries and aquaculture experts and stakeholders (n=15)
• Low education (6%) • Poor communication (6%) • Could not use Internet (17%) • No answer (71%)	• Lack of network (7%) • Low education (13%) • Poor communication (7%) • Could not use Internet (40%) • No answer (33%)	• Lack of network (7%) • Low education (13%) • Poor communication (20%) • Could not use Internet (13%) • Limited finances (7%) • Time management (13%) • No answer (27%)

6. RECOMMENDATIONS

Do you have any specific needs and/or recommendations regarding future capacity building in your region or country?

The specific needs and recommendations for further development of the fisheries and aquaculture sector as noted by respondents across all survey groups are to:

- improve human resources in aquaculture and fisheries management;
- provide training on disease prevention and water quality control;
- establish an environmental monitoring and early warning system;
- provide technical support;
- provide water quality control;
- provide financial support or credit policy to farmers and fishers;
- improve wild fish stocks; and
- improve awareness on environmental issues.

These issues can be broadly categorized as: (i) improvement of fisheries and aquaculture extension; (ii) improving fisheries and aquaculture extension and technical know-how; and (iii) provision of financial support.

6.1 Improvement of fisheries and aquaculture extension

Shifting to individual small-scale fisheries and aquaculture, Cambodia lacks appropriate extension systems both in term of human resources and organizational structure. The inadequate technical knowledge in managing fisheries as well as aquaculture can be primarily attributed to inadequate extension services. The absence of a fully operational fisheries and aquaculture extension system has constrained fishers and fish farmers from realizing their full potential and the contribution that fisheries and aquaculture could offer. In this regard, there is an urgent need to reorganize the traditional extension system into a new structure that involves the participation of fishers and fish farmers in technology design and transfer. Extension programmes should aim at meeting the needs of fishers and farmers and take account of the local field conditions. Extension programmes should cover environmental management, water quality and fish disease control (i.e. improving management practices) rather than placing emphasis on commercial products and equipment.

6.2 Improve the technical aspect on environmental monitoring and early warning system in fisheries and aquaculture

It is clear that a lack of technical know-how is a major constraint for the development of fisheries and aquaculture. Educational attainment and farming experience have impressive impacts on the level of income in the fisheries and aquaculture sector as well as on other farm enterprises. Thus, provision of training opportunities for fishers and farmers is important. Training programmes should aim at upgrading the skills of fishers and farmers on environmental management, fish disease control, water quality management and data collection in this regard.

6.3 Financial support

The development of fisheries and aquaculture needs financial support for improvement of equipment and operations. Most fishers and farmers lack access to finance at reasonable rates for farm operations. Thus, provision of finance for farmers, particularly the poor, is important.

ANNEX 1
Are there are any environmental monitoring systems which provide information to fisheries/aquaculture in Cambodia?

Group categories	Percentage			Total (%)
	Yes	No	Not sure	
Fishers (n=17)	-	94.1	5.9	100
Fish farmers (n=15)	-	86.7	13.3	100
Fisheries and aquaculture experts and stakeholders (n=15)	60.0	20.0	20.0	100
Total (n=47)	**19.1**	**68.1**	**12.8**	**100**

ANNEX 2
Are you aware of any environmental monitoring system that provides information to fisheries/aquaculture in the wider area of the Lower Mekong Basin?

Group interview	Percentage			Total (%)
	Yes	No	Not sure	
Fishers (n= 7)	-	88.2	11.8	100
Fish farmers (n=15)	-	86.7	13.3	100
Fisheries and aquaculture experts and stakeholders (n=15)	60.0	13.3	26.7	100
Total (n=47)	**19.1**	**63.8**	**17.0**	**100**

ANNEX 3
Awareness of any collaboration across countries of the Lower Mekong Basin to provide information through an environmental monitoring system for fisheries/aquaculture

Group interview	Percentage			Total (%)
	Yes	No	Not sure	
Fishers (n=17)	-	94.1	5.9	100
Fish farmers (n=15)	-	73.3	26.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	46.7	20.0	33.3	100
Total (n=47)	**14.9**	**63.8**	**21.3**	**100**

ANNEX 4
Usefulness of providing information of water parameters to fisheries and aquaculture operations by group interview

Group interview	Percentage					Total (%)
	Very useful	Useful	Neutral	Not very useful	No idea	
1. Water temperature						
Fishers (n=17)	70.6	5.9	5.9	0.0	17.6	100
Fish farmers (n=15)	80.0	6.7	6.7	0.0	6.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	73.3	20.0	0.0	6.7	0.0	100
Total (n=47)	**74.5**	**10.6**	**4.3**	**2.1**	**8.5**	**100**
2. Salinity						
Fishers (n=17)	76.5	5.9	0.0	-	17.6	100
Fish farmers (n=15)	86.7	0.0	6.7	-	6.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	46.7	33.3	13.3	-	6.7	100
Total (n=47)	**70.2**	**12.8**	**6.4**	**-**	**10.6**	**100**
3. Harmful algal blooms						
Fishers (n=17)	17.6	0.0	5.9	5.9	70.6	100
Fish farmers (n=15)	46.7	0.0	6.7	0.0	46.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	53.3	40.0	0.0	0.0	6.7	100
Total (n=47)	**38.3**	**12.8**	**4.3**	**2.1**	**42.6**	**100**
4. Water colour						
Fishers (n=17)	82.4	0.0	11.8	-	5.9	100
Fish farmers (n=15)	93.3	0.0	0.0	-	6.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	40.0	40.0	20.0	-	0.0	100
Total (n=47)	**72.3**	**12.8**	**10.6**	**-**	**4.3**	**100**
5. Currents						
Fishers (n=17)	76.5	11.8	5.9	-	5.9	100
Fish farmers (n=15)	93.3	0.0	0.0	-	6.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	46.7	33.3	20.0	-	0.0	100
Total (n=47)	**72.3**	**14.9**	**8.5**	**-**	**4.3**	**100**
6. Tides						
Fishers (n=17)	52.9	0.0	5.9	-	41.2	100
Fish farmers (n=15)	40.0	0.0	0.0	-	60.0	100
Fisheries and aquaculture experts and stakeholders (n=15)	40.0	26.7	26.7	-	6.7	100
Total (n=47)	**44.7**	**8.5**	**10.6**	**-**	**36.2**	**100**
7. Oxygen levels						
Fishers (n=17)	64.7	0.0	11.8	5.9	17.6	100
Fish farmers (n=15)	86.7	0.0	0.0	0.0	13.3	100
Fisheries and aquaculture experts and stakeholders (n=15)	73.3	26.7	0.0	0.0	0.0	100
Total (n=47)	**74.5**	**8.5**	**4.3**	**2.1**	**10.6**	**100**
8. pH						
Fishers (n=17)	58.8	0.0	5.9	-	35.3	100
Fish farmers (n=15)	86.7	0.0	0.0	-	13.3	100
Fisheries and aquaculture experts and stakeholders (n=15)	73.3	20.0	6.7	-	0.0	100
Total (n=47)	**72.3**	**6.4**	**4.3**	**-**	**17.0**	**100**

Annex 4 (continued)

Group interview	Percentage					Total (%)
	Very useful	Useful	Neutral	Not very useful	No idea	
9. Water level						
Fishers (n=17)	64.7	0.0	0.0	-	35.3	100
Fish farmers (n=15)	80.0	6.7	6.7	-	6.7	100
Fisheries and aquaculture experts and stakeholders (n=15)	46.7	46.7	0.0	-	6.7	100
Total (n=47)	**63.8**	**17.0**	**2.1**	**-**	**17.0**	**100**
10. Extraordinary climatic events						
Fishers (n=17)	5.9	0.0	0.0	-	94.1	100
Fish farmers (n=15)	0.0	0.0	0.0	-	100.0	100
Fisheries and aquaculture experts and stakeholders (n=15)	26.7	26.7	6.7	-	40.0	100
Total (n=47)	**10.6**	**8.5**	**2.1**	**-**	**78.7**	**100**

ANNEX 5
Information about the environmental parameters to fisheries/aquaculture operations by group interview

Group interview	Percentage				Total (%)
	In real time	Daily	Weekly	No answer	
1. Water temperature					
Fishers (n=17)	17.6	35.3	5.9	41.2	100.0
Fish farmers (n=15)	6.7	60.0	6.7	26.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	26.7	26.7	33.3	13.3	100.0
Total (n=47)	**17.0**	**40.4**	**14.9**	**27.7**	**100.0**
2. Salinity					
Fishers (n=17)	23.5	17.6	17.6	41.2	100.0
Fish farmers (n=15)	13.3	33.3	20.0	33.3	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	26.7	13.3	46.7	13.3	100.0
Total (n=47)	**21.3**	**21.3**	**27.7**	**29.8**	**100.0**
3. Harmful algal blooms					
Fishers (n=17)	5.9	5.9	0.0	88.2	100.0
Fish farmers (n=15)	40.0	6.7	6.7	46.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	33.3	6.7	40.0	20.0	100.0
Total (n=47)	**25.5**	**6.4**	**14.9**	**53.2**	**100.0**
4. Water colour					
Fishers (n=17)	17.6	29.4	5.9	47.1	100.0
Fish farmers (n=15)	26.7	33.3	13.3	26.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	26.7	0.0	60.0	13.3	100.0
Total (n=47)	**23.4**	**21.3**	**25.5**	**29.8**	**100.0**
5. Currents					
Fishers (n=17)	29.4	29.4	5.9	35.3	100.0
Fish farmers (n=15)	40.0	13.3	13.3	33.3	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	33.3	6.7	40.0	20.0	100.0
Total (n=47)	**34.0**	**17.0**	**19.1**	**29.8**	**100.0**

Annex 5 (continued)

Group interview	Percentage				Total (%)
	In real time	Daily	Weekly	No answer	
6. Tides					
Fishers (n=17)	11.8	17.6	0.0	70.6	100.0
Fish farmers (n=15)	20.0	0.0	0.0	80.0	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	20.0	33.3	26.7	20.0	100.0
Total (n=47)	**17.0**	**17.0**	**8.5**	**57.4**	**100.0**
7. Oxygen levels					
Fishers (n=17)	5.9	35.3	5.9	52.9	100.0
Fish farmers (n=15)	0.0	60.0	6.7	33.3	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	53.3	13.3	20.0	13.3	100.0
Total (n=47)	**19.1**	**36.2**	**10.6**	**34.0**	**100.0**
8. pH					
Fishers (n=17)	11.8	23.5	0.0	64.7	100.0
Fish farmers (n=15)	0.0	60.0	6.7	33.3	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	46.7	6.7	33.3	13.3	100.0
Total (n=47)	**19.1**	**29.8**	**12.8**	**38.3**	**100.0**
9. Water level					
Fishers (n=17)	23.5	23.5	5.9	47.1	100.0
Fish farmers (n=15)	40.0	0.0	33.3	26.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	20.0	13.3	46.7	20.0	100.0
Total (n=47)	**27.7**	**12.8**	**27.7**	**31.9**	**100.0**
10. Extraordinary climatic events					
Fishers (n=17)	11.8	0.0	0.0	88.2	100.0
Fish farmers (n=15)	0.0	0.0	0.0	100.0	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	20.0	6.7	33.3	40.0	100.0
Total (n=47)	**11.1**	**2.2**	**11.1**	**75.6**	**100.0**

ANNEX 6
Indicate how suitable the following media are for providing information to fishers/ aquaculture operators

Media	Group interview	Not suitable (%)	Suitable (%)	No answer (%)	Total (%)
Radio	Fishers (n=17)	11.8	88.2	-	100
	Fish farmers (n=15)	6.7	93.4	-	100
	Fisheries and aquaculture experts and stakeholders (n=15)	20.0	80.0	-	100
	All (n=47)	**12.8**	**87.2**	**-**	**100**
Television	Fishers (n=17)	5.9	94.0	-	100
	Fish farmers (n=15)	6.7	93.4	-	100
	Fisheries and aquaculture experts and stakeholders (n=15)	26.6	73.4	-	100
	All (n=47)	**12.8**	**87.2**	**-**	**100**
Email	Fishers (n=17)	17.6	-	82.4	100
	Fish farmers (n=15)	20.1	-	80.0	100
	Fisheries and aquaculture experts and stakeholders (n=15)	93.3	6.7	-	100
	All (n=47)	**42.6**	**2.1**	**55.3**	**100**

Annex 6 (continued)

Media	Group interview	Not suitable (%)	Suitable (%)	No answer (%)	Total (%)
Extension officers	Fishers (n=17)	5.9	88.3	5.9	100
	Fish farmers (n=15)	6.7	80.1	13.3	100
	Fisheries and aquaculture experts and stakeholders (n=15)	6.7	86.6	6.7	100
	All (n=47)	**6.3**	**85.0**	**8.5**	**100**

ANNEX 7
Awareness of whether fisheries/aquaculture operations in Cambodia provide information to feed into an environmental monitoring system

Group interview		Percentage			Total (%)
		Yes	No	Not sure	
	Fishers (n=17)	-	52.9	47.1	100
	Fish farmers (n=15)	-	26.7	73.3	100
	Fisheries and aquaculture experts and stakeholders (n=15)	46.7	40.0	13.3	100
Total (n=47)		**14.9**	**40.4**	**44.7**	**100**

ANNEX 8
Awareness of whether fisheries/aquaculture operations in LMB provide information to feed into an environmental monitoring system

Group interview		Percentage			Total (%)
		Yes	No	Not sure	
	Fishers (n=17)	-	47.1	52.9	100
	Fish farmers (n=15)	-	20.0	80.0	100
	Fisheries and aquaculture experts and stakeholders (n=15)	28.6	35.7	35.7	100
Total (n=47)		**8.7**	**34.8**	**56.5**	**100**

ANNEX 9
Indicate the usefulness of providing feedback on the following aspects for fisheries/ aquaculture operations by group interview

Group interview	Percentage					Total (%)
	Very useful	Useful	Neutral	Not very useful	No idea	
1. Catch composition						
Fishers (n=17)	88.2	11.8	-	-		100.0
Fish farmers (n=15)	66.7	6.7	-	-	26.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	66.7	13.3	6.7	-	13.3	100.0
Total (n=47)	**74.5**	**10.6**	**2.1**	**-**	**12.8**	**100.0**
2. Condition of farmed species						
Fishers (n=17)	88.2	11.8	-	-		100.0
Fish farmers (n=15)	93.3	6.7	-	-		100.0
Fisheries and aquaculture experts and stakeholders (n=15)	66.7	13.3	6.7	-	13.3	100.0
Total (n=47)	**83.0**	**10.6**	**2.1**	**-**	**4.3**	**100.0**
3. Disease						
Fishers (n=17)	100.0	-	-	-		100.0

Annex 9 (continued)

Group interview	Percentage					Total (%)
	Very useful	Useful	Neutral	Not very useful	No idea	
Fish farmers (n=15)	100.0	-	-	-		100.0
Fisheries and aquaculture experts and stakeholders (n=15)	53.3	20.0	13.3	-	13.3	100.0
Total (n=47)	**85.1**	**6.4**	**4.3**	**-**	**4.3**	**100.0**
4. Fish mortalities						
Fishers (n=17)	94.1	5.9	-	-		100.0
Fish farmers (n=15)	100.0	-	-	-		100.0
Fisheries and aquaculture experts and stakeholders (n=15)	73.3	13.3	-	-	13.3	100.0
Total (n=47)	**89.4**	**6.4**	**-**	**-**	**4.3**	**100.0**
5. Pests						
Fishers (n=17)	76.5	-	-	5.9	17.6	100.0
Fish farmers (n=15)	100.0	-	-	-		100.0
Fisheries and aquaculture experts and stakeholders (n=15)	60.0	20.0	6.7	-	13.3	100.0
Total (n=47)	**78.7**	**6.4**	**2.1**	**2.1**	**10.6**	**100.0**

ANNEX 10
Frequency of monitoring environmental parameters by group interview

Group interview	Percentage						Total (%)
	In real time	Daily	Weekly	Monthly	Less often than monthly	No idea	
1. Catch composition							
Fishers (n=17)	5.9	41.2	17.6	5.9	-	29.4	100.0
Fish farmers (n=15)	6.7	40.0	13.3	13.3	-	26.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	13.3	33.3	20.0	20.0	-	13.3	100.0
Total (n=47)	**8.5**	**38.3**	**17.0**	**12.8**	**-**	**23.4**	**100.0**
2. Condition of farmed species							
Fishers (n=17)	11.8	29.4	35.3	-	-	23.5	100.0
Fish farmers (n=15)	13.3	40.0	40.0	-	-	6.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	20.0	6.7	33.3	26.7	-	13.3	100.0
Total (n=47)	**14.9**	**25.5**	**36.2**	**8.5**	**-**	**14.9**	**100.0**
3. Disease							
Fishers (n=17)	23.5	41.2	11.8	-	-	23.5	100.0
Fish farmers (n=15)	26.7	60.0	6.7	-	-	6.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	13.3	13.3	46.7	13.3	-	13.3	100.0
Total (n=47)	**21.3**	**38.3**	**21.3**	**4.3**	**-**	**14.9**	**100.0**
4. Fish mortalities							
Fishers (n=17)	11.8	41.2	17.6	-	-	29.4	100.0
Fish farmers (n=15)	46.7	33.3	13.3	-	-	6.7	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	20.0	6.7	53.3	6.7	-	13.3	100.0
Total (n=47)	**25.5**	**27.7**	**27.7**	**2.1**	**-**	**17.0**	**100.0**
5. Pests							
Fishers (n=17)	17.6	23.5	23.5	-	-	35.3	100.0
Fish farmers (n=15)	53.3	13.3	20.0	-	-	13.3	100.0
Fisheries and aquaculture experts and stakeholders (n=15)	26.7		40.0	13.3	6.7	13.3	100.0
Total (n=47)	**31.9**	**12.8**	**27.7**	**4.3**	**2.1**	**21.3**	**100.0**

ANNEX 11
Indicate how suitable you think that the following media are for fishers/aquaculture operators to provide information on aspects of their operations

Medium	Group interview	Not suitable (%)	Suitable (%)	No answer (%)	Total (%)
Paper reporting	Fishers (n=17)	18.0	82.0	-	100
	Fish farmers (n=15)	13.0	87.0	-	100
	Fisheries and aquaculture experts and stakeholders (n=15)	33.0	60.0	7.0	100
	All (n=47)	**21.0**	**77.0**	**2.0**	**100**
Email	Fishers (n=17)	41.0	-	59.0	100
	Fish farmers (n=15)	20.0	13.0	67.0	100
	Fisheries and aquaculture experts and stakeholders (n=15)	80.0	13.0	7.0	100
	All (n=47)	**47.0**	**9.0**	**45.0**	**100**
Extension officers	Fishers (n=17)	5.9	94.1	-	100
	Fish farmers (n=15)	-	100	-	100
	Fisheries and aquaculture experts and stakeholders (n=15)	6.7	86.6	6.7	100
	All (n=47)	**4.2**	**93.5**	**2.1**	**100**

PAPER 3

Thailand Country Report

Report of the In-country Baseline Assessment of Existing Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture (Including Climatic Aspects) in Thailand

By

Chittapalapong Tanaporn, Amornrat Sermwatanakul,
Kanit Naksung; and Tiwarat Thalerngkietleela

IN-COUNTRY BASELINE ASSESSMENT OF EXISTING ENVIRONMENTAL MONITORING AND EARLY WARNING SYSTEMS RELEVANT TO FISHERIES AND AQUACULTURE (INCLUDING CLIMATIC ASPECTS) IN THAILAND

The Department of Fisheries, Thailand, signed a letter of agreement with the Network of Aquaculture Centres in Asia-Pacific (NACA) for implementation of an in-country baseline assessment of existing environmental monitoring and early warning systems relevant to fisheries and aquaculture (including climate aspects) in Thailand.

Survey aim and objectives

The objective of the in-country baseline assessment was to determine the current situation regarding climate-related environmental monitoring and warning systems for fisheries and aquaculture in the Mekong Delta of Thailand. The assessment was carried out through a questionnaire survey (https://jfe.qualtrics.com/form/SV_ebKgpfPe0uDQU1n) for local fishers and farmers, experts from fisheries and aquaculture institutions and inter-agency departments, as well as stakeholders from academic institutions and civil society. A total of at least 45 questionnaires were expected to be obtained for Thailand, including 15 questionnaires each from fishers, fish farmers, fisheries and aquaculture experts and stakeholders from inter-agency departments, the private sector, academic institutions and civil society relevant to the issues.

FIGURE 1
Map showing locations of provinces where questionnaire surveys were carried out

Source: http://en.wikipedia.org/wiki/Geography_of_Thailand.

Overview of responses obtained

Questionnaire surveys were carried out in six provinces in northeast Thailand, located along the Mekong River basin from the north to the south, namely the provinces of Nongkhai, Udon Thani, Bueng Kan, Nakhon Phanom, Ubon Ratchathani and Yasothon, respectively (Figure 1). Six groups of professions were categorized: fishers, fish farmers, Tambon Administrative Organization (TAO), sub-district and village leaders, academic institutes and non-governmental organizations (NGOs). Table 1 shows the number of questionnaires (115 total) obtained in each category in each province.

About 72 respondents thought that there were environmental monitoring systems and dissemination of information to fishers and fish farmers in Thailand, 24 did not think that such systems were in place, and 19 respondents were not sure.

About 56 respondents thought that there were no environmental monitoring systems and dissemination of information to fishers and fish farmers in the Lower Mekong Basin, 37 respondents thought that there were such systems, and 22 respondents were not sure.

TABLE 1
Number of questionnaires obtained in each province classified by categories of respondents. Recording of information and communication from national authorities to fishers and fish farmer operators

Provinces	Fishers	Fish farmers	TAO Govt.	Sub-district and village leaders	Academic institutes' leaders	NGOs	Total
Nongkhai	1	7	4	1	1	-	**14**
Udon Thani	-	-	2	-	-	-	**2**
Bueng Kan	1	2	4	1	1	1	**10**
Nakhon Phanom	16	13	8	-	4	5	**46**
Ubon Ratchathani	10	6	3	-	5	-	**24**
Yasothon	6	7	4	-	-	-	**19**
Total	**34**	**35**	**25**	**2**	**11**	**6**	**115**

The institutions, entities and private stakeholders that are currently involved in environmental monitoring in Thailand in the Mekong River Basin are:

- Department of Water Resources and Ministry of Natural Resources and Environment – installed CCTVs along the Mekong River.
- Thai Meteorological Department and Ministry of Information and Communication Technology – have weather monitoring stations in every province.
- Department of Fisheries and Ministry of Agriculture and Cooperatives – provide water quality examination in the Mekong River and for fish ponds and fish disease, etc.
- Office of the National Energy Board and Ministry of Energy – installed 113 electric pump stations in 11 districts and 2 branch districts to pump water from the Mekong River and other water sources for agriculture.
- National Disaster Warning Center and Ministry of Information and Communication Technology – installed warning towers and sirens in provinces located in the Mekong River Basin.
- Department of Disaster Prevention and Mitigation – provides emergency management prior, during and after disasters.
- Geo-Informatics and Space Technology Development Agency and Ministry of Science and Technology – use remote sensing in environmental monitoring in Thailand.

How has the information been collected, processed and fed back to fisheries and farmers? (This may be for water level monitoring, water quality monitoring, flood warning and prevention, weather forecasts, information dissemination, etc.)

- Department of Water Resources and Ministry of Natural Resources and Environment – monitor water level fluctuations in the Mekong River, which provide information on flood situations to government officers.
- Thai Meteorological Department and Ministry of Information and Communication Technology – provide weather forecast information through media such as television channels and radios as morning and evening news.
- Department of Fisheries and Ministry of Agriculture and Cooperatives – provide water quality examination results in the Mekong River and fish ponds to fishers and fish farmers.

- Office of the National Energy Board and Ministry of Energy – coordinate with local authorities and farmers on water supply needs.
- National Disaster Warning Center, Ministry of Information and Communication Technology – communicate with the Thai Meteorological Department and relevant organizations to provide information and/or warning messages to the public.
- Department of Disaster Prevention and Mitigation – provides information and/or warnings to the public.
- Geo-Informatics and Space Technology Development Agency and Ministry of Science and Technology – share information with relevant governmental agencies for planning and use of information.

Data collection/observation recording methodologies, time frames, communication media/pathways

Most of the respondents agreed that there is environmental monitoring in Thailand on the following parameters, namely: water level (62); water temperature (60); oxygen level (60); harmful algal blooms (HABs) (59); extraordinary climatic events (59); pH (59); water colour (58); currents (58); tides (58); turbidity (29).

Most of the respondents thought that it would be useful to very useful to provide fisheries and aquaculture operations with the following parameters, namely: oxygen level (103); water level (102); water temperature (101); extraordinary climatic events (101); tides (99); currents (98); water colour (95); turbidity (81); HABs (69); salinity (60).

Most of the respondents thought that data should be collected in real time, namely: extraordinary climatic events (59); water level (54); currents (52); water temperature (49); HABs (48); water colour (48); tides (47); oxygen level (47); pH (42). The only variable that most respondents think that data should be collected weekly is salinity (56).

Most of the respondents thought that the following media would be effective means in providing information, namely: extension officers (57); radio (53); television (53); telephone (39). Email was mainly found to be ineffective (28).

Are you aware of any incidents in the Lower Mekong Basin region affecting fishers and aquaculture farmers?

The survey collected 141 views on the issue of incidents in the Lower Mekong Basin region. Of these, 37 respondents provided no comments or suggestions. The other respondents, however, shared the following 18 comments:

1. Water in the Mekong River is impacted by wastewater released from factories (18 respondents)
2. Great floods that impact the Mekong River occurred during 2011–2012 (13 respondents)
3. Water quality is poor resulting in less fish because of dam closures and the dry season (12 respondents)
4. Water level fluctuations affected catches and fish in cages (10 respondents)
5. Water turbidity affected fish in cages in 2013 and caused reduction in catches (9 respondents)
6. Dam construction prevent fish migration and climate variability due to deforestation (9 respondents)
7. Fish species losses due to climate variability, habitat changes, and water level fluctuations that change spawning grounds of fish and stocking of exotic species in the Mekong River (5 respondents)
8. In 2013, fish in cages died due to water discharge (3 respondents)
9. Rice farmers have used fertilizer and chemical agents in pest control that affected fish (3 respondents)

10. Lack of oxygen level in water (3 respondents)
11. Fishers and fish farmers do not receive any information about the Lower Mekong Basin (3 respondents)
12. There is illegal fishing in the Mekong River (2 respondents)
13. Water was drained from upstream water without providing early warning information to the downstream areas (2 respondents)
14. There is land encroachment (1 respondent)
15. There is erosion along the riverbank (1 respondent)
16. There was fish disease (1 respondent)
17. Fish in cage do not feed during winter time (1 respondent)
18. Fishers catch less fish (1 respondent)

Recording of information and communication from fishers and fish farmer operators to national authorities

About 60 respondents thought that there were environmental monitoring systems and dissemination of information from fishers and fish farmers to national authorities in Thailand, whereas 41 of them did not think that such systems were in place, and 14 respondents were not sure. About 55 respondents thought that there were no environmental monitoring systems and dissemination of information from fishers and fish farmers to authorities in the Lower Mekong Basin, 36 respondents thought that there were such systems, and 23 respondents were not sure.

Data collection/observation recording methodologies, time frames, communication media/pathways

Most respondents thought that it would be useful to very useful to provide information to fisheries and aquaculture operations, namely: disease (101); pests (99); fish mortalities (97); condition of farmed species (95); catch composition (89).

Most respondents thought that data should be collected in real time for: disease (55); catch composition (48); pests (48); fish mortalities (44); condition of farmed species (36).

Most respondents thought that the following media are effective means in providing information, namely: extension officers (53); telephone (40); paper reporting (30). Email was mainly found to be ineffective (33).

CONSTRAINTS AND CHALLENGES

Are there any reasons that you are aware of why it may be difficult to establish collaboration?

The survey collected 120 views on the collaboration issue. Of these, 48 respondents provided no comments or suggestions. The other respondents noted 23 specific concerns:

1. There are no problems (13 respondents)
2. People do not understand international laws (7 respondents)
3. There is no information provided for fish farmers regarding water utilization in the Lower Mekong Basin (5 respondents)
4. There is no outreach programme (5 respondents)
5. There is currently certain collaboration with fishers (4 respondents)
6. There is no clear coordination mechanism among countries in the Lower Mekong Basin (3 respondents)
7. There is limited budget and personnel (3 respondents)
8. Each country in the Lower Mekong Basin has problems in aquaculture activities (1 respondent)
9. In the past two to three years, people living along the Mekong River have been affected by floods on their vegetation crops and fish cage culture (1 respondent)
10. There is regional collaboration (1 respondent)
11. There are gaps in educational levels, social norms, culture and laws (1 respondent)

12. There is erosion and sand mining (1 respondent)
13. A problem of narcotic drugs makes it difficult to monitor environment (1 respondent)
14. There is no focal point who is responsible for monitoring system (1 respondent)
15. Data collection is not well planned for continuation (1 respondent)
16. Information can be obtained by television (1 respondent)
17. Coordination mechanisms among countries are not effective (1 respondent)
18. Biodiversity losses are due to dam construction (1 respondent)
19. There is dispute on land use for aquaculture (1 respondent)
20. There is a problem with foreign labour issues (1 respondent)
21. Ineffective public relations concerning regional collaboration (1 respondent)
22. Chemical use contaminates the river (1 respondent)
23. There is a problem with the environment (1 respondent)

Are there any difficulties that you are aware of that may make it difficult for fishers and aquaculture farmers to provide information?

The survey collected 122 views on the question of providing information. Of these, 39 respondents provided no comments or suggestion. The 18 specific constraints and challenges from respondents are:

1. Fish farmers and fishers do not record their information; information provided is not on a regular basis; fishers and farmers have no time to provide information; they also avoid tax payment (20 respondents)
2. Fish farmers and fishers do not understand and lack technical knowledge (11 respondents)
3. Fish farmers and fishers live far away from government offices; it is not convenient for them to collect data as they have no time (9 respondents)
4. Fish farmers do not care about water quality data; they do not want to cooperate (8 respondents)
5. Fish farmers have no instruments for data collection (7 respondents)
6. Fishers who may engage in certain types of illegal fishing will avoid meeting government officers (6 respondents)
7. There is no focal agency to receive information (5 respondents)
8. Fish farmers have difficulties accessing information (3 respondents)
9. Fishers and fish farmers cannot read and have no time to learn (2 respondents)
10. Information should be collected by government in collaboration with fishers and fish farmers (2 respondents)
11. It is difficult to provide real time data (2 respondents)
12. There is no guidance from the government (1 respondent)
13. Government officers are limited in number (1 respondent)
14. Data are given orally and often delayed (1 respondent)
15. There is no fish landing site to collect information (1 respondent)
16. Fishers fear illicit drugs (1 respondent)
17. Fishers and fish farmers would need capacity building in data collection (1 respondent)
18. There is no standard fish price to provide (1 respondent)

RECOMMENDATIONS

Any specific needs and/or recommendations regarding future capacity building in Thailand?

The survey collected 127 views regarding capacity building. Of these, 45 respondents provided no comments or suggestions. The other respondents made the following 23 needs and/or recommendations:

1. There is a need to improve knowledge of climate change impacts on fisheries and aquaculture to village leaders (11 respondents)

2. There should be more effective communication between governments and people with outreach programmes (11 respondents)
3. Communities should be engaged on the issues of environmental conservation, data collection and reporting (7 respondents)
4. There should be better coordination mechanisms between government and farmers (6 respondents)
5. There should be a focal point for data collection and information dissemination (5 respondents)
6. There should be local preparedness and response plans for both Thailand and Lao People's Democratic Republic (5 respondents)
7. There should be more clear legal and policy direction (5 respondents)
8. A network of volunteers should be established (4 respondents)
9. A Mekong Disaster Early Warning Centre should be established (4 respondents)
10. Early dissemination of information should be made so that downstream management, preparedness and response can be made effectively (3 respondents)
11. Government should provide fish stocking programme in the Mekong River (3 respondents)
12. A local central information system should be established to monitor climate change and human activities (3 respondents)
13. There should be effective inter-agency collaboration in data collection (2 respondents)
14. There should be a fish culture zonation (2 respondents)
15. There is a need for capacity development in water quality management at the farm level (2 respondents)
16. People should be able to access information (1 respondent)
17. Wastewater should be treated before releasing into natural waters (1 respondent)
18. There should be an integrated data centre among Lower Mekong Basin countries (1 respondent)
19. Information should be provided at the local level for decision-making (1 respondent)
20. Tambon Administrative Organization should be a focal point for coordination at the local level for fish farmers (1 respondent)
21. The government officers should visit communities on a regular basis (1 respondent)
22. Data collection should be kept regularly and provided to fishers and fish farmers (1 respondent)
23. There should be better wastewater control (1 respondent)

CONCLUSION

A baseline assessment through a questionnaire survey was conducted in six provinces of Thailand in the Mekong River Basin to determine the current situation regarding climate-related environmental monitoring and warning systems for fisheries and aquaculture. Data were collected from a total number of 115 questionnaires, including 34 fishers, 35 fish farmers, 29 government authorities, 11 academicians and 6 NGOs.

Most respondents thought that there were environmental monitoring systems and dissemination of information from national authorities to fishers and fish farmers in the country and in the region. Major government institutions in Thailand that are currently doing the environmental monitoring include the Department of Water Resources, the Thai Meteorological Department, the Department of Fisheries and the Office of the National Energy Board. Some respondents perceived the main threats potentially related to climate variability and/or climate change, but others included incidents such as the impacts of wastewater released from factories, the impact of the great floods of 2011–2012, water level fluctuations affecting catches and fish in cages, and water turbidity and quality. Some respondents were aware of the difficulties for fishers and aquaculture farmers to collect or provide information, difficulties that were due to various reasons, such as a lack of record-keeping, lack of understanding or technical knowledge, and inconvenience in collecting data. Most respondents thought that water quality data are useful and should be collected in real time. Most respondents also thought that extension officers, radio, television and telephone are effective means by which to provide information to farmers and fishers.

PAPER 4

Viet Nam Country Report

Baseline Assessment of Existing Environmental Monitoring and Early Warning Systems Relevant to Fisheries and Aquaculture in the Mekong Delta, Viet Nam

By

Tran Dinh Luan, Chau Thi Tuyen Hanh, Hoang Tung and Nguyen Thu Thuy

1. BACKGROUND

Viet Nam covers an area of 331 688 km^2. The country has 86 million inhabitants with about 70.4 percent living in rural areas. It is a developing country, and its economy is still dominated by the agriculture sector. With a coastline of 3 260 kilometres, more than 4 000 islands and 242 970 km^2 of river area (including 112 estuaries), Viet Nam has fisheries for a wide range of species that provide significant potential for further fisheries development.

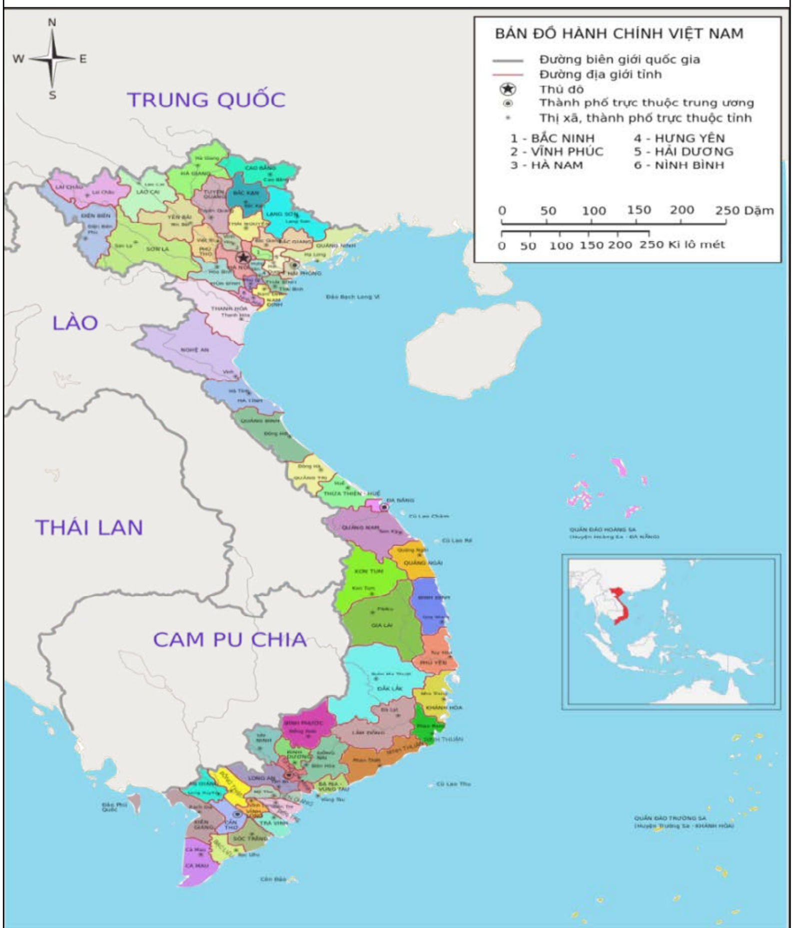
The dynamic and rapidly growing aquaculture sector has become one of the key economic sectors of Viet Nam. In 2014, total fisheries production amounted to 6.3 million tonnes, of which aquaculture production was 3.6 million tonnes and capture fisheries 2.7 million tonnes. Shrimp aquaculture production in 2014 was 660 000 tonnes and catfish was 1.1 million tonnes, produced mainly in the Mekong River provinces.

Aquatic organisms are highly sensitive to the state of the aquatic environment. Environmental monitoring systems can provide information about important water quality parameters to fishers and fish farmers, and can play a critically important role in ensuring sustainable harvesting and production of fish. Environmental monitoring is one of the key issues for reducing risk for farmers.

To support water quality monitoring for aquaculture, the Ministry of Agriculture and Rural Development established in 2004 three centres for environmental monitoring and early warning in the northern, central and southern provinces, which are the Research Institute for Aquaculture No. 1, No. 2 and No. 3. These centres are responsible for selecting monitoring locations and parameters for data collection, reporting and warnings.

The centres for marine environmental monitoring, operated by the Research Institute of Marine Fisheries, were established in 2005. The research institute has been mainly implementing environmental monitoring of marine culture areas, fishing ports and marine protected areas to evaluate seawater quality and provide early warning. Marine environmental monitoring and evaluation of seawater quality is also conducted by the Institute of Oceanography, Vietnam Maritime University and Departments of Natural Resources and Environment in some coastal provinces. The Department of Capture Fisheries and Resource Protection under the Directorate of Fisheries is preparing to outline a project for the establishment of an environmental monitoring

FIGURE 1
Map of Viet Nam



Source: https://osshcmup.wordpress.com/2012/06/18/ban-do-viet-nam-co-the-chinh-su-duoc-bang-latex system for fisheries. However, the budget for sampling and early warning of these centres are costly, and hence monitoring cannot be carried out continuously.

Provinces in which aquaculture is important will typically assign a division for environmental monitoring and early warning. Since 2008, Viet Nam has had 35 provinces conducting environmental monitoring activities relevant to aquaculture, especially in the Lower Mekong Basin, which is the largest producing area of the country. Only one of the thirteen provinces of the Lower Mekong Basin does not have an environmental monitoring plan for aquaculture. The provinces of Soc Trang, Kien Giang and Ca Mau have conducted intensive environmental monitoring.

Environmental monitoring in Viet Nam is focused on intensive shrimp farming and other target culture species such as tilapia, lobster and molluscs. The parameters of the environmental monitoring programmes depend on the species and farming system. Monitoring centres often monitor parameters in water intake areas, such as temperature, salinity, transparency, total suspended solids (TSS), dissolved oxygen, chemical oxygen demand (COD), ammonia, nitrite, nitrate, phosphate, sulfur, total nitrogen, total phosphate, heavy metals (lead, cadmium and mercury), component and density of algae; and parameters in ponds such as temperature, salinity, pH, dissolved oxygen, alkalinity, ammonia, nitrite, nitrate, sulfur, COD, biological oxygen demand (BOD), total phosphate, total nitrogen, total *Vibrio* and total fungi, and occurrence of significant diseases including monodon baculovirus, white spot syndrome virus and yellow head virus in shrimp.

On 12 May 2014, the Ministry of Agriculture and Rural Development issued the Environmental Monitoring Project for Aquaculture. This project is expected to conduct environmental monitoring in the intensive culture areas for five major target species focusing on brackish-water shrimp, lobster, pangasius catfish, molluscs and tilapia. Monitoring parameters depend on the species. For example, for brackish-water shrimp, monitoring is observed both in the pond water and in water intake areas. The parameters observed at intake areas, such as water temperature, dissolved oxygen, salinity, pH and alkalinity, are measured once per day. Others, such as amonia (NH_3), nitrite (NO_2), hydrogen sulfide (H_2S), TSS, organic suspended solids, COD, density and composition of toxic algae, *Vibrio* spp. and *Vibrio parahaemolyticus,* are assessed twice per month. Chemical plant protection and heavy metals (lead, cadmium and mercury) are monitored three times a year. These parameters are considered more related to environmental and disease issues for the species in Viet Nam.

In general, environmental monitoring in aquaculture plays an extremely important role in reducing the risk of diseases and ensuring sustainable development. Environmental monitoring is conducted to know environmental status and trends, to make recommendations to help management bodies, to build seasonal and crop calendars, and to prevent damage caused by environmental pollution. Monitoring is also conducted to evaluate the impact of aquaculture on the environmental surroundings and to evaluate the impact of the environment on aquaculture. Monitoring results also help management agencies in the planning strategies of aquaculture at the local and national levels to forecast environment trends in aquaculture development, and are the basis for the forecasting of water quality. Environmental monitoring also helps fish farmers to manage water quality better and disease prevention.

Environmental monitoring systems for wild-catch fisheries focus on climatic conditions and weather forecasts, and are managed by the National Centre for Hydro-Meteorological Forecasting. The centre maintains a network of environmental recording stations and conducts modelling for forecasting. The environmental monitoring parameters from this centre include temperatures, water levels (including rivers), changes in monsoonal rain patterns, typhoons, drought and storms, as well as the monitoring of pollution to protect aquatic resources. However, environmental monitoring activities for this sector are still new and small scale to compare to those for aquaculture.

The main threats potentially related to climate variability and climate change are changes in monsoonal rain patterns, impacts on water quality, typhoons, flood, drought, pollution of the environment and disease.

Environmental and climate data recorded from climate-related environmental monitoring departments are processed and analysed. Urgent information such as warnings of typhoons, floods, drought, seawater intrusions, red tides and pollution are disseminated immediately; weather forecast information is published every day for fish farmers and fishers in the mass media. Periodic environmental monitoring and recommendations are generally disseminated to fish farmers and fishers three days after monitoring.

Warnings and relevant environmental monitoring information is disseminated to farmers and fishers by radio, television, Web sites, newspapers, email and extension officers.

1.1 Survey overview

1.1.1 Survey location

The survey was conducted in 13 provinces in the lower Mekong River basin by the Research Institute for Aquaculture No. 2 in Ho Chi Minh City and the Directorate of Fisheries in Hanoi.

1.1.2 Sample size

In total, 51 respondents were interviewed, of which 17 were fish farmers, 16 were environmental officers, 15 were fishers, and 3 were researchers in aquaculture. Officers involved in environmental monitoring were working in the Department of Capture and Resource Protection, Aquaculture Department of the Ministry of Agriculture and Rural Development, Research Institute of Aquaculture No. 2, and the Department of Fisheries and Aquaculture of Tien Giang, Can Tho, Tra Vinh, Ben Tre, Soc Trang, Bac Lieu, Kien Giang and Tien Giang provinces. Farmers and fishers were from Tien Giang, Can Tho, Tra Vinh, Ben Tre, Soc Trang and Kien Giang provinces.

1.1.3 Survey method

Based on the questionnaires, the consultant team of Viet Nam interviewed relevant target groups in different provinces in the Mekong River Basin. The survey was conducted between December 2014 and January 2015.

1.1.4 Limitation

Some farmers and fishers do not know about environmental monitoring and therefore they cannot answer some of the questions.

1.1.5 Survey aim and objectives

The aim of the survey was to determine the current situation regarding climate-related environmental monitoring and early warning systems that are relevant to aquaculture and fisheries in the Lower Mekong River Basin.

2. OVERVIEW OF RESPONSES OBTAINED

Based on the requirements of the Network of Aquaculture Centres in Asia-Pacific (NACA), the Vietnamese team conducted surveys with 51 people, of which 33.3 percent were farmers (50 percent of them culture brackish-water shrimp and the remaining grow other species); 31.4 percent were fishers; 29.4 percent were environmental officers from provincial aquaculture departments and the Directorate of Fisheries; and 5.9 percent were researchers at the Research Institute for Aquaculture.

2.1 Current state of environmental monitoring systems communicating information from authorities to fishers and fish farmers

2.1.1 Knowledge of any existing national environmental monitoring systems

For the question: Are there any environmental monitoring systems that provide information to fisheries and aquaculture operations in your country? Of the total, 49 percent of respondents answered "yes", while the number of respondents who responded "no" and "unsure" was at 35.5 percent. both. The majority of those who responded "no" live in areas that have no local monitoring sites and poor communication. The respondents answering "yes" were mainly fish farmers who live in areas that have developed information on environmental monitoring. The fishers' group mainly responded that they did not know and were not sure about environmental monitoring. Most fishers said that they were concerned about the weather forecast, forecasting fishing, tides, currents and water levels; some of them pay a little attention to salinity and felt that these parameters should be informed daily. The fisheries and aquaculture experts' and the stakeholders' group were mostly aware that there are environmental monitoring systems that provide information on fisheries or aquaculture operations in the country.

Respondents who were aware of environmental monitoring systems considered important monitoring parameters to be water temperature, salinity and oxygen level; other parameters such as tides and currents were considered important by some respondents (cited by 36 percent and 28 percent, respectively; Table 1). A range of additional parameters were raised including COD, BOD, TSS, nitrite (NO_2), nitrate (NO_3) ammonia (NH_3), phosphate (PO_4), sulfur (H_2S) and heavy metals content.

TABLE 1
Percentage of respondents knowing of existing environmental monitoring parameters

Parameters	Percentage
Water temperature	96
Salinity	96
Harmful algal blooms	76
Water colour	60
Currents	36
Tides	28
Oxygen levels	96
Extraordinary climatic events	44
pH	88
Water level	48
Other parameters	40

2.1.2 Knowledge of any existing regional environmental monitoring systems

Regarding the question whether there has been any collaboration across countries of the Lower Mekong Basin (LMB) to provide information through an environmental monitoring system for fisheries and aquaculture, 33.3 percent of respondents answered "yes", and they were mainly from the fisheries and aquaculture experts' and stakeholders' group, who have much information about environmental monitoring; 41.2 percent of respondents were unaware of such collaboration and 5.5 percent of them said "unsure". Most of the people in the two last groups were farmers and fishers.

Respondents who knew about the existing regional (LMB) environmental monitoring systems indicated the parameters that are being monitored within these existing systems, as shown in Table 2.

TABLE 2
The percentage of parameters being monitored

Parameter	Percentage
Water temperature	94.1
Salinity	94.1
Oxygen levels	94.1
pH	94.1
Harmful algal blooms	76.5
Water level	70.6
Water colour	65.7
Tides	58.8
Other parameters	41.2
Currents	35.3
Extraordinary climatic events	35.3

Respondents thought that the parameters that should be added to monitor were ammonium (NH_4) and hydrogen sulfur (H_2S).

With regard to awareness of any collaboration across countries of the Lower Mekong Basin to provide information through an environmental monitoring system for fisheries and aquaculture, there was only one person (2 percent) who knew about the collaborations for environmental monitoring in the LMB. Meanwhile, 58.8 percent of respondents answered "no" and 39.2 of respondents were unsure about these collaborations. This shows that almost all respondents did not know about the collaborations for environmental monitoring in the LMB.

Regarding the monitoring parameters that are perceived to be most useful, most respondents thought that information on extraordinary climatic events, oxygen level, pH, water level and tides were very useful (Table 3). Other parameters were still considered necessary for monitoring both for aquaculture and fisheries.

TABLE 3
Perceived utility of different monitoring parameters

Parameter	Very useful	Useful	Neutral	Not very useful	Not useful at all
Water temperature	20.0	60.0	15.6	2.2	2.2
Salinity	26.7	44.4	24.4	4.4	0
Harmful algal blooms	23.7	39.5	23.7	7.9	5.3
Water colour	19.0	38.1	35.7	7.1	0
Currents	19.6	43.5	30.4	4.3	2.2
Tides	34.7	57.1	6.1	2.0	0
Oxygen levels	58.3	36.1	5.6	0	0
Extraordinary climatic events	64.4	17.8	6.7	2.2	8.9
pH	38.5	48.7	10.3	2.6	0
Water level	39.1	43.5	17.4	0	0

With the parameters mentioned, the frequency with which different parameters would ideally be monitored is presented in Table 4. The parameters that were most frequently considered to require real-time monitoring were extraordinary climatic events and oxygen levels, while most other parameters could be monitored daily or weekly.

TABLE 4
Perceived required frequency of the monitoring of different parameters

	In real time	Daily	Weekly
Water temperature	8.9	73.3	17.8
Salinity	7.1	45.2	47.6
Harmful algal blooms	10.5	44.7	44.7
Water colour	2.4	70.7	26.8
Currents	4.3	57.4	38.3
Tides	6.1	63.3	30.6
Oxygen levels	29.7	54.1	16.2
Extraordinary climatic events	54.3	30.4	15.2
pH	12.5	65.0	22.5
Water level	10.6	66.0	23.4

The systems of communication that aim to change the behaviour and knowledge of rural people were also analysed. With regard to appropriate communication media to communicating information on environmental parameters to fishers and farmers, the perceived utility of different communication media was assessed on a scale of 1 to 10, where 1 indicates that the medium is not useful, and a score of 10 indicating very high suitability. Most farmers agreed that email and newspapers are not effective; extension officers have little effect due to a shortage of officers for farmers to consult. Television and radio were regarded as suitable to provide monitoring information because farmers can easily access them and they reach fast. However, monitoring officers thought that email was a suitable way for them to provide environmental information. In general, the results showed that radio and television were considered to be very suitable media with mean scores of 7.94 and 7.9, respectively, as they are readily accessible and these media reach fast. Extension officers were less effective due to a shortage of personnel with a mean of 5.64, and email was not suitable for communicating information to farmers and fishers.

2.2 Provision of information from fishers and fish farmers to authorities: current state of environmental monitoring systems

For the question whether fisheries and aquaculture operations in Viet Nam provided information to authorities which then feed into a national environmental monitoring system, most respondents answered “unsure” at 56.9 percent, while 25.5 percent and 17.7 of respondents answered “yes” and “no”, respectively. Respondents also thought that the parameters that fishers and farmers provide information on for regional monitoring systems were mostly for the condition of farmed species (90 percent) and disease (90 percent); fish mortalities (60 percent) and pests (50 percent).

The respondents were asked about the perceived utility of these parameters; the results for each parameter are shown in Table 5. Most respondents considered the listed parameters to be very useful or useful.

TABLE 5
Perceived utility of these parameters (%)

	Very useful	Useful	Neutral	Not very useful	Not useful at all
Catch composition	34.3	40.0	20.0	5.7	0
Condition of farmed species	34.9	46.5	16.3	0	2.3
Disease	47.7	31.8	15.9	2.3	2.3
Fish mortalities	34.1	43.2	20.5	0	2.3
Pests	20.0	47.5	30.0	2.5	0

The frequency of these parameters that would ideally be monitored by fishers and farmers are shown in Table 6. The parameters should be monitored daily or weekly.

TABLE 6
Frequency of monitoring parameters

	In real time	Daily	Weekly	Monthly	Less often than monthly
Catch composition	17.1	45.7	5.7	25.7	5.7
Condition of farmed species	22.0	51.2	14.6	12.2	0
Disease	33.3	46.2	20.5	0	0
Fish mortalities	4.9	68.3	24.4	2.4	0
Pests	5.3	34.2	47.4	7.9	5.3

The monitoring methods used to collect data about the parameters are in Table 7. Some of the main methods of monitoring, which were used for all four of the parameters, were survey, observation and interview.

TABLE 7
Monitoring methods

Catch composition	Condition of farmed species	Fish mortalities	Pests	Disease
Survey	Survey	Survey	Survey	Survey
Statistics	Observation, monitoring, sample collect	Interview, active surveillance	Interview, active surveillance	Collect samples and observation
Based on catch data	Interview, survey, recording by farmers	Observation ponds	Observation ponds	Using lab
Recording and interviews to fishers based on reality	Collect samples and observation	Monitoring	Monitoring	
Caching net	Observation	Using lab		
Fish finder	Observation ponds	Recording and interviews with farmers based on reality		
Radar	Collect samples, surgery and observation			
Indicator	Periodic aquatic animal health checking and testing			

Respondents were also asked about the way monitoring information was communicated. They rated communication media on a scale of 1 to 10, where 1 indicates that the medium is not useful and a score of 10 indicating very high suitability. The most suitable means for farmers to communicate monitoring information to the authorities was perceived to be through extension officers with 6.1 points, paper reporting at 5.2, and email was not suitable, at only 3.3.

In general, fishers and farmers in the area of the survey paid little attention to environmental monitoring. Many of them had not heard what environmental monitoring was about. Most farmers agreed that environmental monitoring information was difficult for them to reach. This was often because their education levels were low, so it was difficult for some of them to understand the parameters. Some of them also pointed out that they did not know where or when they could see or hear environmental reports; that communication systems at the local level were not good; and that environmental reports provided for farmers were still slow to arrive. Farmer awareness of monitoring appeared to be related to the sites, frequency, and information/reporting results of monitoring. In areas that had no local monitoring sites and bad communication, farmers often had a very poor understanding about monitoring, whereas farmers in provinces with intensive monitoring had better awareness and applied the information on their farms. Intensive shrimp farmers were aware about the importance of monitoring the environment, and they were often interested in monitoring reports about water quality as they had decide when to take water into their ponds or not. Most of them conducted their own monitoring with quick tests to assess parameters such as pH, salinity, dissolved oxygen and alkalinity every day, and ammonia (NH_3) and hydrogen sulfide (H_2S) every week. However, there were still some farmers who were not interested in monitoring reports, mainly because of their lack of knowledge and communication barriers. Environmental monitoring staff or officers related to environmental monitoring activities in aquaculture were aware of environmental monitoring systems that provide information to aquaculture operations in Viet Nam and the Lower Mekong Basin. They recommended that it is necessary to improve monitoring capacity by training monitoring officers, supplying equipment for monitoring, and improving communication systems.

3. CONSTRAINTS AND CHALLENGES

Environmental monitoring systems for aquaculture in Viet Nam still have some shortcomings, such as adequate funds to implement regular monitoring, scope, object, frequency and data analysis. Methods used for environmental monitoring are inconsistent between agencies and inadequate for all provinces; monitoring equipment is still lacking and outdated; and monitoring capacity (human resources) is still low. Moreover, developing a system for environmental monitoring and early warning for aquaculture and fisheries under climate change is needed for sustainable development of the sector.

Challenges to the effective reporting of baseline environmental information by fishers and farmers include time, financial and resource constraints, unwillingness to report, lack of awareness on environmental monitoring, lack of a data recording system, low levels of education, lack of guidance and coordination, reporting delays, non-uniform communication systems, a lack of trust in authority, and not knowing who to provide information to.

It is important to develop an environmental monitoring network at the national and regional levels for better management of the environment, as well as for sharing information in terms of climate change and pollution. However, it is perhaps difficult to establish collaboration across countries of the Lower Mekong Basin to develop such a system for fisheries and aquaculture, as it depends on the status and capacity of neighbouring countries monitoring systems and how they work; it is also difficult for countries with a larger number of farms because more monitoring locations are required; and there is a lack of funds as well as experts for collaboration.

4. RECOMMENDATIONS

Although Viet Nam has had an environmental monitoring and early warning system for aquaculture since 2004, the system is still not working properly. Environmental monitoring systems for fisheries mainly consist of weather forecasts and water pollution monitoring. It is necessary to continue development of the monitoring systems by supporting operational budgets, training officers about monitoring methods, data analysis, preparation and use of early warning reports (recommendation reports). Environmental monitoring and early warning systems as well as weather forecasts to support fisheries innovations are needed. These issues are requiring external support for improvement of early warning systems.

The Lower Mekong River Basin is one of the main sources of water for 13 provinces in Viet Nam; hence, monitoring of the aquatic environment and improvement of early warning systems will strongly support fisheries and aquaculture in the region. While the resources for monitoring are currently limited, the issue is very important. It is necessary to establish collaboration between riparian countries to develop a regional environmental monitoring system for fisheries and aquaculture so that information can be more effectively shared between riparian countries and water management and utilization improved.

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FAO/NACA Workshop
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These proceedings report the result of a sub-regional consultation on the existence and effectiveness of environmental monitoring systems for fisheries and aquaculture in the Lower Mekong basin. The document also includes a baseline assessment of environmental monitoring systems in Cambodia, Thailand and Vietnam, and the report of a regional workshop to discuss the assessments findings and future steps to improve an environmental monitoring and early warning system that will improve climate change adaptation in fisheries and aquaculture in the area.

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