Building Local Warning Networks for the Detection and Human Dimension of Ciguatera Fish Poisoning in Indonesian Communities: The PICES-MAFF Ciguatera Project

Edited by
Mitsutaku Makino and Mark L. Wells

June 30, 2023

Table of Contents

Acknowledgements

PICES has had a long relationship with Indonesia since the first project, which was funded by the Japanese Official Development Assistance Program (ODA) in 2007–2012. We are very pleased that this relationship is still going on.

For our "Transformative Ocean Science" approach in conducting these ODA projects, the aim is to co-design, co-research, and co-implement activities with local communities, rather than to use a more standard parachute-type top-down citizen science tactic. With this approach the local stakeholders become essential members of the project. Productive and reliable connections among the stakeholders and PICES researchers are critical, and without their collaboration the project would not exist.

The National Research and Innovation Agency of Indonesia (Badan Riset dan Inovasi Nasional, BRIN-Indonesia) and the Institute of Technology of Indonesia (Institut Teknologi Indonesia, ITI) have played a critical role in this aspect. These organizations have identified and linked us with local key persons and major organizations, coordinated their intentions and needs, assisted in building mutual trust, arranged capacity building workshop venues and provided logistics for these events, participated in designing training contents, recommended case study sites, planned field visits, and acquired a substantial dataset for the project. Their work was diverse and demanding. We cannot thank them enough.

Special thanks go to Dr. Suhendar I Sachoemar and Mr. Arief Rachman. Without their scientific expertise, and enduring friendships, this project would never have achieved such success. We would like to express our deepest respect and gratitude to them.

We hope this project will contribute to future marine science collaborations and the continuing friendship between PICES and Indonesia.

Executive Summary

Benthic harmful algal bloom (HAB) species, such as the causative organisms underlying Ciguatera Fish Poisoning (CFP), arguably have the greatest human health and economic impacts of any algal-based poisoning syndromes. CFP stems from the human consumption of fish containing toxins produced by benthic microalgae of the dinoflagellate genera *Gambierdiscus* and *Fukuyoa*. Although ciguatera and other toxin-producing benthic HABs can occur in pristine environments, anthropogenic pressures and climate change are leading to its emergence in new regions, and intensification in others. Currently the human health and socio-economic effects of benthic HABs are poorly understood. This was the motivation for PICES (North Pacific Marine Science Organization) to accept a request from the Japanese government to undertake a project entitled "*Building local warning networks for the detection and human dimension of Ciguatera Fish Poisoning in Indonesian communities*" (acronym Ciguatera) and funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan, from the Official Development Assistance Fund. The project started in April 2020 and was completed in March 2023.

The objective of the project was to build the capacity of local small-scale fishers and community members to monitor their coastal ecosystems and coastal fisheries to benefit human health. The project's focus was to detect and monitor benthic HAB species in tropical reef fisheries to ensure seafood safety. Consistent with the directives of the United Nations Decade of Ocean Sciences for Sustainable Development (UNDOS), the project included three major initiatives:

1. Coastal ecosystem monitoring activities by local small-scale fishers and other community members to detect ecosystem changes using smartphone-based technology;
2. Detection of CFP toxin-containing dinoflagellates in the reef environment using two approaches: (a) implementing smartphone-based tools developed during the FishGIS project, and (b) employing internationally-standardized sampling protocols for toxic benthic algae.
3. Training of local fishers and community members to utilize these tools for generating citizen-science data available for local decision-making on coastal fisheries to avoid the transfer of contaminated fish to the tables of families.

COVID-19 seriously affected the project activities because travel limitation largely prevented the planned training workshops in Indonesian communities. However, several important outputs were produced.

- A Project Design Matrix (PDM) was developed to effectively manage the project. Though we were unable to fully benefit from this approach due to pandemic restricted interactions, applying the Project Cycle Management strategy and the PDM will accelerate progress in future projects.
- A smartphone-based tool (FishGIS application) that enables local communities to collect environmental observations and fisheries data to aid in the development of fisheries management

strategies was updated, with major modifications, and made available on Apple Store and Google Play.

- Planktoscope, a low-cost microscope platform that allows automated image collection of phytoplankton cells for species identification and enumeration, was deployed in the Gili Matra region.
- Scientific planning input and funding support were provided for five field sampling surveys in Gili Matra waters, led by our Indonesian colleagues. Indonesian researchers also collected fundamental socio-economic data in the area using the same methodology as in the previous PICES-MAFF projects (on-site surveys, questionnaires, and focus group discussions). Analysis of samples is still ongoing, but preliminary results indicate that the threat of CFP in this area currently is low.
- A community training and knowledge dissemination workshop was held in January 2023, in Lombok, Indonesia. Workshop and research activities in the Gili Matra region were widely reported by the Indonesian mass media.
- Finally, a (bow-tie) CFP risk assessment model was constructed that summarizes the connections among the coastal environment, ciguatoxins, human exposure to these toxins, and the CFP risk.

Although not all of the originally planned activities of the Ciguatera project were implemented due to the COVID-19 pandemic, a new 3-year PICES-MAFF project has been approved, with expectation that a major case study site will be the Gili Matra region, where a field sampling protocol has been developed, preliminary network of local people and researchers has been established, a basic understanding of potential CFP impacts has been communicated to local communities and the regional government, technical training has been initiated, and technologies have been disseminated among the key local individuals. The Provincial Government of West Nusa Tenggara has indicated strong interest and political will to assist in supporting the new project, which will be essential for sustaining the planned observation and response activities after completion of the project.

1 Introduction

1.1 Project background, objective and initiatives

PICES member countries have significant resources for monitoring environmental conditions and fisheries in coastal waters. At the same time developing nations are far more limited in their capacity for collecting data needed to advance their management practices in these waters. Citizen-based monitoring is an approach designed to improve the efficiency and effectiveness of monitoring efforts when technical and financial resources are not sufficient. There are many successful examples of citizen-based monitoring in developed countries. However, this approach has not been widely applied yet to the collection of environmental and fisheries data in developing nations. Based on such recognition, PICES has already conducted a citizen-based monitoring project "*Building capacity for coastal monitoring by local small-scale fishers*" (2017–2020; FishGIS), funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan.

Motivation was the same for a follow-up project entitled "*Building local warning networks for the detection and human dimension of Ciguatera Fish Poisoning in Indonesian communities*" (Ciguatera). This 3-year (April 1, 2020–March 31, 2023) project was also funded by MAFF, through the Fisheries Agency of Japan (JFA), from the Official Development Assistance (ODA) Fund. The objective of the project was to build the capacity of local small-scale fishers and community members to monitor their coastal ecosystems and coastal fisheries to benefit human health in Pacific Rim developing countries. The project's focus was to detect and monitor benthic harmful algal bloom (HAB) species in tropical reef fisheries to ensure seafood safety.

Benthic HAB species, such as the causative organism underlying Ciguatera Fish Poisoning (CFP), arguably have the greatest human health and economic impacts of any algal-based poisoning syndromes. CFP stems from the human consumption of fish containing toxins produced by benthic microalgae of the genera *Gambierdiscus* and *Fukuyoa*, dinoflagellates which are the initial sources of ciguatoxin. Ciguatoxin affects sodium transport channels in an organism by lowering the voltage-gated opening in their cells, thereby altering the nervous system in ways that negatively affect numerous aspects of fish and animal physiology. Ciguatoxin is lipophilic, meaning that it accumulates in fatty tissues and becomes concentrated up the food web. When present in sufficiently high concentrations in raw or cooked fish, it leads to the onset of the major CFP symptoms – vomiting, diarrhea, numbness of extremities, mouth and lips, reversal of the sensations of hot and cold, muscle and joint aches – within 1 to 3 hours of ingestion and may last for days, weeks or even months.

The effect of CFP on the human dimension extends far beyond the proximate health and economic outcomes – chronically-impacted communities in the Pacific region and elsewhere can become fearful of local and other fish sources and transition from their traditional ways of life to one where all protein is imported from foreign sources, altering their cultural heritage.

CFP is endemic in many tropical Pacific regions. Although Ciguatera and other toxin-producing benthic HABs can occur in pristine environments, anthropogenic pressures and climate change are leading to its emergence in new regions, and intensification in others. There is evidence of range extension of these species into the waters of PICES member countries, which is raising significant concerns. The expansion of dead corals and eel-grass habitats that replace healthy coral reefs facilitates intrusion and establishment of exotic populations of toxin-producing benthic algae. Despite the widespread impacts of benthic HABs, the resultant health and socioeconomic effects remain poorly understood.

Indonesia was chosen as a developing Pacific Rim country to implement the Ciguatera project. This country is part of the Coral Triangle, the most biodiverse marine area on Earth, and these extensive reefs are key to maintaining the ecological products that contribute to fisheries in this region. However, presently only about 7% of these coral reefs are in excellent condition, while anthropogenic stressors have left more than 30% in poor condition. Decreasing coral health in Indonesia is a relatively new phenomenon compared to other areas of the world, and the human coastal populations living adjacent to the deteriorating corals are not yet fully aware of the consequences of this change. Communities must understand the risks of exposure to keep the impact of benthic HABs to a minimum. The highest risk is when the reefs, which communities depend on for fish, have large patches of dead coral or large seagrass mats, as these surfaces are ideal for the growth of benthic algal cells. Current reports of benthic HAB occurrences such as CFP are low in Indonesia, almost certainly because diagnosis is difficult without proper training and experience.

The FishGIS project led to the development and implementation of smartphone-based tools for fisheries and environmental observations, such as water quality, phytoplankton, fish catch, floating garbage (plastics) and Illegal Unregulated and Unreported (IUU) fishing, by local small-scale fishers and community members in Indonesia. The Ciguatera project aimed to adapt and further refine these smartphone-based capabilities for measurement and automated reporting, with the addition of benthic toxic algae measurements, to empower Indonesian coastal communities to minimize their CFP exposure in community-scale fisheries.

Consistent with the directives of the United Nations Decade of Ocean Sciences for Sustainable Development (UNDOS), the project included three major initiatives:

1. Coastal ecosystem monitoring activities by local small-scale fishers and other community members to detect ecosystem changes (*e.g.*, changes in water quality and the presence and changes in the spatial distribution of dead coral and eel-grass benthic environments) using smartphone-based technology developed during the FishGIS project and modified/refined during the Ciguatera project;

2. Detection of CFP toxin-containing dinoflagellates in the reef environment using two complimentary approaches: (a) implementation of smartphone-based tools developed during the FishGIS project, and modified/refined during the Ciguatera project, and (b) employing internationally-standardized sampling protocols for toxic benthic algae;

3. Training of local fishers and community members to utilize these tools for generating citizen-science data available for local decision-making on coastal fisheries to avoid the transfer of contaminated fish to the tables of families until the presence of CFP toxin-containing dinoflagellates is minimized.

In addition to the primary initiatives, early steps were taken to explore two secondary initiatives: modifying the FishGIS application to incorporate (1) artificial intelligence-based assessment of fish stocks from the collective catch data reported by the local fishers, and (2) a tsunami early warning notification for remote fishing communities, with the goal of laying the foundation for future full development of these capabilities.

It was expected that the primary initiatives will be supported by a series of capacity building workshops led by scientists from PICES member countries, aiming to work with local communities to increase the sustainability of their fishing resources by providing them with CFP information. The field observations were planned to be carried out by local small-scale fishers and community members. It was anticipated that the combination of training and citizen-science contributions in the project would: (1) generate the needed capacity for monitoring CFP hotspots in Indonesian waters, (2) provide valuable datasets for the study of *Gambierdiscus* and *Fukuyoa* and the factors controlling their abundance in reef systems, and (3) increase human wellness by identifying fishing regions where the health of community members is at risk.

However, the COVID-19 pandemic seriously affected the original project strategy, especially by limiting the opportunity for PICES experts to visit field sites and organize meetings and community training workshops with local people. Only one capacity building workshop was held in Lombok close to end of the project, in January 2023 (see Chapter 6). The pandemic-related delays to the planned on-site training workshops led to augmenting and expanding Indonesia's National Research and Innovation Agency (BRIN-Indonesia; hereafter referred to as BRIN)-planned surveys of waters surrounding the Gili Islands (Gili Matra) consisting of three islands: Gili Trawangan, Gili Meno, and Gili Ayer, to facilitate data collection. A portion of Ciguatera project funds was re-directed to support a total of five extended surveys conducted in different seasons during the period from May 2022 to February 2023.

1.2 Linkages within PICES and project organization

The request to undertake the Ciguatera project was approved by PICES Governing Council in February 2020. The project principles agreed to by MAFF/JFA and PICES are listed in Appendix 1.

The project had strong connections and interactions with the PICES Scientific Committees on Human Dimensions (HD), Fishery Science (FIS), and Marine Environmental Quality (MEQ) (through the Section on *Ecology of Harmful Algal Blooms in the North Pacific* — S-HAB), PICES Technical Committee on Data Exchange (TCODE) and Monitoring (MONITOR), and the PICES FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Ecosystems) program (specifically, Research Theme 3 on "*How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?*"). HD was the parent committee for the project (Fig. 1.1).

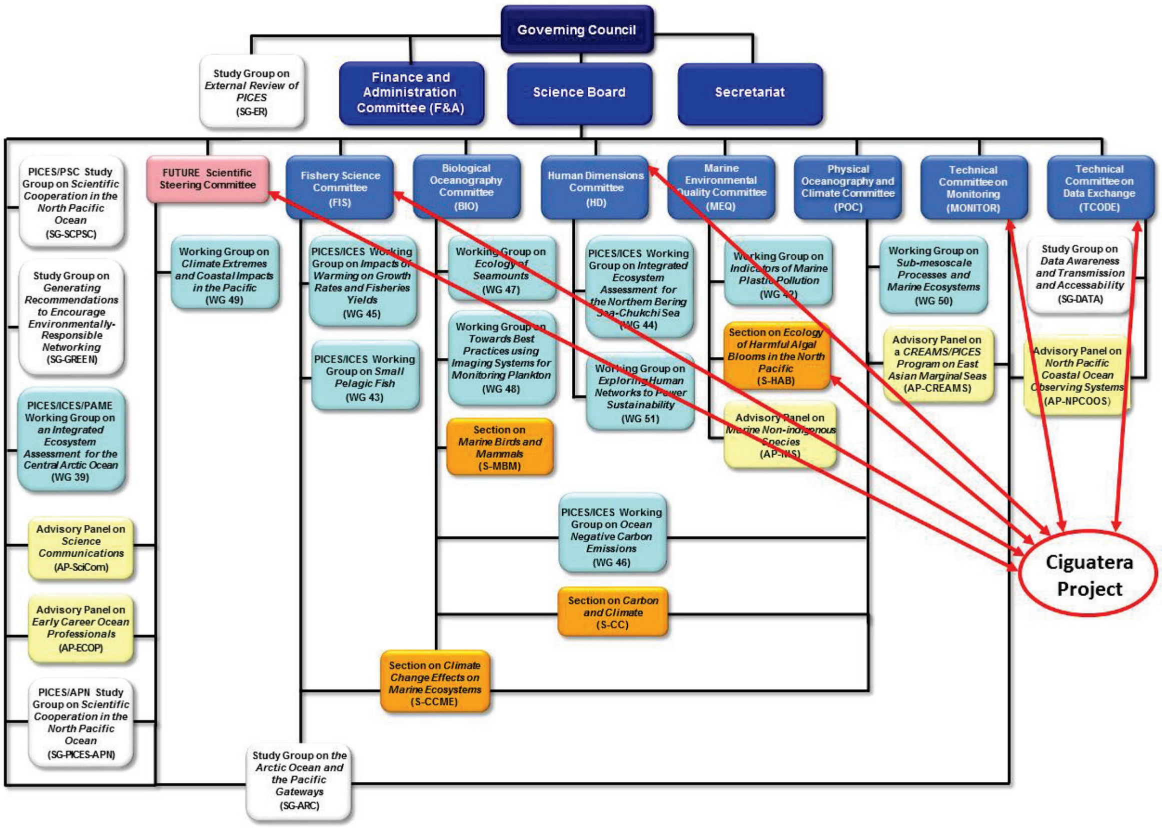


Fig. 1.1 PICES (North Pacific Marine Science Organization) structure for 2022–2023 showing links between the Ciguatera project and PICES expert groups and committees.

To direct the project, a Project Science Team (PST) was formed by PICES Science Board based on principles and procedures detailed in the PICES Policy for approval and management of special projects (Decision 2017/A/7). All PICES member countries and relevant Scientific and Technical Committees were represented on the PST. The majority of the PST members were involved in the 2017–2020 FishGIS project. As the leading Indonesian collaborators were also those who participated in the previous PICES-MAFF projects, retaining this core group was important to facilitate implementation of this project. PST membership is shown in Table 1.1 and contact information for PST members is provided in Appendix 2.

The PST was co-chaired by Dr. Mitsutaku Makino (HD Committee Chair; Japan) and Dr. Mark Wells (S-HAB Co-Chair; USA), and this selection provided the desirable geographical balance and the balance of expertise between the human dimension and harmful algal bloom components of the project. The PST Co-Chairs were responsible for the scientific implementation of the project and annual reporting to MAFF/JFA and to PICES Science Board through the HD Committee. In PICES, Science Board took on the task for reporting to Governing Council on the progress and achievements of the project. The Year 1 progress report was submitted to MAFF/JFA on June 20, 2021 (accepted on June 27), and the Year 2 progress report was provided to MAFF/JFA on June 12, 2022 (accepted on June 29).

Table 1.1 Project Science Team membership.

Name	Affiliation	Country/Group
Daisuke Ambe	Japan Fisheries Research and Education Agency	Japan/TCODE
Seung Ho Baek	South Sea Research Institute, KIOST	Korea/S-HAB
Vladimir Kulik	Pacific Branch of VNIRO ("TINRO")	Russia/MONITOR
Mitsutaku Makino*	Atmosphere and Ocean Research Institute, The University of Tokyo	Japan/HD
Shion Takemura	Japan Fisheries Research and Education Agency	Japan/HD
Naoki Tojo	Hokkaido University	Japan/FIS
Vera Trainer	Northwest Fisheries Science Center, NOAA/Univ. of Washington	USA/S-HAB
Charles Trick	University of Toronto	Canada/S-HAB
Pengbin Wang	Second Institute of Oceanography, Ministry of Natural Resources	China/S-HAB
Mark Wells*	University of Maine	USA/S-HAB

* Project Co-Chairs

During the lifetime of the project, the PST had seven formal meetings. Due to the COVID-19 pandemic, the first five meetings (including all four meetings in Year 1 and Year 2) were held online, and only the last two meetings in Year 3 were in-person. The PST meeting reports can be found in Appendix 3.

- The first PST meeting was held on March 10, 2021 (Japanese Standard Time – JST) to: (1) review the overall strategy and general directions for the project, (2) create timelines for project activities and deliverables, (3) determine the main elements of the Year 2 workplan, and (4) initiate the development of a Project Design Matrix (PDM).
- The main objectives for the second PST meeting on July 13, 2021 (JST) were to: (1) review the updates in the FishGIS smartphone application, (2) discuss the draft PDM and further steps in the development of this framework, and (3) reassess and modify the project implementation planning.
- The main objectives for the third PST meeting on August 31, 2021 (JST) were to: (1) review existing data on benthic HABs in Indonesia, (2) evaluate the developed PDM (ver. 1) and Plan of Operation (PO; ver. 1), and (3) discuss research ethics issues.
- The main objective for the fourth PST meeting on September 16, 2021 (JST) was to discuss the PDM and PO development with emphasis on the inputs from the PST members and Indonesian colleagues, and on the anticipated outcomes.
- The main objectives for the fifth PST meeting on April 26, 2022 (JST) were to: (1) summarize Year 2 activities, (2) review the current state of the FishGIS application and suggested improvements, and to discuss the Terms of Use and Privacy Policy of the application, (3) reassess and modify, if needed, plans for the enhanced field sampling program in Indonesia, and (4) initiate planning for a community training and dissemination workshop in the Gili Matra region in early 2023.
- The sixth PST meeting (Fig. 1.2) was convened September 22, 2022, in Busan, Korea, in conjunction with the 2022 PICES Annual Meeting to: (1) review the current state of the FishGIS application, (2) assess the results to date from the field sampling program in the Gili Matra region and modify, if needed, plans for the follow-up surveys, and (3) discuss activities for the rest of Year 3, including a community training and dissemination workshop in Lombok in January 2023 and a final PST meeting in March 2023.

- The seventh (final) PST meeting (Fig. 1.3) was held March 16–18, 2023, in Yokohama, Japan, to: (1) review the outcomes from the January 2023 community training workshop in Lombok (Indonesia) and the results from the Indonesian field sampling program in the Gili Matra region (May 2022–February 2023), (2) summarize the outcomes from the project and finalize the tasks for the preparation of the final reports, and (3) set the stage for a new 3-year PICES-MAFF project (2023–2026).

Fig. 1.2 Participants of the sixth PST meeting held September 22, 2022, in Busan, Korea (l to r): first row – Suhendar I Sachoemar (ITI and BRIN, Indonesia), Mitsutaku Makino, Shion Takemura, and Tatsuki Oshima (MAFF/JFA, Japan); second row – Arief Rachman (BRIN, Indonesia), Alexander Bychkov, Vera Trainer, Seung Ho Baek, Mark Wells, Charles Trick, Daisuke Ambe, and Moonho Son (NIFS, Korea).

Fig. 1.3 Participants of the seventh PST meeting held March 16–18, 2023, in Yokohama, Japan (l to r): first row – Suhendar I Sachoemar, Pengbin Wang, Mitsutaku Makino, Tatsuki Oshima, Dong Wook Kim (NIFS, Korea), and Mihye Hwang (MOF, Korea); second row – Alexander Bychkov, Charles Trick, Mark Wells, Naoki Tojo, Daisuke Ambe, Seung Ho Baek, Shoto Sato (MAFF/JFA, Japan), Moonho Son, and Arief Rachman. Missing from photo – Shion Takemura.

In addition, there were several virtual meetings involving the PST leadership and main Indonesian colleagues (Dr. Suhendar I Sachoemar and Mr. Arief Rachman) to: (1) explore revisions to the project implementation plan under the Indonesian pandemic restrictions for national and international travel, (2) review the overall design and field program for the Ciguatera Indonesia project, and (3) discuss and develop a justification and framework for initiating a new formal collaboration between PICES and the Institute of Technology of Indonesia (ITI).

1.3 Project funding

A total MAFF contribution for the project was $292,653 CAD: $99,861 in Year 1, $99,875 in Year 2 and $92,917 in Year 3.

In accordance with the financial principles agreed to by MAFF/JFA and PICES (Appendix 1), Dr. Alexander Bychkov was appointed by the PICES Executive Secretary to serve as the Project Coordinator and was responsible for the management of the fund and annual reporting on its disposition to MAFF/JFA and to PICES Finance and Administration Committee. In PICES, the Finance and Administration Committee took on the task of reporting to Governing Council on the financial and management aspects of the project.

Annual reports to MAFF/JFA are due within 90 days after the close of each project year ending March 31. The Year 1 financial report was submitted on June 12, 2021, the Year 2 financial report was provided on June 12, 2022, and the Year 3 (final) financial report was submitted on June 16, 2023.

1.4 Project support and partners in Indonesia

Indonesia was chosen as a developing Pacific Rim country to implement the Ciguatera project. The importance of having more effective fisheries management practices is widely recognized in Indonesia, and this has led to support by the federal government and the willingness of stakeholders to consider new approaches such as the development and implementation of a citizen/fisher-based observation system linked with fisheries scientists and managers.

The Ciguatera project was the fourth PICES project in Indonesia funded by MAFF, with its foundation being the strong collaborations developed with the Indonesian government agencies and research institutions during PICES-MAFF projects conducted in the period from 2007 to 2020. One of the first, and strongest, lessons learned from these projects is the importance of connecting with organizations in a developing country which can facilitate and advance the project – these organizations and their key people are needed to understand the project and to translate it into the local context.

The Indonesian Agency for the Assessment and Application of Technology (BPPT) and the Indonesian Institute of Sciences (LIPI) have been our major partners for the previous three PICES-MAFF projects (for more than a decade!) – "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" (2007–2012), "*Marine ecosystem health and human well-being*" (2012–2017; MarWeB), and "*Building capacity for coastal monitoring by local small-scale fishers* (2017–2020; FishGIS). Recently, BPPT and LIPI have been incorporated into the National Research and Innovation Agency of Indonesia (BRIN), which better enables the collective collaboration in the Ciguatera project.

In addition, PICES has established a Memorandum of Understanding (MOU) with the Institute of Technology of Indonesia (ITI) with the goal of integrating both faculty expertise and student involvement into the project to enhance its longer-term sustainability. A virtual MOU Signing Ceremony took place on March 23, 2022 (JST) (Fig. 1.4). ITI's focus on the application of technology across environmental science and industry is well suited as a framework for supporting current and future PICES-MAFF projects in Indonesia. Project activities also were supported by the Provincial Government of West Nusa Tenggara (WNT) which provided invaluable assistance in organizing a community training and dissemination workshop in Lombok.

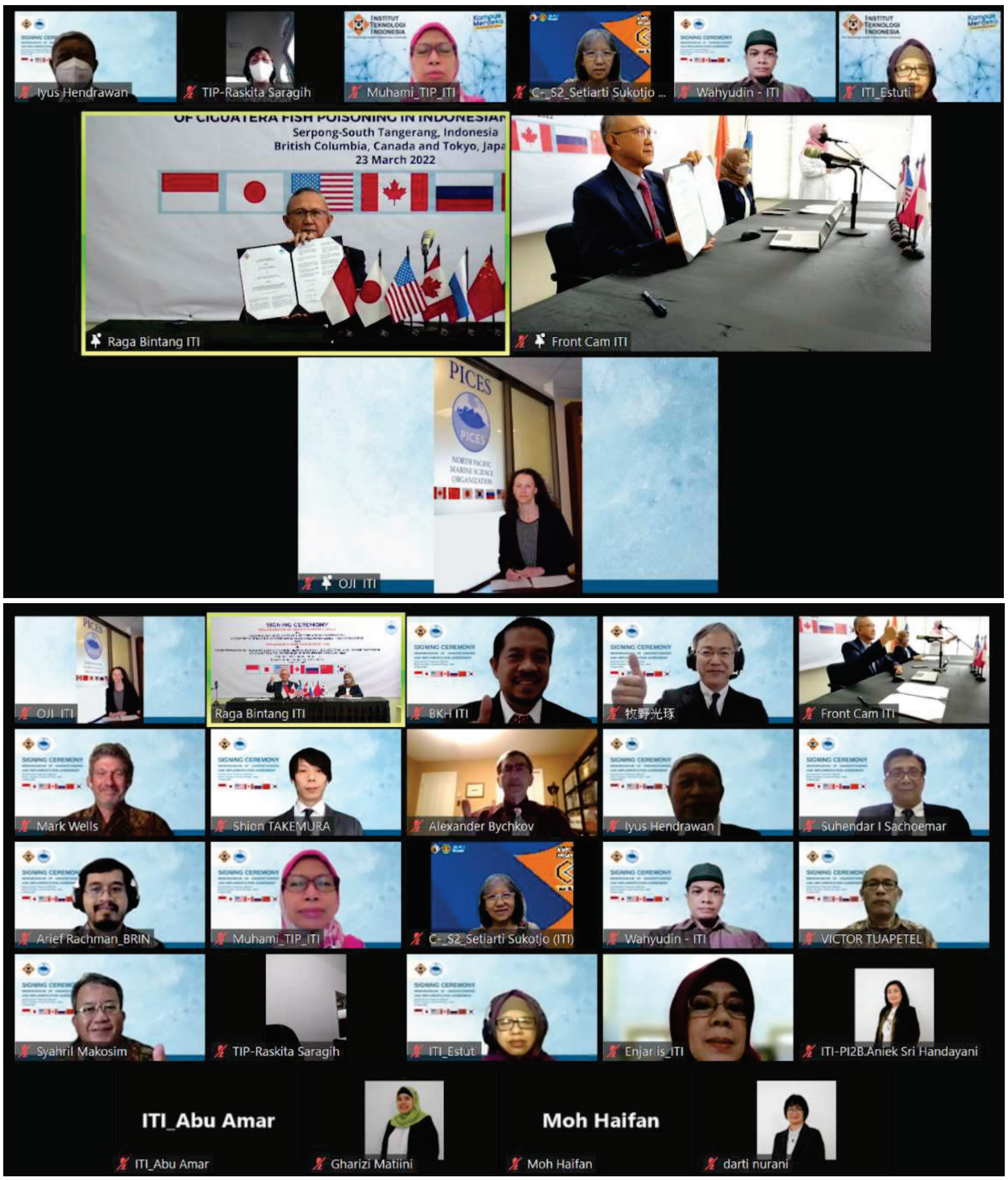


Fig. 1.4 Participants of the virtual Signing Ceremony for the MOU between ITI and PICES held on March 23, 2022. The MOU was signed by Dr. Marzan A Iskandar (ITI Chancellor) and Dr. Sonia Batten (PICES Executive Secretary).

2 Research and the Collaboration between PICES and MAFF

Research fosters the exchange of ideas and engagement around essential concepts in private and public realms and can thus be a force for social meaning and change. Compelling research communicates, connects, and transforms individuals, communities, and institutions.

Social meaning is particularly poignant when researchers step outside the institution directly into communities. The social, economic, and civil collectives of many coastal communities are undergoing significant pressures from losing an association with marine resources. The common attribute of marine resources is food, from the financial risks and benefits of fishing to the sustainable supply of marine-based human nutrition.

In 2016, PICES created the Human Dimensions Committee (HD) with the expressed aim to "promote and coordinate interdisciplinary research that leads to increased understanding of the relationship between North Pacific marine ecosystems and the people, communities, and economies that are part of those systems and rely on the resources and services they provide." The mandate of HD was robust. It would generate an integrated science project considering the impact of biophysical changes on the well-being of people, communities, and economies considering their characteristics and values. Adding members of associated PICES groups, such as the Marine Environmental Quality Committee through its Section on Ecology of Harmful Algal Blooms in the North Pacific, broadened the research into the drivers of change in marine ecosystems. For PICES, the triad of discovery is illustrated in Figure 2.1a.

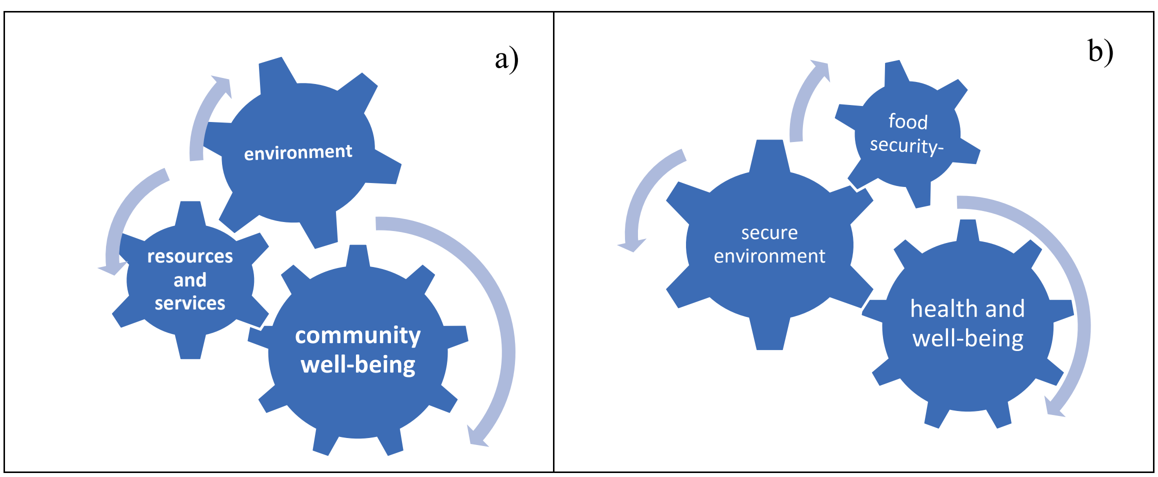


Fig. 2.1 Illustrations reflecting the purposeful mandates of (a) PICES and (b) MAFF regarding community research and marine resources.

When PICES partnered with the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, the latter's mission blended almost seamlessly with the PICES mandate (Fig. 2.1b). MAFF is dedicated to ensuring that future generations have food security and a secure environment, as these are the basis for human health and well-being. While denoted differently in each organization, the three criteria in Figure 2.1a represent the design of the Ciguatera project and all the other MAFF-PICES collaborations.

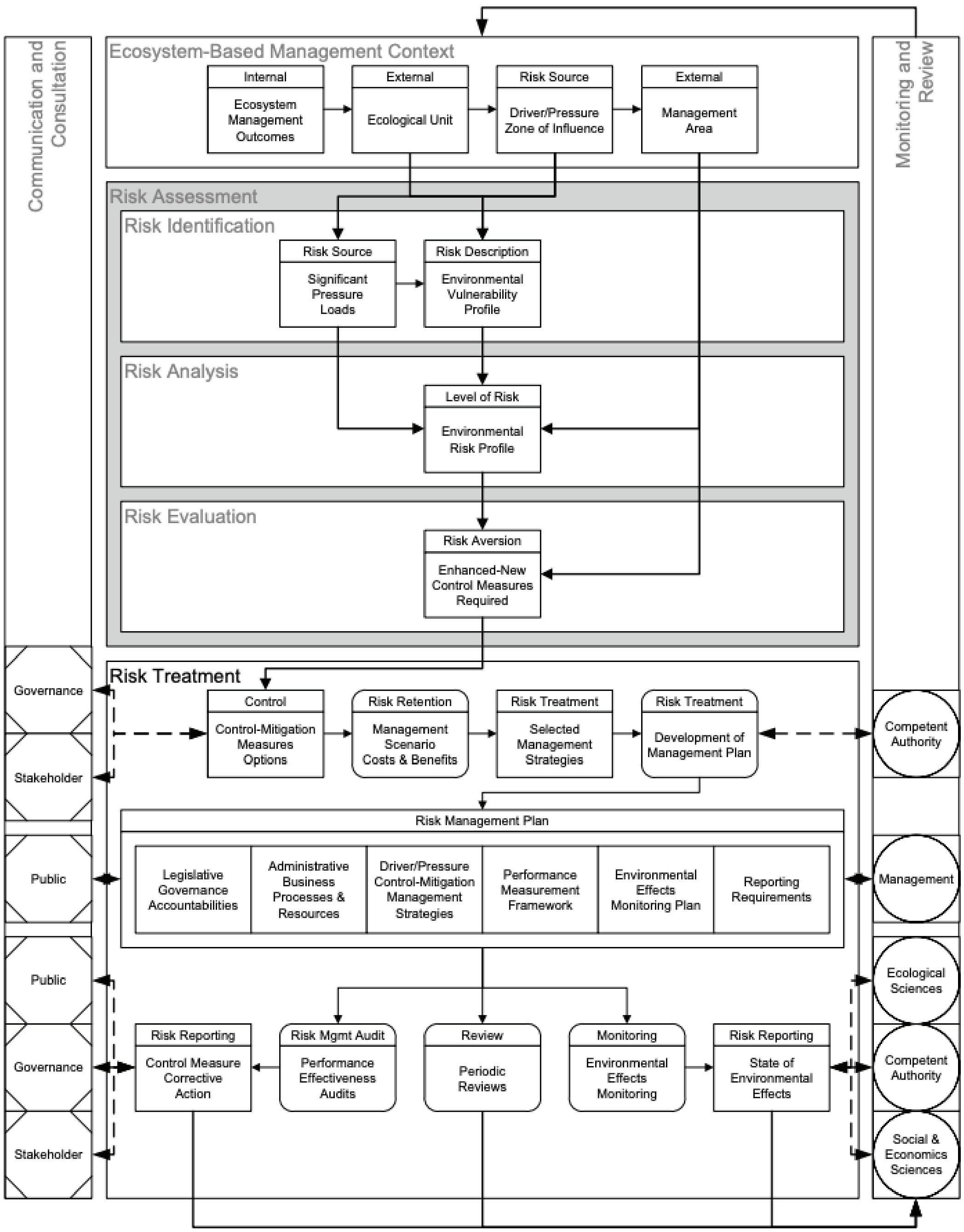


Fig. 2.2 The DPSIR (driving forces, pressures, state, impacts, responses) frameworks for marine system design assessment and risk. From Cormier *et al.*, 2013.

While comparing definitions indicates considerable intellectual and practical overlap, Figure 2.1 also reveals the need for evidence-based information to bring adequate understanding regarding the definitions. Alternative models of research design are required. One of the most common general frameworks for marine system design assessment is DPSIR (driving forces, pressures, state, impacts, responses, Cormier *et al*., 2013) and represents the "gold standard" of community-based risk assessment regarding marine systems (Fig. 2.2). Though the complexity gives the DPSIR model robustness and broad application, a simpler model is needed to convey marine risk, environmental change, and community response — the bow-tie assessment.

The basic structure of the bow-tie assessment is illustrated in Figure 2.3. This is a modified version of the ISO 30100 risk assessment model. One of the project PST members (Prof. Charles Trick) has used it for water quality-human risk assessments in the Laurentian Great Lakes.

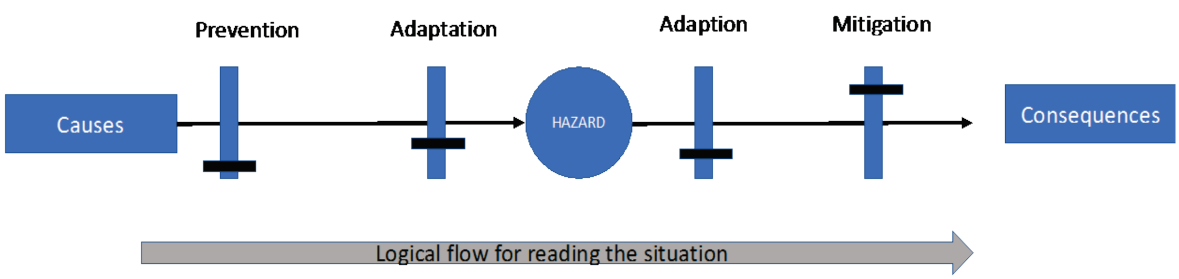


Fig. 2.3 Diagram of the standard design and components of the bow-tie risk assessment model. In the cases of PICES and MAFF, the hazard is the marine toxin (ciguatera toxin – CTX), and the consequences are issues of either having CTX-containing fish in the community catch (economic decline) or eating CTX-containing fish (ciguatera fish poisoning, CFP). The causes are environmental drivers that alter the level of CTX-producing dinoflagellates, the level of CTX per cell, or the relative transfer of CTX to fish. Control of the drivers prevents the accumulation of the toxin. Control the processes on the right of the hazard, and control humans' exposure (mitigation) to the risk. The vertical bars with the horizontal slide are indicators of knowledge of how important the movement along the arrow is. A high slider for mitigation might mean that toxin measurement is in effect. The community exposure to the toxin can be low by redirecting the fish away from the food supply. The low slider on the left, for example, for this chosen environmental driver, is not variable and is not affecting the levels of toxin to a great extent.

A more fully realized bow-tie for this project would resemble Figure 2.4. Here, there are multiple drivers, each with some logic as to how the driver might affect the toxin level in the fish. In addition, there are various consequences on how the toxin might impact a community (illness, lack of well-being, loss of food security, *etc*.).

Building on this model, the Ciguatera workshop activities can be aligned with the different environmental drivers that are likely to impact the establishment of the CTX-producing cells, the level of CTX in the phytoplankton, the effective movement into a sub-group of the fish, and the transfer to the plates of community members (Fig. 2.5). Overall, the PICES measurements could be used as an adequate early warning of risk to the fish ecology and the consumers. When there are specific changes in the environment, a mental alarm goes off, and there is a perceived increase in the risk of CTX transfer to the community. This risk is assessed even when there are no measurements of toxin levels. This is commonly called the "Sentry Assessment."

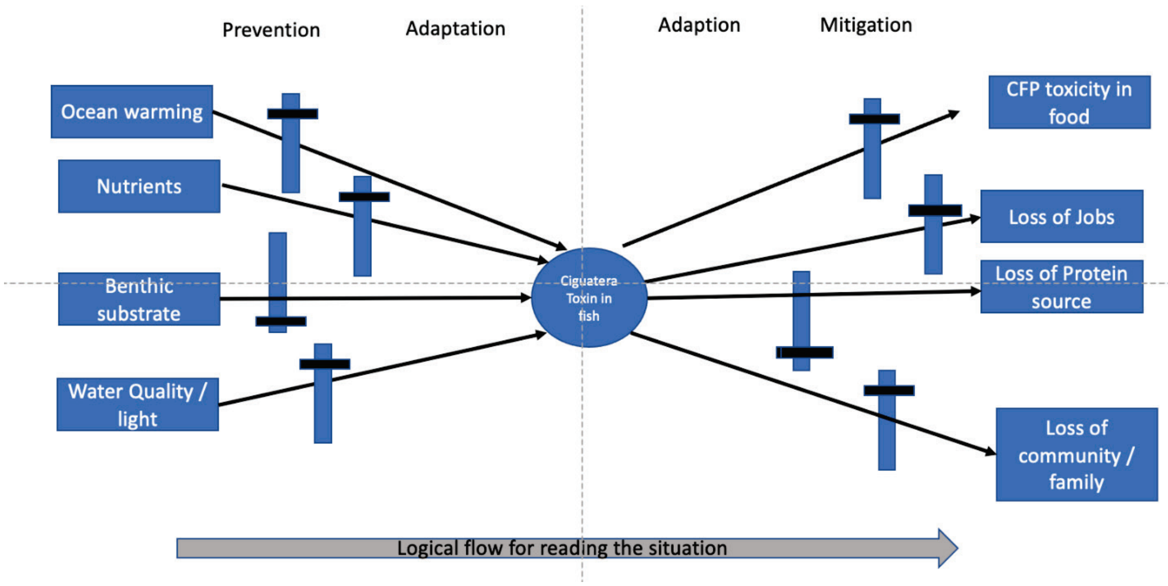


Fig. 2.4 A scientifically robust model of the PICES-MAFF ciguatera toxin assessment. Here, the sliders are presented as examples and still need to be linked to empirical data. Note that the drivers are a consequence of human activity, not natural environmental conditions.

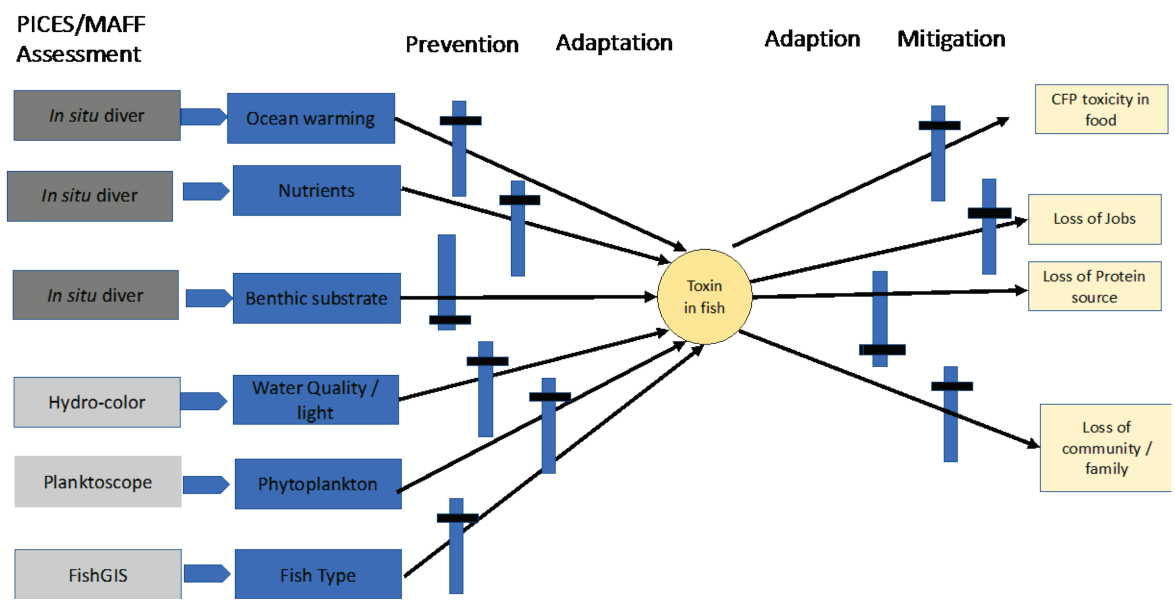


Fig. 2.5 The bow-tie model is linked to the activities and developed analytics of the PICES-MAFF research team. Boxes in light shading on the right are either not part of the community analysis – since CTX is not part of the environment – or cannot be measured (toxins in fish).

Admittedly, the correlation between the primary attributes (*i.e*., the frequency of benthic dinoflagellates and the level of toxin in fish) cannot be established because the analytical assessment of toxin levels is not logistically (or financially) feasible in these communities. While the association between fish, toxins, and human health is the "gold standard" for a scientific study, the present design nevertheless provides community members valuable tools to appreciate environmental change, the variability of data, and a link between the risk model and the consumers. A systematic, structured site and sampling design is needed for the model to inform decisions that achieve sufficient robustness to be meaningful. That is, the project purpose is to implement tools in a structured manner so that in addition to creating scientific interest among the communities, it helps to develop a recognized connection between the environment, toxins, exposure, and risk.

3 Project Design Matrix

Project Cycle Management (PCM; FASiD, 2001) is a method of planning and management of projects based on the logical structure of the project background and a continuous "cycle" of monitoring and revisions of activities. PCMs are commonly used to plan and manage international developmental and cooperative projects. The Japan International Cooperation Agency (JICA) began applying this method in the 1980s, and it is presently used in 64 on-going international projects in 139 countries (JICA, 2022). Under the auspices of the Official Development Assistance (ODA) program, the PCM method has been applied for management of the PICES-MAFF Ciguatera project.

The repeated cycle of planning, implementing and monitoring/evaluation of a PCM (Fig. 3.1) organizes issues around a focal problem based on their cause-and-effect relationships. Problems identified in the initial analysis are interpreted as "objectives", and alternatives for problem solving are visualized (Fig. 3.2). The resultant project design is a logical framework of criteria and standards of achievement (Objectively Verifiable Indicators: OVI) and reference information and observations (Means of Verification: MOV, Fig. 3.3). This logical framework describing the overall project is called the Project Design Matrix (PDM). It is structured to list the Project Goals (to codify the overriding objectives), the Project Purpose (the intended impacts and anticipated benefits), the Results/Outputs (the objectives the project management must achieve and sustain), and the Activities (steps taken to achieve the desired results/outputs). A well-designed PDM helps the project manager and counterparts visualize the project and navigate evaluation of its activities, including the necessary research and field monitoring practices.

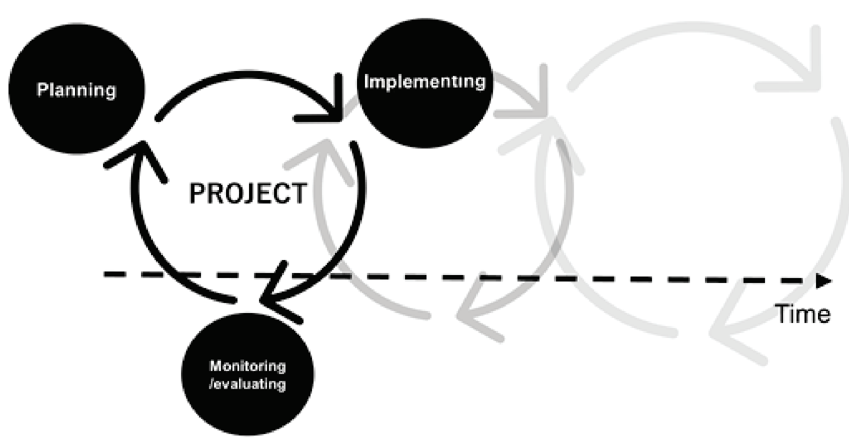


Fig. 3.1 Project image with the Project Cycle Management (PCM) method. A project repeats the cycle of plan-implement-evaluation then improving its quality and increasing its impact.

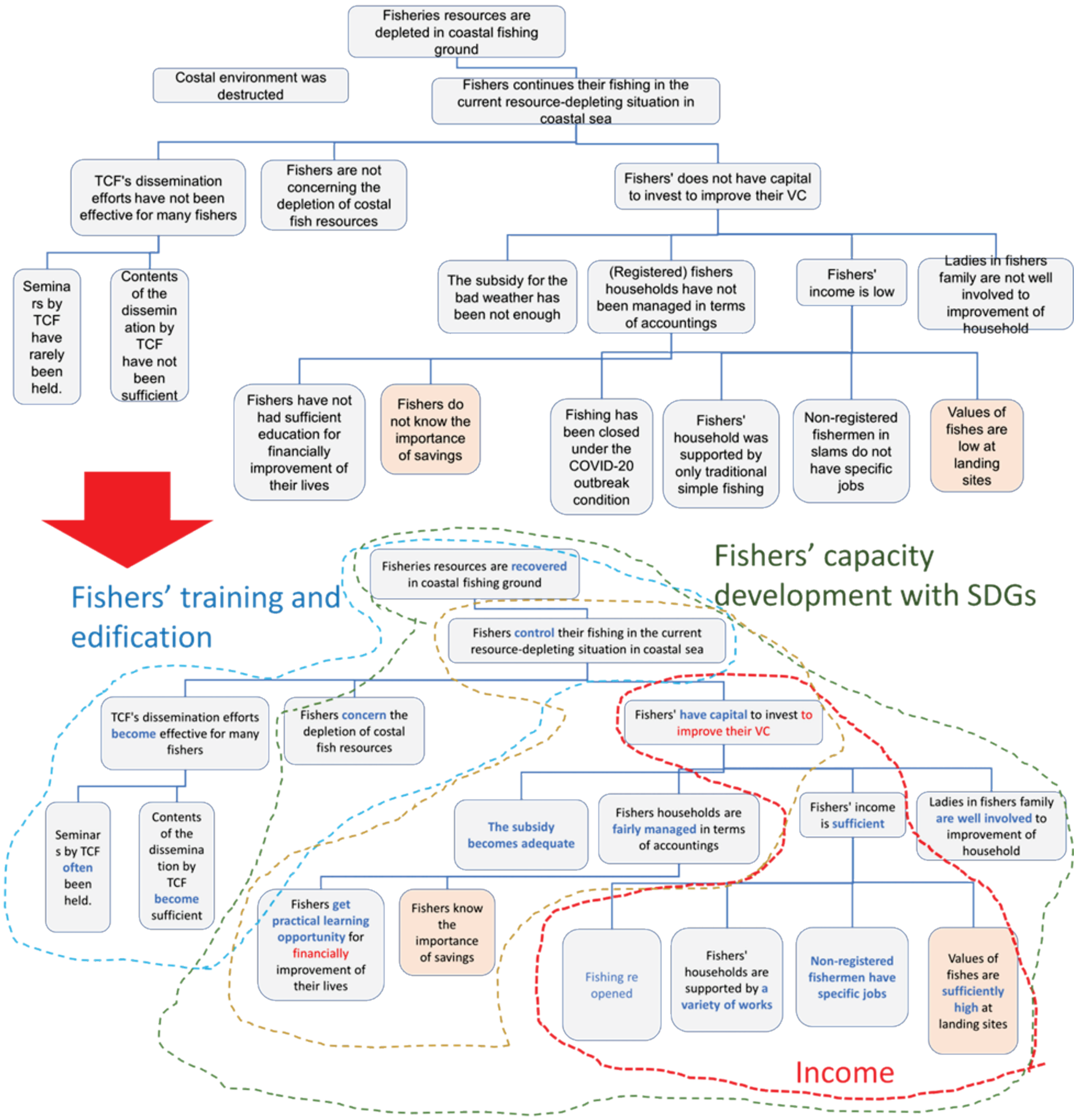


Fig. 3.2 Process from "problem analysis" to "objective analysis". Logically organized problems turn to objectives and alternatives for problem solving by changing expressions.

Date, Version Project title: Project Area:	Completion period: Target Group: (Specific group of stakeholders)		
Narrative summary	**Objectively Verifiable Indicators (OVI)**	**Means of Verification (MOV)**	**Important Assumptions**
Overall goal	Specific indicator to evaluate completeness of overall goal	Evidences, sources of information, references for OVI of overall goal	
Project purpose	Specific indicator to evaluate completeness of Project purpose	Evidences, sources of information, references for OVI of Project purpose	Assumptions to complete works for project purpose then reach to overall goal
Output	Specific indicator to evaluate completeness of Output(s)	Evidences, sources of information, references for OVI of Output(s)	Assumptions to complete works for Output(s) then reach to Project purpose
Activity	Inputs (Specific installations, provided resources for the project etc.)		Precondition Condition to do, continue and complete the project overall

Fig. 3.3 Fundamental structure of a Project Design Matrix.

PST members identified 48 issues around a focal problem—*livelihoods of coastal communities of Indonesia have uncertain risks from CFP and degradation of coral reef ecosystems*—and a problem tree was visualized with "cause and effect" relationships (Fig. 3.4). A PDM was designed working from this problem tree (Table 3.1). The PDM had three "outputs" that define the overall objectives of the project, and "activities" to attain those objectives:

1. To detect and assess the status and potential risk of Ciguatera Fish Poisoning (CFP) by introducing scientific observation methods;
2. To mitigate the risks of poisoning by enhancing CFP awareness and knowledge of stakeholders;
3. To encourage the self-sustainability of these actions by Indonesian stakeholders both during and after the project.

Example: TOJO thoughts after the reports from the site	
Problems	Remarks
Fishes are not fresh in some retailors	"some"...does it means some had fresh fishes? In what conditions did they have them.
There is not many processed products of fishes by locals	Many: no varaety? No amount?, let me assume both until I diretly confirm because the report said "fresh fish" as major product, "most of frozen fishes in the market are imported"
Many consumers cannot clean fishes by themselves	Consumers are also important influencing to entire distribution channels and economic senarios through Noris market
Fisheries resources are depleting in coastal fishing ground	
~~Fishers continues their fishing in coastal fishing ground~~	Well, fishing itself is not problem if resources are not depleting
Fishers continues their fishing in the current resource-depleting situation in coastal sea	
Fishers have not had sufficient education for improvement of their lives	As their final academic carrer, Middle school...seemingly around Noris and Noris economy has tourisms, training opportunities (even limited). May be their knowledge is not sufficient. Imagine they try to manage their financial matters
Non-registered fishermen are majority of Noris fishing sector	IS it because they do not want to register? They just do not know? They may not be able to register because of limited numbers for the available fishing right (e.g. Japan, Mauritius). I assume all here from overall described information around fishers in Noris (e.g. local guides, etc).
~~Licenses for fishing are not sufficient~~	Present effectivity of resource conservation withit may need to be evaluated, but limitation itself may not be bad as a management alternative for sustainability.
Population of fishers and numbers of licenses are not balanced	We can think that number of fishers and alternatives for fishers' income sources as well as potential problems in the licence system
Non-registered fishermen in slams do not have specific jobs	
TCF's dissemination efforts have not been effective for many fishers	
Methods of TCF's dissemination have not been effective	Splited into two from the report
Contents of the dissemination by TCF have not been sufficient	"because of the way and contents"
Seminars by TCF have rarely been held.	
~~Seminars by TCF have been held in the ministry building~~	It is true that I do not want to be in the building for long time. But, the problem may be more going out to capital than staying there. It must be so far for some fishers and they also need to skip their work. (I hope TCF pays for all transports...may be not. I cannot imagine paying for all fishers... How about non-registered fishermen?)
Major dessiminations have not been made in Noris	↑Integrated it to the information, "a half of officers has never been in Noris"
Tourism has been closed under the COVID-19 outbreak condition	
Fishing has been closed under the COVID-20 outbreak condition	
The Bay of Pacume has been destructed by human impacts	Splited into three from the text
Vessels pollute water in the Bay	
Rivers transport pollutants to the Bay	
Fishers' houshold was supported by only traditional simple fishing	
Fishers are not concerning the depletion of costal fish resources	The value chain model does not indicate fishers' action upon resources
Fishers does not consider the change of fish size as the sign of resource depletion	From the value chain
Local retailers generally does not improve their ways of businesses	No expenditures upon techical inprovements for each activities, outbound logistics and aftercares were ignored (e.g. delibary, the way of take out, traceability)
Fishers' income is low	1.9 USD/day is the phovaty line. 5 members in per family!
Fishers' does not have capital to invest	No saving. It is uncertain that FC assist their investiment though
The subsidy for the bad weather has been not enough	
There is informal marets, potentially influencing prices	Unregistered fishermen are majority here. Resources are depleting.... Quality in the official market seemed not good=improvement may be inhibited? Value may be lower in the official flow.
Postharvest treatment is not well done	Fish quality was noted Under sunlight
Unregistered fishermen does not know any other alternative for income than fishing	
Fish prices at landing are not depending upon the shape of the product	
Soking time of gillnet fishing here is so long	It is one of the cause of low quality of harvested fishes
Products at retailers are only whole fishes unless there are requests	Noris consumers seemed that they do not know how to clean fishes well
Many fishes are descarded at markets	
Local eco tour guides does not aware of safety of customers	
Local eco tour guides does not aware of ecological information	It is not eco tour...
Offshore recreation was only run by foreigners	They may know it well, but it may be good to have local guides someday.

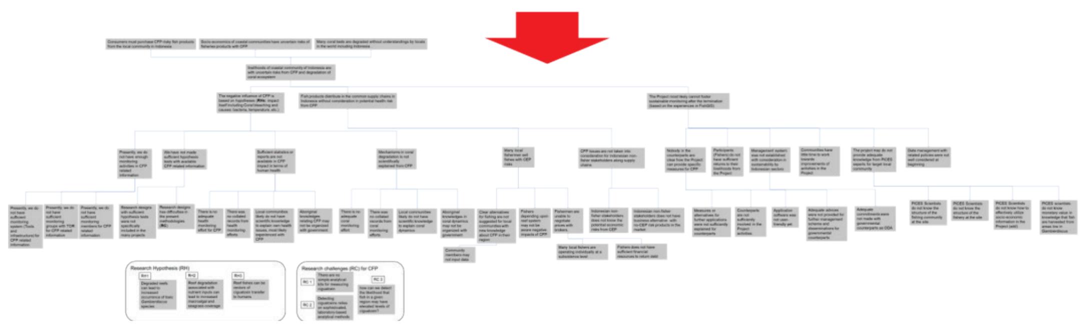


Fig. 3.4 Development of a Problem Tree from online discussion by PST members in May 2021.

These "outputs" were consistent to the conceptual components in the "bow-tie model" (see Chapter 2) of the project.

The project had marked achievements in the PDM, due largely to the very active contributions by our Indonesian collaborators, but several discrepancies were identified during the final PST meeting in March 2023 between PDM expectations and *in situ* actions and outcomes (Table 3.2; see also Appendix 3.7). Some predefined objectives and activities were:

(1) Not ideally fit to the on-site realities for the project and required modification,

(2) Not achieved or dropped from the PDM due to logistical limitations imposed by the COVID-19 pandemic.

Table 3.1 Project Design Matrix (PDM) designed for the PICES-MAFF Ciguatera project.

Narrative summary	Objectively Verifiable Indicators (OVI)	Means of verification	Important assumptions
Overall goal* *...3-5 years after the Project, monitored by post - project evaluation			
1. Consumers can purchase CFP-risk free fish products from the local community in Indonesia 2. Socio-economics of coastal communities do not have to fully depend upon products with CFP-risks 3. Many coral beds declines are of interest and understood by local communities in developing nations, including Indonesia	1. There is more than 1 product or 1 certificate based on the Project activities that can be provided to Indonesian supply chains with information of CFP control 2. Half of members in target communities improved their socio-economic capacity (*e.g.*, capital, income sources) based on efforts based on the technical transfers in the Project 3a. A coral ecosystem status is monitored using > 2 biological indicators at least once a season by locals with governmental instruction 3b. > 2 International publications are published 3c. > 100 local stakeholders continuously follow the official Social Networks after the termination of the Project	1. Product or/and certificate with CFP control information 2. Results of evaluation surveys with questionnaires for locals (Adequate questionnaires will be developed during the Project with observers) 3a. Survey reports by officers, submitted to Ministries 3b. Publications with authors from Counter Parts (CPs) 3c. Followers of official SNS account (Official SNS should be established during the Project)	
Project purpose* *…evaluated at the Project termination			
Capacities of coastal community of Indonesia are improved in sustainable manner with less uncertainties and risks from CFP and degradation of coral ecosystem	1. > 100 of total local fishers participate in the annual meeting for technical transfer and information exchanges (= "general workshop") 2. Total > 2 small workshops at target communities are held with representing locals (= "local workshop") 3. More than half of government extension officers and community leaders who participate in general workshop are certificated by BPPT and PICES with more than 70 % of understanding in the technologies and necessary background knowledge (as a good status).	1. Lists of participants from general workshops and local workshops 2. Certification officialized by BPPT training workshops with scores of exams (The exam will be provided from PICES expert in the workshop)	

Table 3.1 Continued.

Narrative summary	Objectively Verifiable Indicators (OVI)	Means of verification	Important assumptions
Output			
1. The influence of CFP upon human dimensions and ecological sustainability of coastal communities are explained based on specific hypotheses tests "DETECT and ASSESS"	1-1. >2 scientific reports or other publications on CFP are publicized or presented with quantified impacts/ influences (1 for HD, 1 for ecology/biology) 1-2. Test at least 1 hypotheses with available CFP related information 1-3. The explanation (oral presentations, brochure, and/or other media) in the impacts/potential impacts of CFP are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-4. The explanation (oral presentations, brochure, and/or other media) of the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-5. >2 scientific reports or other publication in the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are publicized or presented in PICES (1 for HD, 1 for others)	1-1. Published scientific report/journal articles 1-2. and 1-3. a. Official agenda with the title of presentations and supplemental brochures b. Media provided by experts and partner organizations 1-4. Presentation in the PICES annual meetings …"MUST be done anyway" as a comment in the discussion	
2. Fish products distribution in the common supply chains in Indonesia is with consideration in potential health risks from CFP "AVOID"	2-1. >1 scientific reports or other publication in the potential health risks are publicized or presented. 2-2. > 1 model products with CFP controls are produced based on collected information in the Project 2-3. An integrative warning system is suggested based on the collected information, chemical analyses, and regional oceanography 2-4. Awareness of the stakeholders increases > 20% from the Project information and activities	2-1.a Published scientific report/journal articles 2-1.b Presentation in the PICES annual meetings 2-2. Model product with certification and consumers Willingness to Pay (WTP) upon it in the regional markets in the official surveys 2-3. Warning system with a Geographic Information System (GIS) platform 2-4. Responses to questionnaires in general workshops and local workshops (Adequate questionnaires will be developed during the Project with observers)	

Table 3.1 Continued.

Narrative summary	Objectively Verifiable Indicators (OVI)	Means of verification	Important assumptions
Output			
3. Sustainable monitoring continues after the termination of the project + "POST PROJECT SUSTAINABILITY"	3.1. Members of partner organizations operate monitoring activities at least once a season. 3.2. Members of partner organizations publish the status report of monitoring activities at least once a year. 3.3. Members of partner organizations hold > 2 committee meeting with PICES experts for activities and self improvement in the topic in the Project. 3.4. Saving of actively involved stakeholders, who joined to the monitoring >80% of fishing days, maintained or increased during the Project	3.1. Extension officers report 3.2. Status report with confirmation of supervisors 3.3. Agenda and RD* from the meeting 3.4. Responses to questionnaires in the first and final general workshops (Adequate questionnaires will be developed during the Project with observers) *...Record of Discussion	

Table 3.1 Continued.

Narrative summary			
Activities	**Input**		**Preconditions**
1-1. Carry out monitoring activities to obtain sufficient CFP-related data/information 1-2. Test multiple hypothesis with the available CFP-related data/information 1-3. Locate and synthesize statistics or reports in CFP impact in terms of human health 1-4. Conduct background study in mechanisms of CFP issues with priorities with specific hypotheses 2-1. Suggest specific alternative for Local fishermen to sell fishes with reduced CFP risks 2-2. Disseminate knowledge in CFP risks for Indonesian non-fisher stakeholders along supply chains	***PICES and MAFF side:*** 1. PICES experts – Proposal(s) in the protocol and design for CFP survey – Smartphone based monitoring/warning system (technologies, techniques and advices for application) – GIS and database techniques – Practical social mapping methods ("EZU" methodology) 2. Provide Software and Equipment – Photo-base sampling technologies, including new version of smartphone software (FishGIS) – Necessary survey devices including tablets and CFP survey toolkit 3. Training of Indonesian Counterpart Personnel in Japan – Program(s) covering: - Photo-base sampling technologies - GIS and database techniques - Practical social mapping methods ("EZU" methodology) in Japanese fields and case studies – Fees for traveling of the program participants* 4. Costs – Costs for the general workshop* – Costs for community workshop* – Costs for Equipment *...based on specific agreement with chief adviser through the Project coordinator of Japanese side	***Indonesian side:*** 1. Counterparts in the field of: – CFP and coral ecosystem survey & analysis – Fisheries Sciences (esp. coastal resources) – Food sciences/human health – Socio-economic survey and analysis – IT – Technical dissemination and developmental education (*e.g.*, extension office) 2. Facilities and equipment – Meeting Spaces (Jakarta and Gili Islands) – Web server (BPPT) and the sufficient Internet connections – Fundamental laboratory spaces for on-site research activities – Research vessel and its fuel – CFP survey toolkit – Fundamental experimental equipment – Part of tablets, cellphone and sim card for dissemination 3. Costs – Operation and maintenannce of research vessel – Operation and maintenannce of survey tools and devices – Personnel expenses of counterpart personnel – Agreed logistics for officers for workshops – Per-diem and other supports for desparched counterparts for the training program to Japan	Duties and responsibilities of BPPT and LIPI will not be changed. Organizations were reformed during the Project. The agreement with the logical framework (*i.e.*, PDM) should have been revised with necessary modifications

Table 3.1 Continued.

Narrative summary			
Activities	**Input**		**Preconditions**
3-1. Visualize measures and the process of problem solving to counterparts of target organizations and local communities in the Project 3-2. Monitor and provide technical assistance for financial and economic returns/uncertainties to participants (Fishers) from the Project 3-3. Suggest a management system for CFP risk warning with consideration in sustainability by Indonesian sectors 3-4. Provide technical guidance to maximize the efficiency of fishing activities with CFP monitoring 3-5. Provide opportunities to disseminate practical knowledge for target local community with consultation by PICES experts 3-6. Follow data management with related policies in Indonesia			

Table 3.2 Result of evaluation of the Project Design Matrix designed for the Ciguatera project.

Narrative summary	Objectively Verifiable Indicators (OVI)		Means of Verification	Important Assumptions
Overall goal* *...3-5 years after the Project, monitored by post-project evaluation		**Check**		
1. Consumers can purchase CFP-risk free fish products from the local community in Indonesia 2. Socio-economics of coastal communities do not have to fully depend upon products with CFP-risks 3. Many coral beds declines are of interest and understood by local communities in developing nations, including Indonesia	1. There are more than 1 product or 1 certificate based on the Project activities that can be provided to Indonesian supply chains with information of CFP control 2. Half of members in target communities improved their socio-economic capacity (*e.g.*, capital, income sources) based on efforts based on the technical transfers in the Project 3a. A coral ecosystem status is monitored using > 2 biological indicators at least once a season by locals with governmental instruction 3b. > 2 International publications are published 3c. > 100 local stakeholders continuously follow the official Social Networks after the termination of the Project	1. Not expected to be obtained 2. Not expected 3. Expected to be attained 4. Expected 5. Not Expected	1. Product or/and certificate with CFP control information 2. Results of evaluation surveys with questionnaires for locals (Adequate questionnaires will be developed during the Project with observers) 3a. Survey reports by officers, submitted to Ministries 3b. Publications with authors from Counter Parts (CPs) 3c. Followers of official SNS account (Official SNS should be established during the Project)	
Project purpose* *…evaluated at the Project termination				
Capacities of coastal community of Indonesia are improved in sustainable manner with less uncertainties and risks from CFP and degradation of coral ecosystem	1. > 100 of total local fishers participate in the annual meeting for technical transfer and information exchanges (= "general workshop") 2. Total > 2 small workshops at target communities are held with representing locals (= "local workshop") 3. More than half of government extension officers and community leaders who participate in general workshop are certificated by BPPT and PICES with more than 70% of understanding in the technologies and necessary background knowledge (as a good status).	1. No (not fishers but significant stakeholders: not captured necessary modification) 2. No 3. (*) qualitywise-No exams+organization was reformed)	1. Lists of participants from general workshops and local workshops 2. Certification officialized by BPPT training workshops with scores of exams (The exam will be provided from PICES expert in the workshop)	

Table 3.2 Continued.

Narrative summary	Objectively Verifiable Indicators (OVI)		Means of Verification	Important Assumptions
Output		**Check**		
1. The influence of CFP upon human dimensions and ecological sustainability of coastal communities are explained based on specific hypotheses tests "DETECT and ASSESS"	1-1. >2 scientific reports or other publications on CFP are publicized or presented with quantified impacts/influences (1 for HD, 1 for ecology/biology) 1-2. Test at least 1 hypotheses with available CFP related information 1-3. The explanation (oral presentations, brochure, and/or other media) in the impacts/potential impacts of CFP are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-4. The explanation (oral presentations, brochure, and/or other media) of the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-5. >2 scientific reports or other publication in the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are publicized or presented in PICES (1 for HD, 1 for others)	1-1. Expected 1-2. Yes 1-3. Yes 1-4. Yes 1-5. Yes, many are expected before the termination	1-3. Published scientific report/journal articles 1-2. and 1-3. a. Official agenda with the title of presentations and supplemental brochures b. Media provided by experts and partner organizations 1-4. Presentation in the PICES annual meetings …"MUST be done anyway" as a comment in the discussion	
2. Fish products distribution in the common supply chains in Indonesia is with consideration in potential health risks from CFP "AVOID"	2-1. >1 scientific reports or other publication in the potential health risks are publicized or presented. 2-2. > 1 model products with CFP controls are produced based on collected information in the Project 2-3. A integrative warning system is suggested based on the collected information, chemical analyses, and regional oceanography 2-4. Awareness of the stakeholders increases > 20% from the Project information and activities	2-1. Yes 3-2. No 2-3. No 3.4 (*) Evaluation with quationers were not made	2-1.a Published scientific report/journal articles 2-1.b Presentation in the PICES annual meetings 2-2. Model product with certification and consumers Willingness to Pay (WTP) upon it in the regional markets in the official surveys 2-3. Warning system with a Geographic Information System (GIS) platform 2-4. Responses to questionnaires in general workshops and local workshops (Adequate questionnaires will be developed during the Project with observers)	

Table 3.2 Continued.

Narrative summary	Objectively Verifiable Indicators (OVI)		Means of Verification	Important Assumptions
Output		**Check**		
3. Sustainable monitoring continues after the termination of the project + "POST PROJECT SUSTAINABILITY"	3.1. Members of partner organizations operate monitoring activities at least once a season. 3.2. Members of partner organizations publish the status report of monitoring activities at least once a year. 3.3. Members of partner organizations hold > 2 committee meeting with PICES experts for activities and self improvement in the topic in the Project. 3.4. Saving of actively involved stakeholders, who joined to the monitoring >80% of fishing days, maintained or increased during the Project	3.1 Yes: Began and confirmed 3.2 Yes 3.3 Yes 3.4 (*) Criteria should have been modified	3.1. Extension officers report 3.2. Status report with confirmation of supervisors 3.3. Agenda and RD* from the meeting 3.4. Responses to questionnaires in the first and final general workshops (Adequate questionnaires will be developed during the Project with observers) *...Record of Discussion	

Table 3.2 Continued.

Narrative summary						
Activities	**Check**	**Input**	**Please review**	**Input**	**Please review**	**Preconditions**
1-1. Carry out monitoring activities to obtain sufficient CFP-related data/information 1-2. Test multiple hypothesis with the available CFP-related data/information 1-3. Locate and synthesize statistics or reports in CFP impact in terms of human health 1-4. Conduct background study in mechanisms of CFP issues with priorities with specific hypotheses	1-1. Yes* partially 1-2. Modified 1-3. Yes* partially 1-4. Yes	***PICES and MAFFside:*** 1. PICES experts – Proposal(s) in the protocol and design for CFP survey – Smartphone based monitoring/warning system (technologies, techniques and advices for application) – GIS and database techniques – Practical social mapping methods ("EZU" methodology) 2. Provide Software and Equipment – Photo-base sampling technologies, including new version of smartphone software (FishGIS) – Necessary survey devices including tablets and CFP survey toolkit 3. Training of Indonesian Counterpart Personnel in Japan – Program(s) covering: - Photo-base sampling technologies - GIS and database techniques - Practical social mapping methods ("EZU" methodology) in Japanese fields and case studies – Fees for traveling of the program participants*		***Indonesian side:*** 1. Counterparts in the field of: – CFP and coral ecosystem survey & analysis – Fisheries Sciences (esp. cosatal resources) – Food sciences/human helath – Socio-economic survey and analysis – IT – Technical dessemination and developmental education (*e.g.*, extention office) 2. Facilities and equipment – Meeting Spaces (Jakarta and Giri Island) – Web server (BPPT) and the sufficient Internet connections – Fundamental laboratory spaces for on-site research activities – Research vessel and its fuel – CFP survey toolkit – Fundamental experimental equipment, – Part of tablets, cellphone and sim card for dessimination		Duties and responsibilities of BPPT and LIPI will not be changed. Organizations were reformed during the Project. The agreement with the logical framework (*i.e.* ,PDM) should have been revised with necessary modifications

Table 3.2 Continued.

Narrative summary						
Activities	**Check**	**Input**	**Please review**	**Input**	**Please review**	**Preconditions**
2-1. Suggest specific alternative for Local fishermen to sell fishes with reduced CFP risks 2-2. Disseminate knowledge in CFP risks for Indonesian non-fisher stakeholders along supply chains 3-1. Visualize measures and the process of problem solving to counterparts of target organizations and local communities in the Project 3-2. Monitor and provide technical assistance for financial and economic returns/uncertainties to participants (Fishers) from the Project 3-3. Suggest a management system for CFP risk warning with consideration in sustainability by Indonesian sectors 3-4. Provide technical guidance to maximize the efficiency of fishing activities with CFP monitoring 3-5. Provide opportunities to disseminate practical knowledge for target local community with consultation by PICES experts 3-6. Follow data management with related policies in Indonesia	2-1. No 2-1. Yes 3-1. Yes 3-2. No 3-3. Yes* partically 3-4. No 3-5. Yes 3-6. Yes	***PICES and MAFFside, continued:*** 4. Costs – Costs for the general workshop* – Costs for community workshop* – Costs for Equipment *...based on specific agreement with chief adviser through the Project coordinator of Japanese side		***Indonesian side, continued:*** 3. Costs – Operation and maintenannce of research vessel – Operation and maintenannce of survey tools and devices – Personnel expenses of counterpart personnel – Agreed logistics for officers for workshops – Per-diem and other supports for desparched counterparts for the training program to Japan		

In an ideal situation, the PCM involves participants in a repeated design and sharing process, helping to impart project ownership and responsibility for activities established in the project. The COVID pandemic created major challenges to effectively involve all PST members and Indonesian colleagues with in-depth discussion and considerations, given the practical limitations of conducting virtual meetings across 12 time zones. It was not until the final months of the project that in-person discussions were possible, significantly impacting our ability to effectively design and revise the PDM activities. As an example, our Indonesian colleagues took the initiative to develop and implement a community survey, part of the PDM, with limited input from PST members. Although these self-sustained activities are a strength of the project, and valuable data were obtained, a more optimal survey design would have benefited the project. The COVID-based limitation of exchange among PST members and Indonesian colleagues also meant that we were unable to move to the next level of PCM by developing a Plan of Operation (PO) to manage the *in situ* activities and operations (FASiD, 2001).

Applying the PCM and PDM approach to future stages of the Ciguatera project and other PICES projects requires a focus on improving and maintaining involvement from all participants, so that in situ updates can be shared on a timely basis. More creative efforts were needed during this project to mitigate the pandemic effect and enhance communication for project management.

4 Smartphone Applications

4.1 *Overview of FishGIS*

FishGIS is a smartphone application and GIS-based cloud database service provided to PICES by Green Front Laboratory, Inc. (GFL, Japan) for a citizen-based monitoring project "Building capacity for coastal monitoring by local small-scale fishers" (2017–2020; FishGIS), funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), from the Official Development Assistance (ODA) Fund. Through this project, GFL released an initial version of FishGIS, a customized version of the Furusato Photo Memory System®, into a smartphone application. During the Ciguatera project, from April 2020 to March 2023, GFL made major updates to FishGIS. The Furusato Photo Memory® System, an integrated field survey data reporting and sharing service for supporting citizen-science-based surveys and research (Reg. No. 5738785), is developed by Green Front Institute, Inc. and is issued as a trademark by the Japan Patent Office in 2015.

FishGIS consists of three components (Fig. 4.1). The first is a smartphone application (*FishGIS app*) that allows users to report accurate location information and photos or videos, even when there is no cell phone signal. The second component is a secure GIS-based cloud database (*FishGIS db*) where data reported from the smartphone application are stored. The third component is a web application for a desktop PC (*FishGIS dashboard*) that allows data managers who have received permission to use the data from a reporter to access the reported data set from the cloud database and use it for analysis.

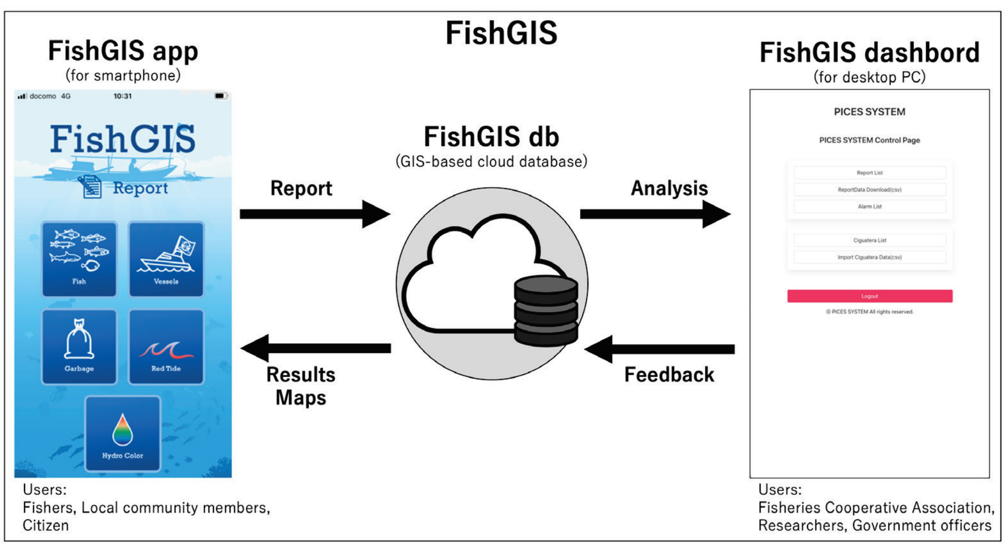


Fig. 4.1 Overall view of FishGIS and its three components.

Fishers can use the *FishGIS app* to submit, revise or delete their own reports and share information within a limited group – users who have the same group ID (Takemura *et al*., 2019). Data reported by the fishers, and the information fed back to them by research or government agencies, cannot be shared by an unspecified number of users.

The *FishGIS dashboard* allows fishers, Fisheries Cooperative Associations, research institutes, government agencies, universities, and other local organizations such as NPO/NGO to obtain and analyze reports from fisheries professionals, which can then be fed back to the reporter. Only those who have received permission to use the data from the reporter and PICES can view and use the data.

4.2 Major updates to FishGIS

This section describes new functions of FishGIS developed during the Ciguatera project between April 2020 and March 2023.

4.2.1 Compliance with access to genetic resources and benefit sharing

Article 15 of the Convention on Biological Diversity (CBD) stipulates the basic rules of Access to genetic resources and Benefit Sharing (ABS), and the Nagoya Protocol was adopted at COP10 in 2010 as an international instrument establishing procedures to ensure the steady implementation of ABS. The latest version of a reporting scheme in FishGIS is in compliance with ABS, and this is one of the most significant upgrades of FishGIS implemented during the Ciguatera project.

In the previous version, the challenge was that all data reported from their smartphones by users in third countries other than Japan, such as Indonesia, were stored directly to a software server located in Japan (Fig. 4.2, left). In the new version, all data reported from smartphones by users in Indonesia are stored first on a server located in Indonesia, and then a copy of the data is transferred to a server located in Japan (Fig. 4.2, right). Users in Indonesia can view maps, analysis results, and other information provided by the software server in Japan from FishGIS.

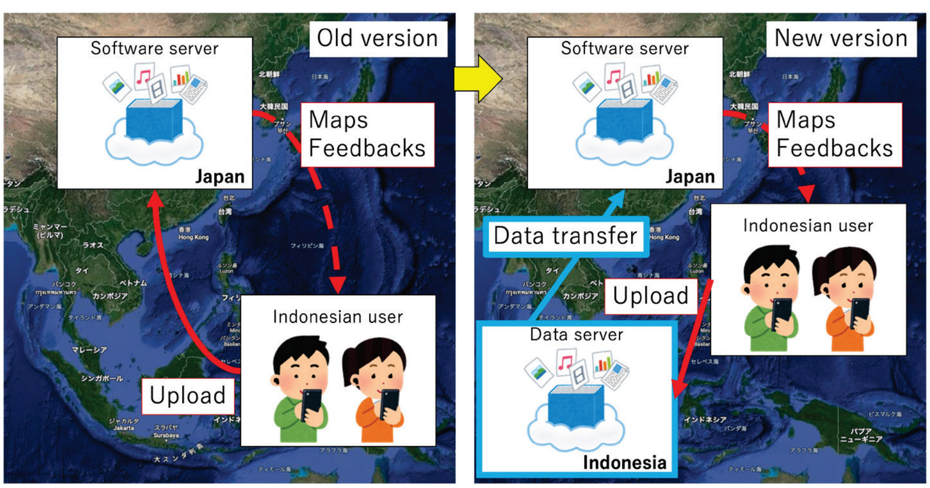


Fig. 4.2 ABS-compliant reporting scheme in FishGIS (right panel) and the reporting scheme for the old version (left panel).

Upon request, a transfer of data from a server in Indonesia to a server in Japan can be stopped immediately. However, if the transfer is stopped, some problems may occur in the use of the *FishGIS app* in Indonesia due to the design of FishGIS. As of the end of March 2023, the only countries that have established the ABS-compliant reporting schemes in FishGIS are Japan and Indonesia.

4.2.2 User interface upgrade

The next major change in the *FishGIS app* in the Ciguatera project is an improved user interface. Figure 4.3 shows a screenshot of the old version and a screenshot of the new version after the update. The new version displays the logos of organizations that support the Ciguatera project when the application is launched. The new *FishGIS app* is available on the Apple Store and Google Play and can be installed on iOS 10 and Android 7 or later smartphone devices.

Fig. 4.3 User interface of the FishGIS app before (upper panel) and after (lower panel) an upgrade.

4.2.3 Function to link with the HydroColor application

HydroColor is a smartphone application developed by Swquoia Scientific, Inc., whose source code was published in February 2023. HydroColor is also available to everyone through the Apple store and Google Play. The application can calculate RGB reflectance based on remote sensing algorithms by capturing three images of gray cards, water surfaces, and the sky, and then estimate water quality from sea color information (for more information, see Leeuw and Boss, 2018). HydroColor measurements can be sent in a text file format to any email address, allowing users to share them among interested parties using Dropbox or other tools. The new *FishGIS app* allows the user to directly launch the HydroColor app (Fig. 4.4) and to automatically load HydroColor data from a shared folder such as Dropbox and display them on a map (Fig. 4.5).

Fig. 4.4 Launching the HydroColor application from the *FishGIS app*.

Fig. 4.5 Mapping function of HydroColor data in the *FishGIS app*.

4.2.4 Integration with the Indonesian government's tsunami warning application

The new *FishGIS app* allows the user to directly launch the Info BMKG app (Fig. 4.6), an official application for smartphones developed by the Indonesian government's Agency for Meteorology, Climatology, and Geophysics (BMKG). The Info BMKG app, which provides information on weather, ocean conditions, and tsunamis in the event of a disaster, can then be used for evacuation and other actions.

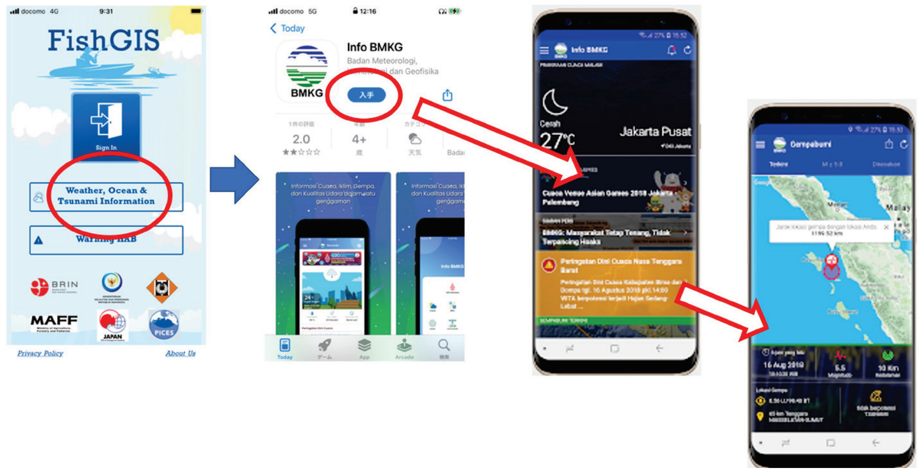


Fig. 4.6 Launching the BMKG application from the *FishGIS app*.

4.2.5 Mapping function for Ciguatera assessment survey data

The new *FishGIS app* has a function to map Ciguatera assessment survey results obtained through the Ciguatera project field surveys in Indonesia (Fig. 4.7). Users can browse the results by clicking on the pins of the observation points shown on the map. Ciguatera assessment survey results can be imported into FishGIS by uploading them from the *FishGIS dashboard* (Fig. 4.8). The data can only be viewed by users who have the same group ID and cannot be shared by an unspecified number of users.

Fig. 4.7 Mapping function of the Ciguatera assessment survey data in the *FishGIS app*.

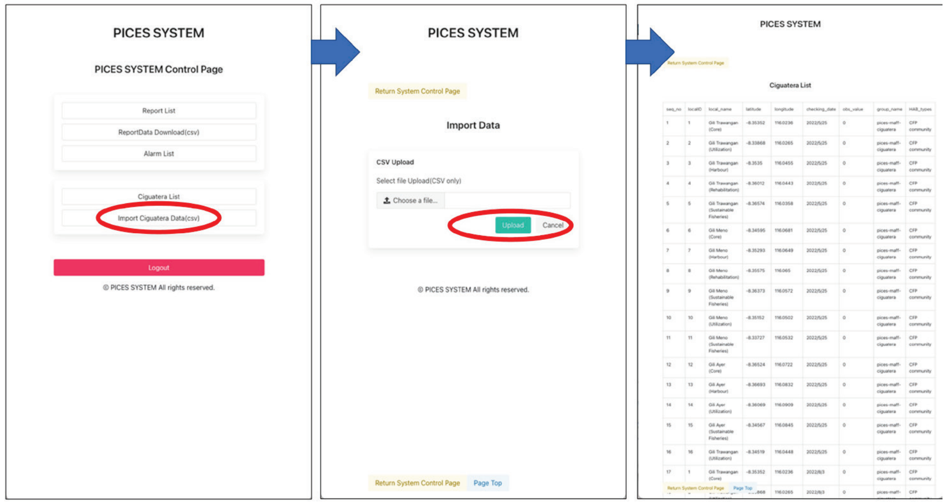


Fig. 4.8 Screenshot of the *FishGIS dashboard* for uploading the Ciguatera assessment survey results.

4.2.6 FishGIS dashboard for data management

All data reported from the *FishGIS app* are stored in a cloud database. The data manager can search the results by monitoring items and view any image or video, as well as supplemented meta-information such as the date and time of their capture, photographer, and location (latitude and longitude) from the *FishGIS dashboard* (Fig. 4.9.). Again, the results can only be accessed by those who have received permission to use the data from the reporter. Additionally, the data manager can download the reported data (images or videos) and its meta-information (CSV file in spreadsheet format) from the *FishGIS dashboard* (Fig. 4.10.) and use them directly for data analysis and visualization since the file names are linked to each other.

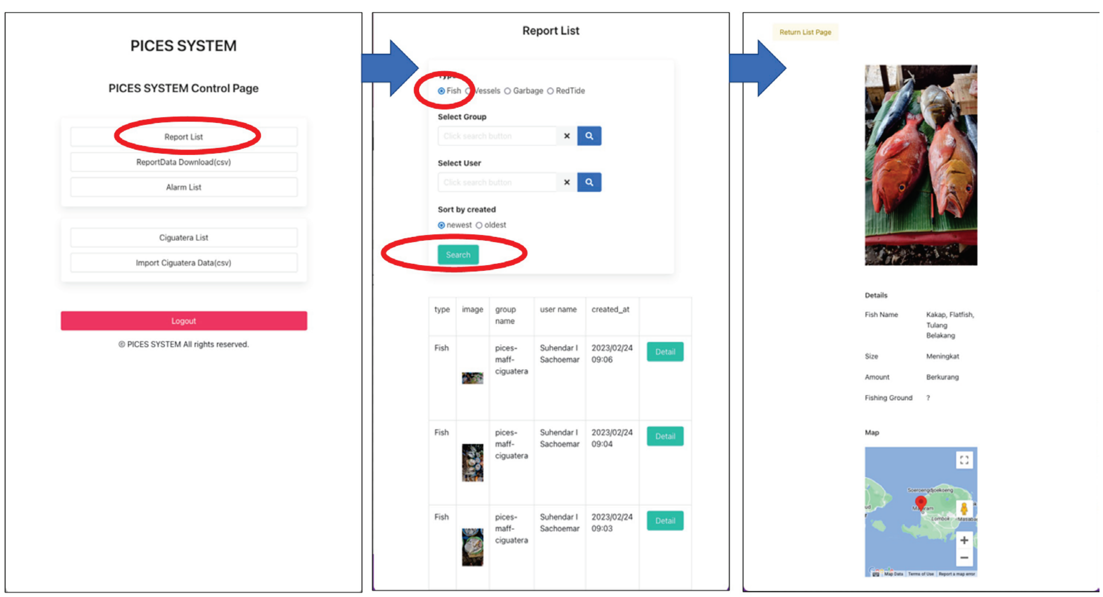


Fig. 4.9 Data search and view function of the *FishGIS dashboard* service.

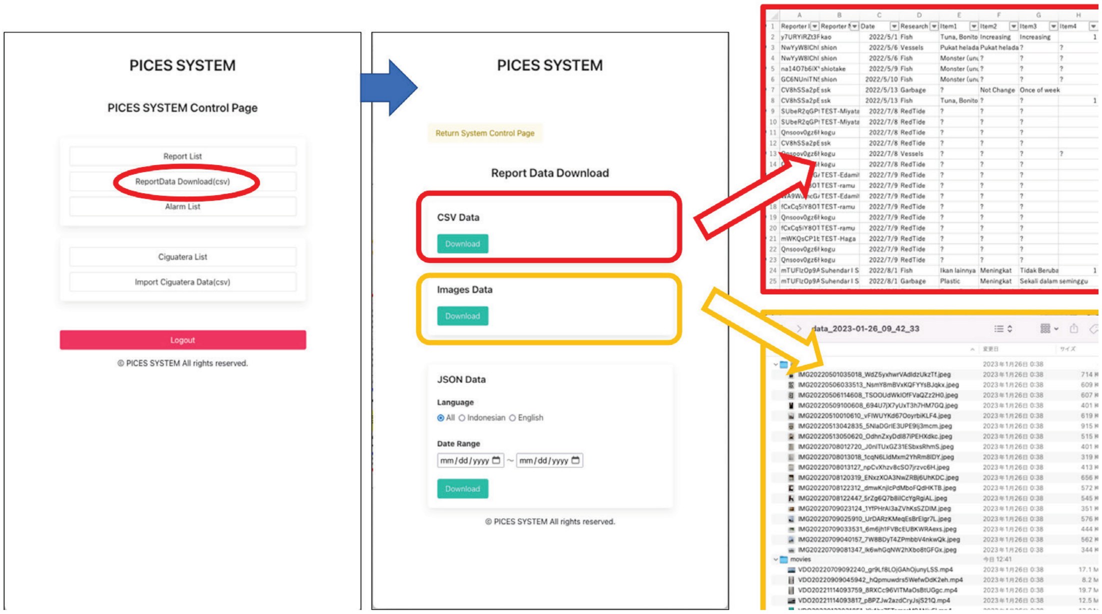


Fig. 4.10 Data download function of the *FishGIS dashboard* service.

4.3 Preliminary results of using FishGIS

4.3.1 Images of fish catch

Images of fish catches collected by an Indonesian research team at a local market in Lombok using the *FishGIS app* show that waters around Lombok Island is home to a wide variety of fish, including great barracuda, tuna, bonito, snappers, groupers, small pelagic fish such as sardines, and other reef fishes (Fig. 4.11). These results indicate that FishGIS can be used as a tool to understand the actual status of major fish species and their composition in the area through the collection of images of fish catches.

Fig. 4.11 Images of catches in Lombok, Indonesia, collected using the FishGIS app.

Figure 4.12 shows the preliminary results of fish length measurements by image analysis from images collected using the *FishGIS app* (Takemura *et al*., in prep.). Specifically, VoTT is used to record the four corner coordinates and species name of the fish body in the image of the fish catch, as well as the four corner coordinates of the scale on which the fish body is based, and then the fish body length is calculated from the ratio to the scale. The time required to extract the coordinates of a fish body from an image depends on the number of fish in the image, but normally it takes only a few minutes per image. By performing this procedure for all fish in the image taken, the program can output a histogram of fish body size distributions for each fish species (Fig. 4.13).

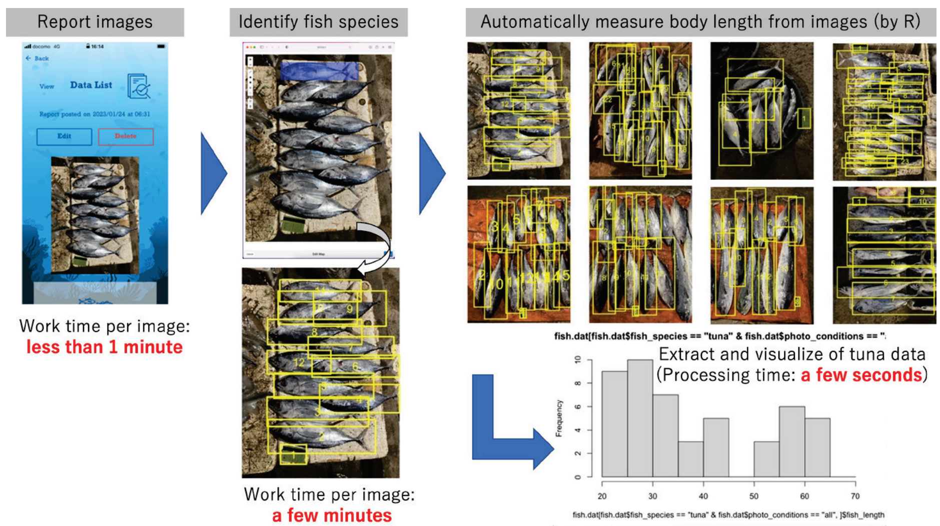


Fig. 4.12 Image analysis procedure for attempting to measure fish length from a fish catch image in Gili Matra, Lombok, Indonesia.

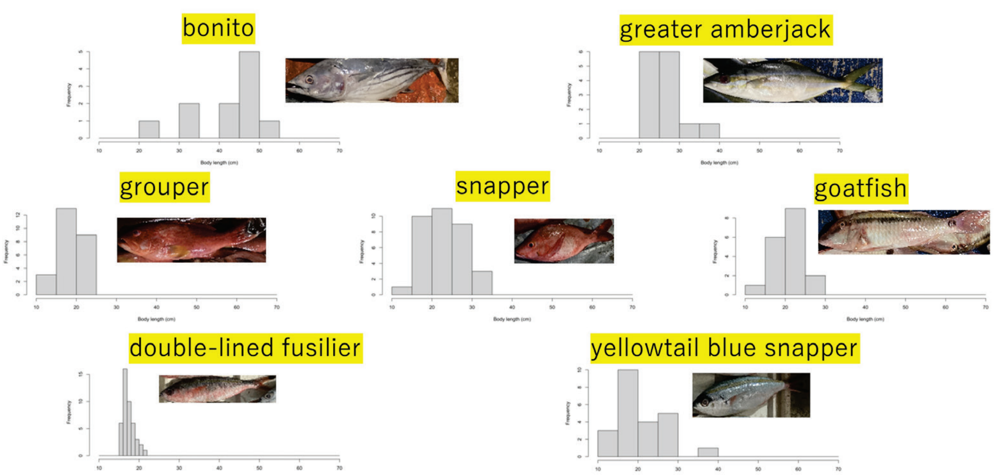
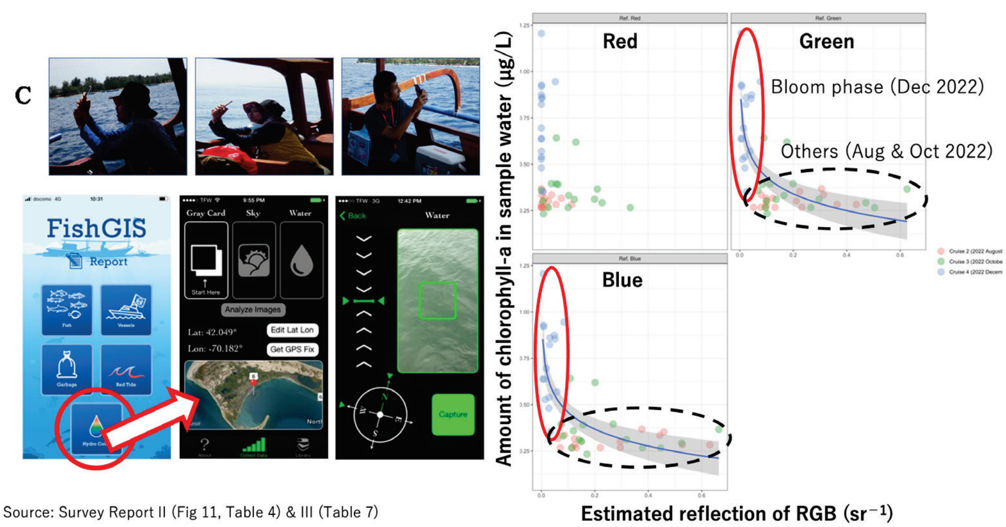


Fig. 4.13 Preliminary results of an attempt to measure fish length from fish catch images in Gili Matra, Lombok, Indonesia.

4.3.2 Image of sea color

Figure 4.14 shows the relationship between the amount of chlorophyll in the sample water and RGB reflections estimated by HydroColor, using data from three of a total of five field surveys conducted in the Gili Islands (Gili Matra) region by a local research team (see Chapter 5). The results indicate that the estimated green and blue reflections can be a useful tool for understanding whether a bloom is occurring or not in the waters surrounding Gili Matra. As this preliminary analysis was conducted using only one year of data, further field work is required to update the data and verify whether similar trends can be detected by HydroColor.



Source: Survey Report II (Fig 11, Table 4) & III (Table 7)

Fig. 4.14 Preliminary results of HydroColor data calibrated with water quality profiles in Gili Matra, Lombok, Indonesia.

5 Ciguatera Field Surveys

5.1 Introduction

5.1.1 Background

Harmful algal blooms (HABs) are one of 10 Plagues of the Seas whose presence can threaten the balance of ecosystems and people's lives in coastal areas (Duarte *et al*., 2014). The types of microalgae that cause HABs can be divided into two groups, namely red tide makers and toxin producers. The red tide maker group is composed of microalgae that experience a population explosion, causing discolouration in the water column. Red tides cause oxygen depletion, namely anoxia and hypoxia, which can interfere with the respiration of marine life. In addition, certain types of microalgae can cause mechanical and chemical dysfunction in fish gills (Hallegraeff, 1991). Meanwhile, the toxin producer group consists of microalgae that can produce secondary metabolites in the form of bioactive toxic compounds (toxins) that can accumulate in the bodies of aquatic biota (GEOHAB, 2001). If the biota are consumed by humans, the toxin can cause various types of poisoning, some of which can be fatal, such as Diarrhetic Shellfish Poisoning (DSP), Paralytic Shellfish Poisoning (PSP), Neurotoxic Shellfish Poisoning (NSP), Amnesic Shellfish Poisoning (ASP), and Ciguatera Fish Poisoning (CFP).

Benthic dinoflagellates, especially *Gambierdiscus toxicus*, are known to be capable of producing a toxic compound, namely ciguatoxin (CTX), which can cause CFP in humans and other mammals, due to consuming reef fish contaminated with it (Randall, 1958; deSylva, 1994; Lehane and Lewis, 2000). In addition, other benthic dinoflagellate species, such as *Ostreopsis ovata*, *Prorocentrum lima*, *P. concavum*, *P. mexicanum* (*rhathymum*), and *Amphidinium carterae* are frequently found in association with *G. toxicus* and can cause CFP (Burkholder, 1998; Lehane and Lewis, 2000). Ciguatoxin produced by benthic dinoflagellates can affect the gastrointestinal system of humans, causing the typical symptoms of CFP, including: diarrhea, nausea, vomiting, and abdominal pain; and the nervous system, namely fever and cold inversion, muscle and joint pain, tingling sensations, numbness of the lips and tongue, itching, and hypotension (deSylva, 1994; Lehane and Lewis, 2000). CFP is the most commonly reported seafood poisoning illness in the world, and the frequency and number of reports is increasing in this Anthropocene era.

The presence of benthic dinoflagellate species that have the potential to cause CFP, such as *Amphidinium* sp., *G. toxicus*, *O. ovata*, *O. siamensis*, *P. lima*, *P. concavum*, and *P. rhathymum*, have been found in several Indonesian waters, such as those of The Thousand Islands (West Penjaliran Island, Pramuka Island, Panggang Island, Semak Daun Island, Pari Island, Ayer Island, and Tidung Island) and Belitung Island (Buyut Island, Tanjung Kelayang, and Keran Island) (Widiarti, 2002, 2010, 2011; Widiarti and Pudjiarto, 2015). In addition, the presence and high density of several genera of benthic dinoflagellates, namely *Gambierdiscus*, *Ostreopsis*, and *Prorocentrum*, have also been reported in the waters of Bali (Kuta, Sanur, and Nusa Dua) (Skinner *et al*., 2011), west coast of South Sumatra and coastal Bintan Island – Riau Islands (Thamrin, 2014), coastal waters of Padang City (Dwivayana *et al*., 2015; Eboni *et* *al*., 2015; Seygita *et al*., 2015; Oktavian *et al*., 2017), Lampung Bay (Pahawang Besar Island and Kelagian Island Small) (Widiarti and Adi, 2016), and Weh Island, North Aceh (Rubiah Island) (Widiarti *et al*., 2016b).

The Gili Matra Aquatic Tourism Park (Taman Wisata Perairan/TWP) is the center for marine tourism and a well-known marine conservation area in West Nusa Tenggara Province. However, the pressure of human activities originating from tourism and fishing activities around TWP Gili Matra can cause damage to coastal ecosystems, especially coral reefs. Damage to coral reef ecosystems due to uncontrolled tourism activities, such as activities that trample the surface of the reefs, disposal of waste into the waters, or overfishing of coral reefs can further reduce the quality of the waters around Gili Matra (Gili Trawangan, Gili Meno, Gili Ayer). The damage has the potential to provide new growth sites for various macroalgae, which are the preferred substrate for toxic benthic dinoflagellates (deSylva, 1994) so that these conditions further support the presence and abundance of benthic dinoflagellate communities.

Based on previous research, several genera of benthic dinoflagellates that are classified as dangerous and/or toxic, namely *Prorocentrum*, *Gambierdiscus*, and *Ostreopsis*, have been found in the waters of Gili Trawangan (Skinner *et al*., 2011), and in the waters of Gili Meno and Gili Ayer (Widiarti *et al*., 2016a). This does not rule out the possibility of finding other genera in the community of benthic dinoflagellates that cause CFP, such as *Amphidinium* and *Coolia*. This makes research on benthic dinoflagellate communities that cause CFP in the waters of West Lombok and Gili Matra to be important, as a basis for mitigating potential disasters that can be caused by the Dangerous Algae phenomenon in the region.

CFP is a type of poisoning that occurs in humans due to the consumption of reef fish that have been contaminated with ciguatoxin, and has become a global issue. Coral reefs in Indonesia are the richest in the world. It is estimated that of the total coral reef area in the world, which reaches 284,300 km^2, 18% (85,200 km^2) is located in Indonesia (Terumbu Karang Indonesia, 2014). Inside these reefs there are 2,500 species of fish, 1,500 species of mollusks, 1,500 species of crustaceans, and 590 species of coral. However, nowadays, due to increasing human activities in coastal areas and the existence of climate change and global warming, there has been much damage and death of coral reefs that have triggered the emergence of CFP caused by eating fish contaminated with ciguatoxin produced by tropical dinoflagellates (single cell organisms) that live in microalgae that grow a lot on dead coral. The Indonesian government identified that more than 30% of the total area of coral reefs in Indonesia, which reaches 18,000 km^2, was severely damaged. Apart from being caused by overexploitation of natural resources, this condition is exacerbated by the impact of climate change. Over the last 50 years, the share of decline in Indonesia's coral reefs has increased from 10% to 50% based on the 2002 Reefs at Risk report (Burke *et al*., 2002). CFP is one of the most damaging food-borne illnesses to human health. Although Indonesia is not widely known as a tropical country rich in coral reefs, it is critical to be aware of this algal-based poisoning syndrome. For this reason, a collaborative research project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" (Ciguatera project) between the North Pacific Marine Science Organization (PICES) and the Institute of Technology of Indonesia (ITI), supported by the National Research and Innovation Agency of Indonesia (BRIN), the University of Indonesia (UI) and the University of Mataram (UNRAM), is very important and provides the opportunity to deliver knowledge about the dangers of CFP to all levels of Indonesian society, including policy makers in government. This research, funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was also supported by BRIN through its House of Biological and

Environmental Research Organization Program and BRIN’s Expedition and Exploration Funding on research on the Potential Threats of the Phenomenon of Dangerous Algae (HABs) and Ciguatera Fish Poisoning (CFP) in Relation to Human Activities in the Aquatic Tourism Park area (Taman Wisata Perairan/TWP) area, Gili Matra Islands, Lombok (Fig. 5.1). Its implementation in the field was supported by the Provincial Government of West Nusa Tenggara (WNT) and its Regional Apparatus Work Units (SKPD), universities, the Kupang National Water Conservation Area (BKKPN), the Regional Research and Innovation Agency (BRIDA) of West Nusa Tenggara Province (WNT, Department of Marine Affair and Fisheries, and Department of Environment and Forestry which were also involved in a training workshop in January 2023.

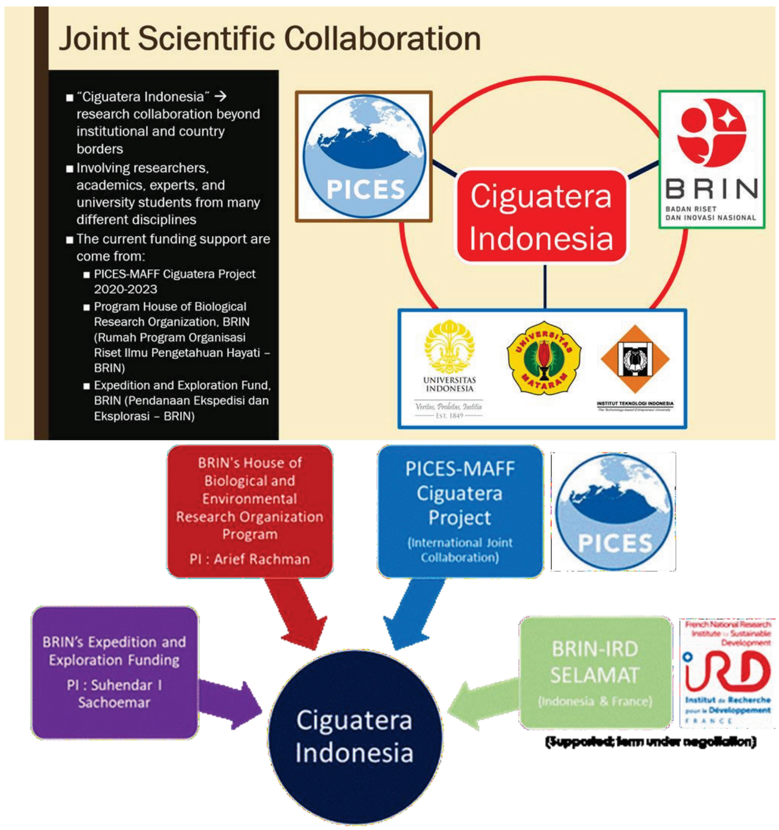


Fig. 5.1 Funding and scientific support for the Ciguatera Indonesia project.

5.1.2 Research objectives

The overall project goal was to build the capacity of local small-scale fishers and community members to monitor their coastal ecosystems and coastal fisheries. The aim was to encourage community empowerment, which would lead to benefitting human health in Pacific Rim developing countries. The focus of this project was CFP in tropical reef fisheries, which globally has the greatest human health and economic impacts of any algal-based poisoning syndromes. The key question, and aim of the project was: How to best foster the use of smartphone-based citizen-science technologies, developed in the 2017–2020 PICES-MAFF project on “*Building capacity for coastal monitoring by local small-scale fishers*” (FishGIS), to empower Indonesian coastal communities to assess, detect, and minimize their exposure to CFP in community-scale fisheries?

Another objective was to study benthic dinoflagellate communities that have the potential to cause CFP, with target genera namely *Gambierdiscus*, *Prorocentrum*, *Coolia*, *Ostreopsis*, and *Amphidinium*, and their relation to habitat conditions and water quality in the Gili Matra area, as well as to study the level of pressure on these communities from human activities and potential economic losses due to the abundance of harmful algae/CFP.

The third objective was to disseminate information and increase public awareness on the potential dangers of HABs and CFP in the Gili Matra area and the coast of West Lombok through capacity building activities (training workshops).

5.1.3 Scope of research

The scope of this research activity covered various aspects closely related to CFP in an integrated manner, including:

- Study of phytoplankton, including benthic dinoflagellate (ciguatera) communities, through field surveys, laboratory analysis, DNA and machine learning, including identification of density, diversity and uniformity of dinoflagellate causes of CFP;
- Aquatic biophysichemical environmental studies through field surveys, laboratory analysis, HydroColor and FishGIS, including analysis of the quality of the aquatic environment and coastal ecosystems (coral reefs and seagrass beds);
- E-DNA studies for fish diversity identification;
- Study of food safety and traceability of fish products;
- Study of social economics and the Human Dimension;
- Workshops and training for capacity building.

The scope of research activities is shown schematically in Figure 5.2.

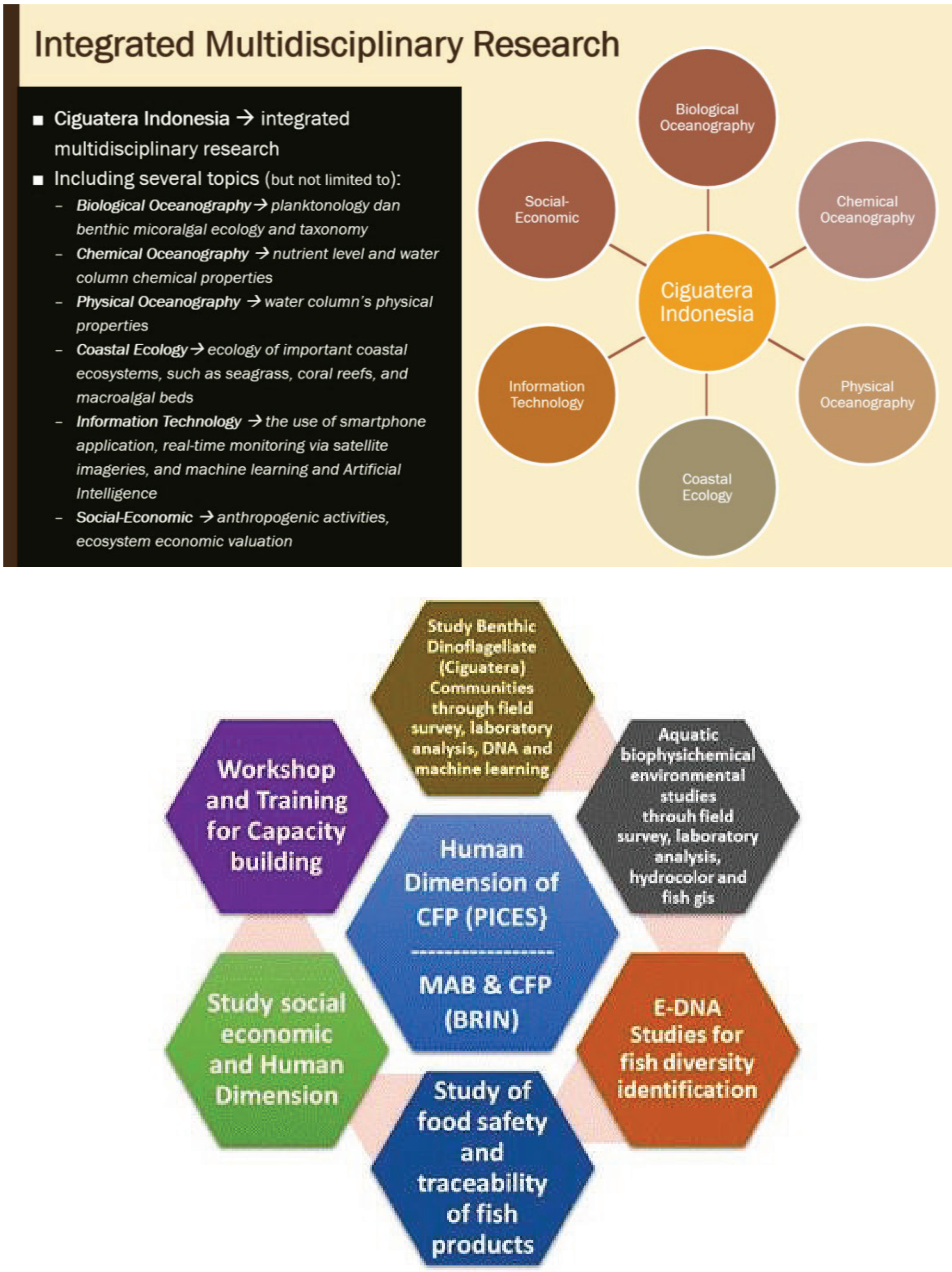


Fig. 5.2 Scope of research in the Ciguatera Indonesia project.

5.2 Method

5.2.1 Time and location of research surveys

Five research surveys were conducted:

- First survey (Survey I) on May 23–28, 2022
- Second survey (Survey II) on August 1–5, 2022
- Third survey (Survey III) on October 10–16, 2022
- Fourth survey (Survey IV) on December 12–18, 2022
- Fifth survey (Survey V) on February 20–25, 2023

The research surveys (see Appendix 4 for members of the Survey Team) were carried out at the TWP (Taman Wisata Perairan/Aquatic Tourism Park) Gili Matra. TWP Gili Matra is a tourism and conservation area in the coastal waters of West Lombok (Fig. 5.3). TWP Gili Matra which consists of Gili Meno, Gili Ayer and Gili Trawangan has an area of 2,273.56 ha (2,954 km2). The area of Gili Meno ± 150 ha with circumference of ± 4 km, Gili Ayer ± 175 ha with circumference of ± 5 km and Gili Trawangan ± 340 ha with a circumference of ± 7,5 km, and the rest are marine waters. TWP Gili Matra has an important ecosystem of aquatic resources, ranging from mangroves, coral reefs and seagrasses, in which these ecosystems are areas serving vital functions for protecting rare animals, such as the black fin sharks, white fin sharks, manta rays, clams and turtles. However, the pressure of human activities in the TWP Gili Matra area can lead to a decrease in water quality, and trigger the occurrence of the phenomenon of harmful algal blooms (HABs) and/or CFP. Area sampling and data collection were carried out in the waters (in certain zoning) around Gili Trawangan, Gili Meno, and Gili Ayer. Sampling activities were carried out 5 times during the Ciguatera project, in May 2022 (Transition Season I), August 2022 (July/August Dry Season), October 2022 (September/October Transition Season II,), December 2022 (Northwest Monsoon/rainy/wet season, November/December), and February 2023 (end of the rainy/wet season, January/February).

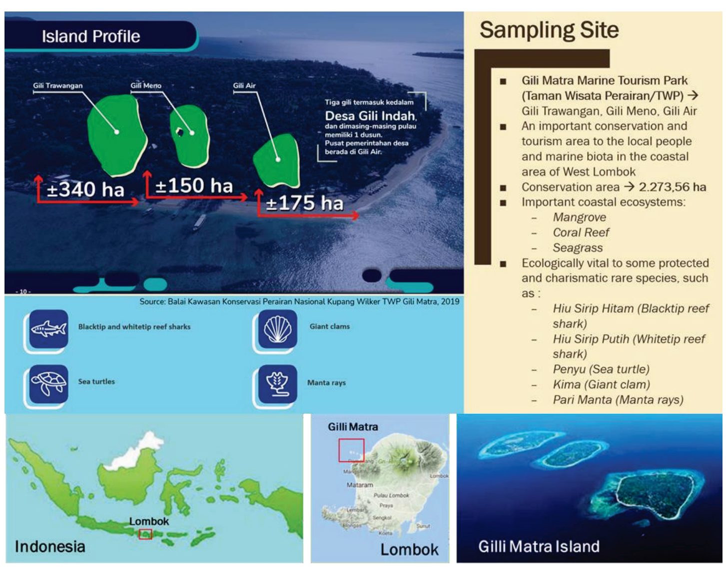


Fig. 5.3 Location of TWP Gili Matra off Lombok, West Nusa Tenggara, Indonesia.

5.2.2 Data collection and analysis

5.2.2.1 Sample collection of phytoplankton assemblages at TWP Gili Matra

Phytoplankton samples were collected from 16 sampling sites/stations around TWP Gili Matra (Table 5.1, Fig. 5.4) during field work in May, August, October, December 2022 and February 2023. A vertical tow from a depth of 10 m was performed using a Kitahara net (30cm; mesh size 20 µm) to collect the samples. Phytoplankton identification and enumeration were done under 100–400X magnification with a Nikon Diaphot 300 inverted phase-contrast microscope and Sedgewick Rafter Counting Chamber (SRCC). Phytoplankton images were taken under phase-contrast and bright field lighting mode with a DSLR 500D (Canon, Japan). To enhance contrast and get more morphological details, a GIF filter was used in the microscope and images were taken in monochrome mode. Whenever possible, phytoplankton identification was done up to species level, except for genera such as *Pseudo-nitzschia* spp., *Thalassiosira* spp., and other small-sized diatoms such as *Navicula* spp., in which distinguishing characters were unobservable under light microscopy (LM).

As a note, zooplankton samples were also collected from the same sampling sites using the same method, but with a NORPAC net (30 cm; mesh size 125 µm). All plankton samples were preserved by adding 10–20mL Lugol's Iodine to them, depending on the density of plankton in the samples.

Table 5.1 Coordinates, colour codes, and zone names of each sampling site/station in the surveys.

Station	Long. (°E)	Lat. (°S)	Colour Code	Zone	Island
1	116.0236	–8.35352	Red	Core	Gili Trawangan
2	116.0265	–8.33868	Green	Utilization	Gili Trawangan
3	116.0455	–8.3535	Blue	Harbour	Gili Trawangan
4	116.0443	–8.36012	Grey	Rehabilitation	Gili Trawangan
5	116.0358	–8.36574	Light-blue	Sustainable Fisheries	Gili Trawangan
6	116.0681	–8.34595	Red	Core	Gili Meno
7	116.0649	–8.35293	Blue	Harbour	Gili Meno
8	116.065	–8.35575	Grey	Rehabilitation	Gili Meno
9	116.0572	–8.36373	Light-blue	Sustainable Fisheries	Gili Meno
10	116.0502	–8.35152	Green	Utilization	Gili Meno
11	116.0532	–8.33727	Light-blue	Sustainable Fisheries	Gili Meno
12	116.0722	–8.36524	Red	Core	Gili Ayer
13	116.0832	–8.36693	Blue	Harbour	Gili Ayer
14	116.0909	–8.36069	Green	Utilization	Gili Ayer
15	116.0845	–8.34567	Light-blue	Sustainable Fisheries	Gili Ayer
16	116.0448	–8.34519	Green	Utilization	Gili Trawangan

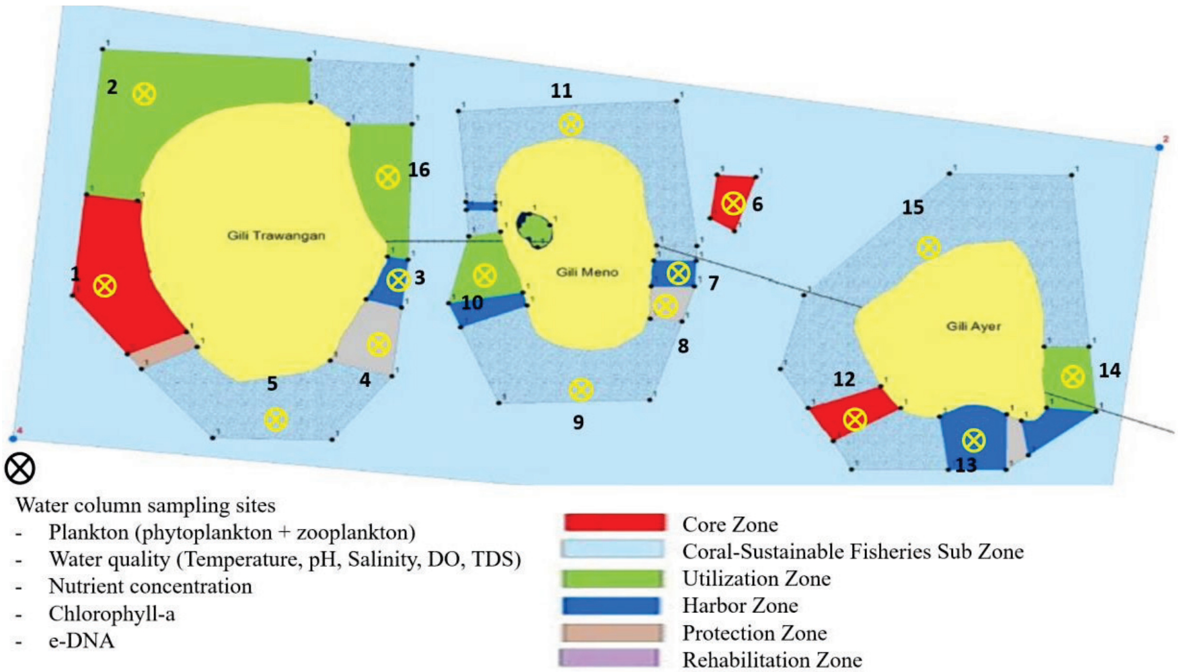


Fig. 5.4 Plankton sampling sites in TWP Gili Matra during field surveys in May, August, October, December 2022 and February 2023. The sites' locations were based on a previous study in 2019 (Rachman, 2019).

A trial study to observe some diatoms cells under a Scanning Electron Microscope (SEM) was conducted on selected samples. In this case, the diatom cells were cleaned using the sodium hypochlorite (NaOCl) method by Carr *et al*. (1986) with some modifications. About 2–5 mL of Lugol's preserved phytoplankton sample were filtered with a nylon filter membrane (mesh size 15 µm) in a plastic filter holder. The sample was then washed two times with deionized (DI) water, and NaOCl solution (6%) was poured onto the filter. The filter holder was then placed in a beaker glass filled with NaOCl solution and left for 15 minutes. The organic matter oxidation reaction was stopped by washing the filter five times with DI water, followed by serial dehydration with 30–50–70–99% ethanol. The sample was then pipetted into the aluminium sample stub with carbon tape and air dried in an environmental chamber at 27°C and RH 40%. The uncoated samples were then analysed in PRISMA-E (Thermo Fisher Scientific) SEM under low-vacuum (40–50 Pa) with an accelerating voltage between 5–10 kV. Another set of cleaned diatom samples was coated with gold-palladium using a Quorum sputter coater and was analysed in PRISMA-E SEM under a high-vacuum with accelerating voltage between 15–30 kV.

New method for collecting ciguatoxin from water columns

In December 2022 sampling, a new method for collecting ciguatoxin directly from the water column was tried. The method was originally developed by another joint research project, the International Joint Laboratory–SEntinel LAboratory of the Indonesian MArine biodiversity (IJL-SELAMAT) IRD French–BRIN Indonesia, in which Mr. Arief Rachman was involved.

This method utilized a new tool named SPATT (Solid Phase Adsorption Toxin Tracking, Fig. 5.5) which could be deployed with the set of artificial substrates in the selected permanent sites for benthic dinoflagellate sampling in TWP Gili Matra. The preparation of SPATTs and deployment methods followed the "Step-by-step protocol Sampling of Toxic Dinoflagellates and Ciguatoxines SELAMAT – CIBSEEA 2022", with some modifications. In the method, SPATT filters were prepared by putting 3 g of synthetic adsorbent resin in between the nylon mesh and then secured with a circular frame made from PVC and rubber (Fig. 5.6). The filter set was activated by submerging the filter in methanol solution for 3 hours, then rinsing the filter with MiliQ water at least two times to wash away the excess methanol. The filter was then placed in a jar filled with MiliQ water and kept at a low temperature (max. 4°C) before being deployed in the field within 48 hours from the time of filter activation.

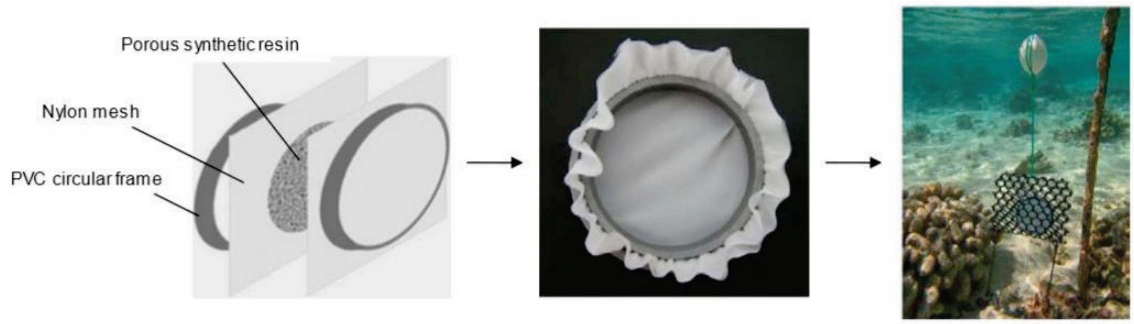


Fig. 5.5 Example of SPATTs assembly and deployment in the field.

In the field, three SPATT filters were assembled inside a plastic container/"cage" and were combined with one set (three pieces) of artificial substrate (Fig. 5.6B). The entire rig of SPATTs and artificial substrates was then deployed at the benthic dinoflagellate sampling site at a depth of 4–5 m for 5 days (Fig. 5.6C, D). After 5 days, the SPATT filter was collected from the cage and placed in a cooler/ice box with an ice pack/ice for transportation back to the hotel/field accommodation. Back at the accommodation, the SPATT filter was placed in the freezer (<0°C). Later on, the filter was stored in a deep freezer at temperatures ≤15°C located at the Plankton Laboratory, Laterio Building, Research Center for Oceanography BRIN. The ciguatoxin analysis from this method will be done later in the laboratory of IRD or Montpellier University, France, which is planned for mid-2023.

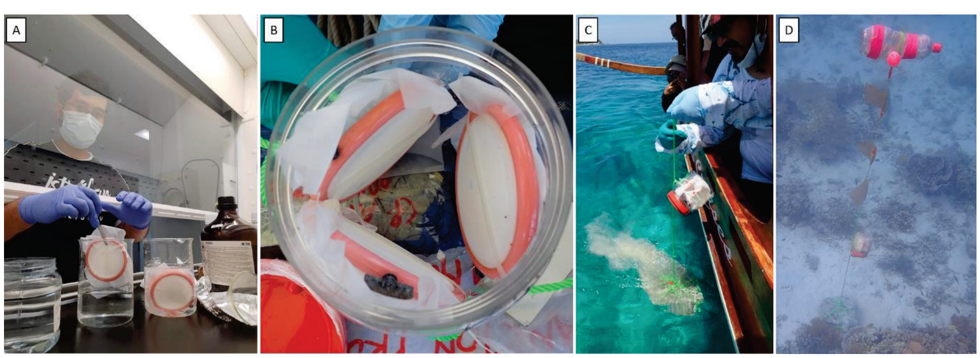


Fig. 5.6 New method to collect ciguatoxin directly from the water column. (A) preparing the SPATT filters in the laboratory, (B) SPATT filters inside the plastic container/cage, (C) deployment of the SPATT rig from the boat, (D) SPATT rig in the water at a depth of 4–5 m.

Additionally, the artificial substrates from the SPATT rig were collected and treated with the same method as that for the benthic dinoflagellate sampling. All artificial substrate samples from the SPATT rig were also stored at the Plankton Laboratory, Laterio Building, Research Center for Oceanography BRIN.

New method for analyzing phytoplankton samples

In February 2023 sampling, a trial for a new method for analyzing phytoplankton samples with Planktoscope was conducted (Fig. 5.7). The Planktoscope is a highly modular and open-source system capable of performing high-throughput quantitative imaging of plankton samples. The Planktoscope used in Survey V was one of the two Planktoscopes that were given by PICES to the Plankton Laboratory, Research Center for Oceanography, BRIN (PRO-BRIN) and to the Faculty of Science, Mataram University (FMIPA UNRAM). Both pieces of equipment have identical hardware configuration, although the PRO-BRIN's Planktoscope software was configured for online remote operation.

In this trial, a live and unpreserved (fresh) sample from the phytoplankton vertical tow was used. A fresh sample was used instead of a Lugol's Iodine preserved sample to prevent Lugol staining of Luer Ibidi flow cell and to ensure the phytoplankton had intact chloroplasts or pigments that could help identify their genera or species under bright field imaging conditions. To avoid clogging in the flow cell, the sample was diluted by adding 1 mL of fresh phytoplankton sample into 9 mL of filtered seawater. The sample was then run through the Planktoscope in several short-run (5–10 runs with 100 sample images per run) to reduce the operational load of the Planktoscope software and hardware.

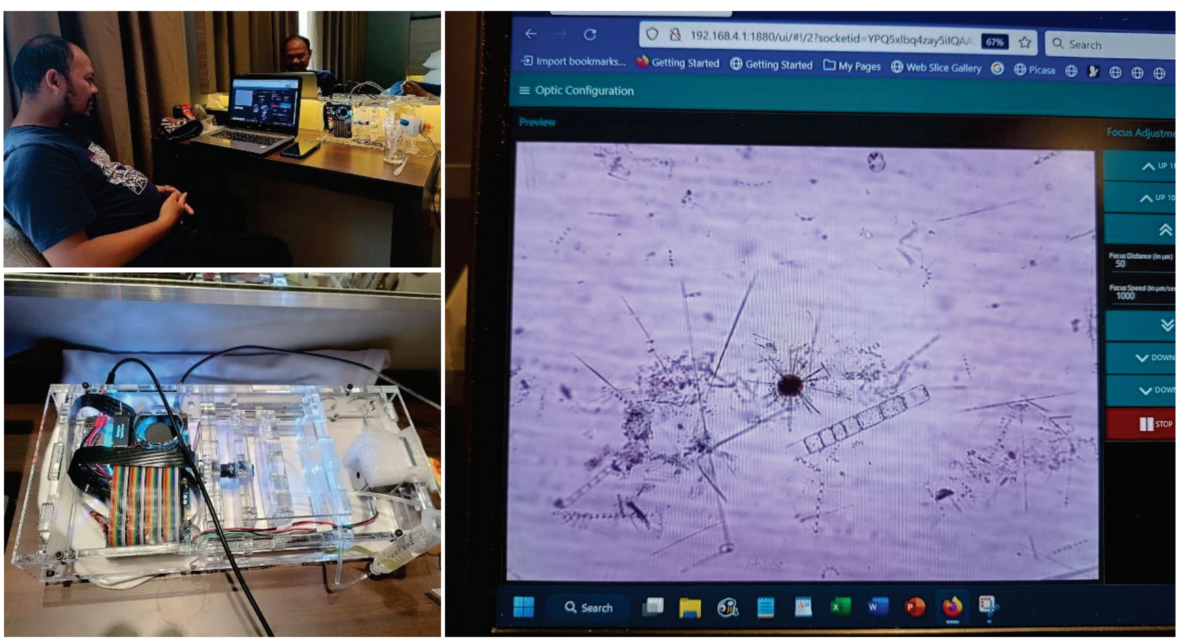


Fig. 5.7 Documentation of a trial run to analyze a phytoplankton sample using the Planktoscope. Both the PRO-BRIN and FMIPA UNRAM Planktoscope were used and performed well during the analysis.

5.2.2.2 Potentially toxic benthic dinoflagellates causing CFP at TWP Gili Matra

To study toxic benthic dinoflagellates, sampling was conducted in the reef flats of Gili Trawangan, Gili Meno and Gili Ayer area (Table 5.2, Fig.5.8), from February 20–25, 2023).

Table 5.2 Sampling coordinates at each station around TWP Gili Matra.

Station	Sampling point	Coordinates	
Gili Trawangan	GT-1	–08°20′51.78″ S	116°02′34.57″ E
	GT-2	–08°20′52.28″ S	116°02′34.73″ E
	GT-3	–08°20′52.80″ S	116°02′34.94″ E
Gili Meno	GM-1	–08°20′54.29″ S	116°03′05.42″ E
	GM-2	–08°20′55.24″ S	116°03′05.19″ E
	GM-3	–08°20′56.02″ S	116°03′05.26″ E
Gili Ayer	GA-1	–08°21′54.93″ S	116°04′49.02″ E
	GA-2	–08°21′54.00″ S	116°04′47.70″ E
	GA-3	–08°21′53.69″ S	116°04′46.57″ E

Fig. 5.8 Sampling locations at TWP Gili Matra (red pins).

Data collection and observation

The thallus and seagrass leaves of macroalgae were randomly harvested along with coral rubble on the reef flat areas of 50 to 100 cm depth and placed inside wide-mouthed plastic bottles containing ambient seawater. The whole process was conducted underwater to avoid sample disruptions due to air and sunlight exposures. A series of artificial substrates which consisted of nylon/fiberglass gauze measuring

15 × 10 cm, tied with ropes and fishing floats, was then anchored to the sea floor with lead weights and left for 24 hours after which the nylon gauze was retrieved and put into a 1 L bottle. Conditions of some benthic HABs (bHABs) habitats and artificial substrate sampling at TWP Gili Matra can be seen in Figures 5.9 and 5.10, respectively.

After collection, each plastic bottle containing the microsubstrate and seawater was shaken vigorously for 1 minute to detach the benthic dinoflagellates from the substrate. The samples were filtered through a series of sieves with a mesh size of 125 and 25 μm to separate samples from sediments and other larger organisms. Samples were then fixed using ethanol 96% to reach the final concentration of 4% (v/v).

Cell shape and size were observed using a LM Leica DM 500. The fixed cells were isolated using a modified Pasteur pipette, dripped onto the object-glass, and sealed with a cover glass. The slides were then observed under the microscope with 200X magnification. Cells were photographed using a LEICA LAS EZ 2.0.

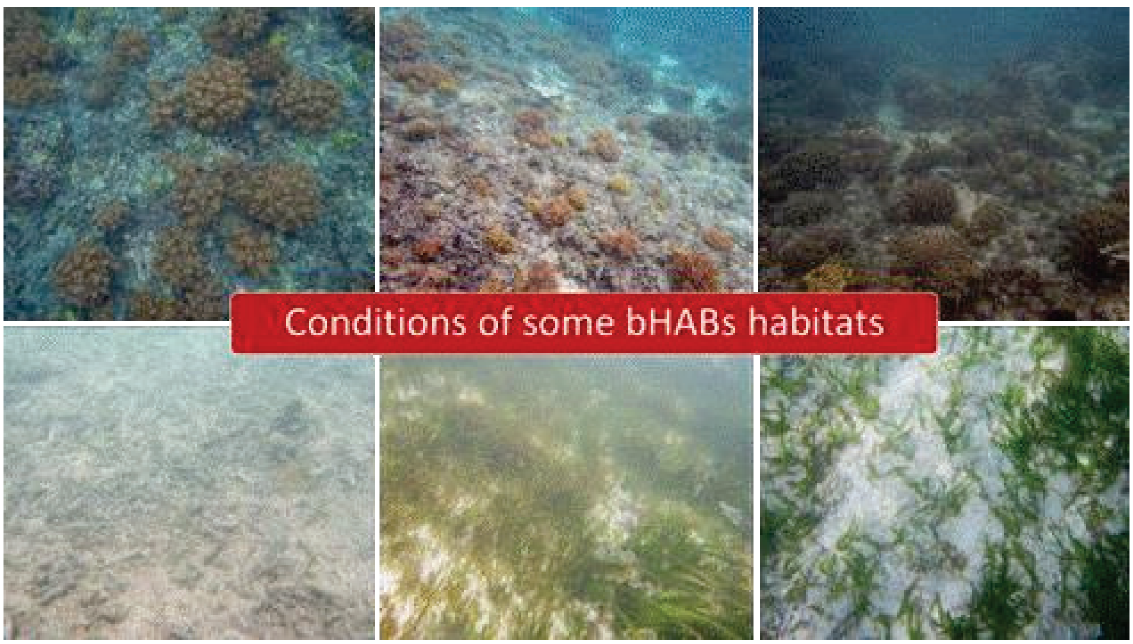


Fig. 5.9 Conditions of some benthic HABs (bHABs) habitats at TWP Gili Matra, Lombok.

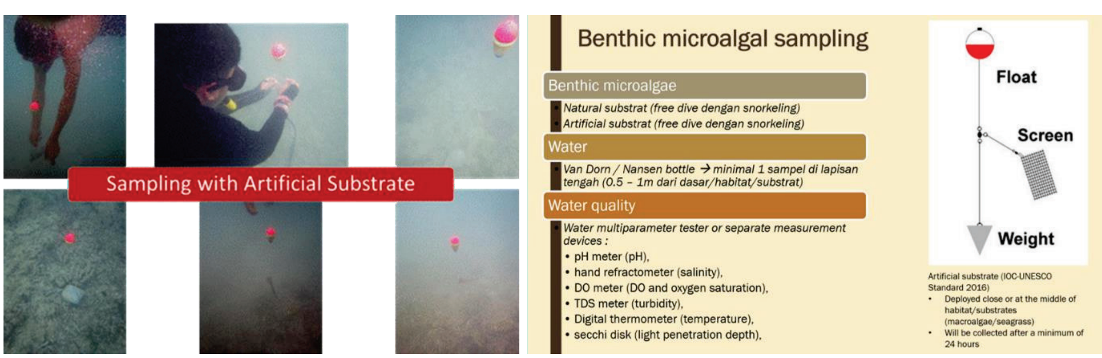


Fig. 5.10 Artificial substrate sampling at TWP Gili Matra.

DNA isolation and extraction

DNA extraction was performed by freeze-thaw and single cell Polymerase Chain Reaction (PCR) method (Hernández-Rosas *et al*., 2017; Chomérat *et al.*, 2018) with modifications. The tube containing the target cell was stored in a freezer at –20°C for 18–20 hours. The tube was then removed from the freezer and placed into a water bath at 95°C for 5 minutes and in a sonicator for 1 minute. Afterward, it was immediately stored back in the freezer at –20°C until the subsequentDNA analysis treatment.

Amplification and electrophoresis

The PCR mixtures were performed in a volume of 25 µL containing 1 µL extracted cells, 9 µL ddH_2O, 12.5 µL My Taq Red Mix, 1.25 µL primers D1R forward (5'-ACCCGCTGAATTTAAGCATA-3') and 1.25 µL D2C reverse (5'-CCTTGGTCCGTGTTTCAAGA-3') (Laza-Martinez *et al.*, 2011; Tawong *et al.*, 2015). The PCR amplification involved pre-denaturation at 94°C for 5 minutes followed by 37 cycles of denaturation at 94°C for 30 seconds, annealing at 54.4°C for 50 seconds, extension at 72°C for 45 seconds, and final extension at 72°C for 6 minutes (Zhang *et al.*, 2015). The PCR product was then delivered to the PT. Genetika Science Indonesia sequencing service.

Phylogenetic tree

The sequencing result was edited using MEGA 7.0 (Molecular Evolutionary Genetics Analysis) software for reading the base sequences and DNA alignment was edited using the alignment Clustal W method (Tamura *et al*. 2011). The data obtained were then adjusted to the reference sequence/database from Genbank (NCBI) using BLAST (Basic Local Alignment Search Tool). Phylogenetic analysis on *P. lima* was carried out with the Maximum Likelihood (ML) and Neighbor Joining (NJ) method using MEGA software, with 500 bootstrap replications (Tawong *et al.* 2015; Zhang *et al.* 2015).

5.2.2.3 Deep (Machine) Learning for phytoplankton identification using microscopy images

Plankton are free-floating organisms that live, grow, and move with the ocean currents. These free-floating organisms play an important role as primary producers, serve as energy transfer links, and are factors that regulate biogeochemical cycles. Indonesia, with nearly 60% of its territory covered by oceans, has a wide variety of planktonic species. However, one of the problems in ordinary planktonic studies is the lack of fast and accurate methods for identifying and classifying plankton types. Thus, a computer vision method on microscopic images is proposed to solve the problem. Classification follows two main steps: detecting the location of the plankton followed by differentiation of the plankton. A segmentation algorithm is needed to limit the determination area. This study describes the method of segmentation of fifteen types of plankton where U-Net based architecture is implemented to divide the plankton texture from other objects.

5.2.2.4 Water quality assessment at TWP Gili Matra

Physical parameters of water (temperature, turbidity, total dissolved solids, and specific gravity) were measured on-site using a water quality checker Horiba U-5000, and total suspended solids (TSS), suspended particulate matter (SPM) and Chlorophyll-a were measured with HydroColor and FishGIS applications. Brightness was measured by lowering a secchi disk into the water column until the disc was no longer visible. TSS was measured by calculating the difference in weight of 0.45 m filter paper before and after the water was filtered according to SNI 06- 6989.3-2004.

Seawater samples for chemical analysis were taken on the surface layer and deep layer (5 m depth) at 16 station points using a Van Dorn water sampler. Prior to analysis, seawater samples were filtered using filter paper made from cellulose acetate with a diameter of 47 mm and a pore size of 0.45 µm. After filtering, 250 mL of the water sample were put into a polyethylene bottle and placed in a cool box for analysis in the laboratory.

Water chemistry parameters (pH, oxidation reduction potential, conductivity, salinity, and dissolved oxygen (DO)) were measured on site using a Horiba U-5000 water quality checker. The concentrations of phosphate (PO_4), nitrite (NO_2), nitrate (NO_3), ammonia (NH_4), and silicate (SiO_3) were measured using the spectrophotometric method by reacting a sample of water that had been filtered using 0.45 µm filter paper with each kit and then reading with a Hach DR 900 spectrophotometer.

5.2.2.5 E-DNA for fish species diversity assessment at TWP Gili Matra

Currently, molecular approaches are commonly used to identify the presence and abundance of fish species, although conventional identification based on morphological characters is sometimes still carried out. Identification using the molecular approach is cost-effective, fast, does not require taxonomic skills, and minimizes errors with near 100% accuracy.

Environmental DNA, or e-DNA, is DNA collected from various environmental samples such as soil, seawater, snow or air, and not directly from individual organisms. When various organisms interact with their environment, their DNA is released and accumulates in their environment from various sources, including feces, mucus, gametes, scales, skin, carrion and hair. Furthermore, to better differentiate between organisms in the sample, e-DNA metabarcoding is used in which the sample is analyzed and previously studied DNA libraries, such as BLAST, are used to determine what organisms are present.

The purpose of this study was to apply the e-DNA metabarcoding technique to seawater samples from Gili Matra waters to identify fish species living in these waters. The study also constructed a phylogenetic tree with identified marine fish species based on the e-DNA metabarcoding approach. This study will provide preliminary information on fish biodiversity in the waters of TWP Gili Matra, which will help identify the types of fish that are potentially contaminated with CFP in the area.

Water sampling

Sea surface water samples were taken with a volume of 1 L for each location/station at 16 stations (Table 5.3) and stored in plastic bottles. A total of 2 L of sample water was filtered with a 0.45 µM 47MM cellulose nitrate filter and filter paper results were stored in each plastic and preserved at –20°C.

Table 5.3 TWP Gili Matra sampling station coordinates.

Station	Coordinates	
	Latitude	Longitude
1	–835.352	116.0236
2	–833.868	116.0265
3	–83.535	116.0455
4	–836.012	116.0443
5	–836.574	116.0358
6	–834.595	116.0681
7	–835.293	116.0649
8	–835.575	116.065
9	–836.373	116.0572
10	–835.152	116.0502
11	–833.727	116.0532
12	–836.524	116.0722
13	–836.693	116.0832
14	–836.069	116.0909
15	–834.567	116.0845
16	–834.519	116.0448

DNA extraction and concentration measurement

Half of the filter paper was used as a DNA extraction material using the ZYMO Quick-DNA Miniprep plus kit. The extraction results were dissolved in a total volume of 50 µL of elution buffer and stored at –20°C. The results of the extraction of each station were measured using the Nanodrop tool. As much 2 µL were taken to measure the DNA concentration at a A260/A280 wavelength.

5.2.2.6 Food safety and traceability of reef fish at TWP Gili Matra and surroundings

The development of a reef fish traceability system related to CFP is intended to fulfill three goals:

1. To provide responses/actions to the potential risks that may arise from food originating from coral waters and to ensure that reef fish food products and their associations are safe for public consumption.
2. To develop a reef fish traceability system by the appropriate agencies or food businesses to identify and trace any root causes of food poisoning caused by ciguatoxin poisoning. That way, the problem can be isolated and ciguatoxin-contaminated products can be prevented from reaching consumers.
3. To withdraw products that are suspected of having been exposed to ciguatoxin contamination to reduce the risk of adverse events to human health.

The traceability system is also in line with international regulations such as the Codex Alimentarius Commission Guideline (CAC/GL) 60-2006, which aims to protect consumers against food-borne hazards, based on the International Organization for Standardization (ISO) 22005/2007, and the use of traceability to support food quality and safety.

Based on ISO 22005/2007, traceability is used to support food quality and safety, meet consumer specifications, determine product history or origin, and facilitate product recalls. Traceability is also used to identify organizational responsibilities in the food chain and to facilitate verification of product-specific information.

Data collection was sourced from actors in the distribution of reef fish for consumption from upstream to downstream, that is, from collectors, wholesalers, small traders/retailers, to restaurant owners/managers. The actors in the distribution chain were then used as respondents who were interviewed and observed during fish handling and processing at their respective facilities.

Data collection was carried out by observation and interviews using a questionnaire regarding the freshness of fish, and about the handling and processing of fish. Characteristics of fresh fish are based on SNI 2729 of 2013 (Fig. 5.11).

Fig. 5.11 Fish sampling for ciguatoxin analysis.

5.2.2.7 Social economics and the Human Dimension of TWP Gili Matra

Based on the results of an original study in the Decree of the Minister of Maritime Affairs and Fisheries Number KEP.67/MEN/2009, geographically, TWP Gili Matra which consists of Gili Trawangan, Gili Meno and Gili Ayer are located at 116°01'–116°12' east longitude and 08°20'–08°22 south latitude (Fig. 5.12).

Administratively, the boundaries of TWP Gili Matra are as follows:

- North: bordered by the Java Sea
- South: bordered by the Lombok Strait
- West: bordering the Java Sea
- East : bordered by Sira Sea

Conservation targets of TWP Gili Matra include coral reefs, seagrass, mangroves and fish resources. Social, cultural and economic targets include local communities, especially fishers, tourism activities and residents.

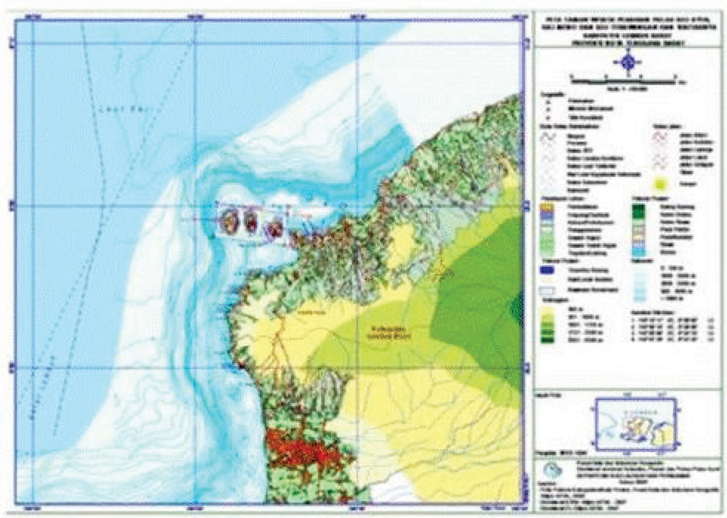


Fig. 5.12 Map of TWP Gili Matra (Gili Trawangan, Gili Meno and Gili Ayer), Lombok, according to the Decree of the Minister of Maritime Affairs and Fisheries Number KEP.67/MEN/2009.

Social economic analysis of ciguatera fish poisoning (CFP): People awareness

As stated in the Introduction, CFP is a type of poisoning in humans that occurs due to consumption of reef fish that have been contaminated with ciguatoxin, and is closely related to environmental and human health problems. Various studies related to ciguatera have been carried out by scientists in various parts of the world (Katz *et al*., 1993; Jeong *et al*., 2012; Tester *et al*., 2013; Chan, 2014; Kohli *et al*., 2017; Xu *et al*., 2021). However, in Indonesia the problem of CFP is not widely known. The Indonesian government has identified more than 30% of its coral reefs as severely damaged.

Gili Matra has a marine conservation area of 2,273.56 ha (2,954 km^2) which includes various important ecosystems, such as mangroves, coral reefs and sea grasses. These areas serve vital functions in protecting endangered species such as blackfin sharks, whitefin sharks, manta rays, clams and turtles. However, the pressure of human activity in the Gili Matra area poses a threat to water quality, as well as triggering the phenomena of HABs and/or CFP.

The aim of this study was to analyze community awareness of CFP. We used a survey to find out how aware the locals were about the CFP phenomenon. A structured questionnaire containing several questions was distributed to 100 respondents in TWP Gili Matra (Fig. 5.13).

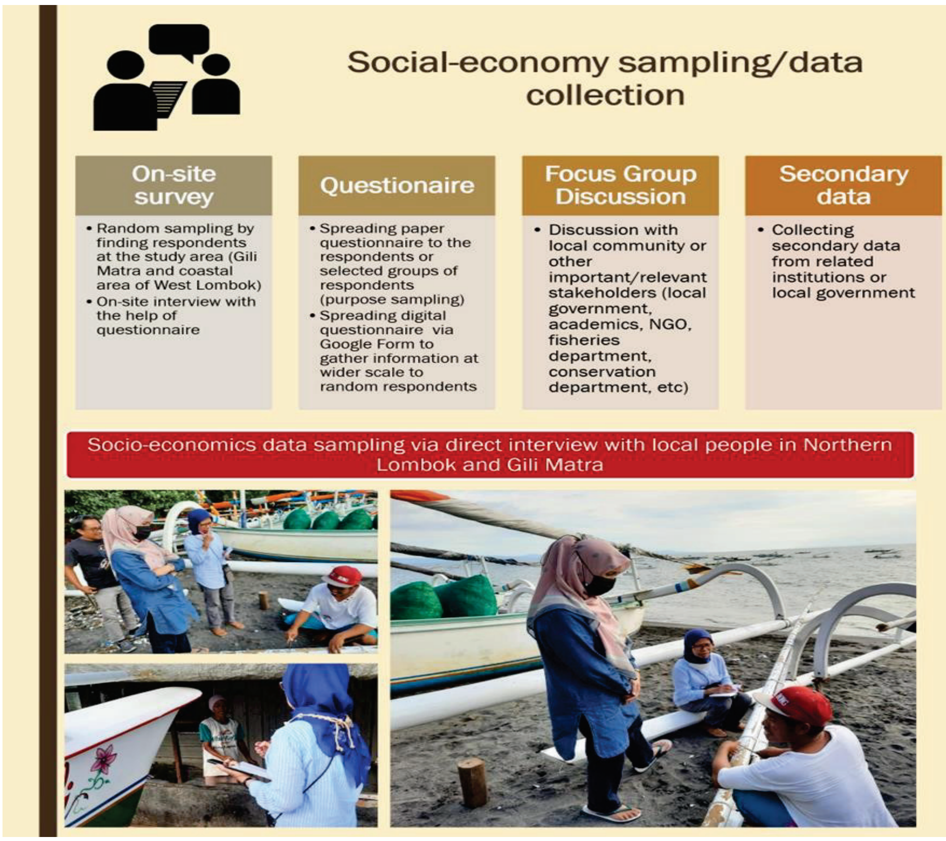


Fig. 5.13 Social Economy Survey distributed to the local community at TWP Gili Matra.

5.3 Results and discussion

5.3.1 Phytoplankton assemblages at TWP Gili Matra

It is well known that phytoplankton play an important role in the foundation of the aquatic ecosystem, which regulates primary productivity and the biogeochemical cycle. Due to their quick response to the changes in environment, phytoplankton assemblages are often used as a proxy to detect anomalies and determine the water's environmental qualities. However, fast and uncontrolled population growth of phytoplankton, particularly of toxin-producing species, *i.e*., HABs, can cause damage to the ecosystem. Although the causes of HABs are complex and different for each case, their occurrence is generally linked to increasing anthropogenic activities in coastal areas.

In this part of the Ciguatera project study, we examined the phytoplankton assemblages in the waters surrounding the three islands of Gili Matra, *i.e*., Gili Trawangan, Gili Meno and Gili Ayer. The main goal of the study was to determine the diversity of phytoplankton and to detect the occurrence of potentially harmful species in the water column. The phytoplankton data from this study will serve as a tool to help monitor the water quality and be used as a basis for HABs management in the area.

Although the sample and data analysis is not finished, several important findings have been made. From the current samples and dataset, it was estimated that the phytoplankton community in Gili Meno consisted of between 215 to 242 species, of which 202 have been identified up to the species level. Among those species, 17 species were categorized as potentially harmful due to their records of causing blooms in Indonesia and/or in other tropical countries. One of those potentially harmful species, the cyanobacteria *Trichodesmium erythraeum* dominated the phytoplankton communities in Gili Meno during the Dry Season (August 2022) and Transition Season II (October 2022). However, the domination of cyanobacteria was completely replaced by diatoms in the Wet Season (December 2022 and February 2023). Similarly, a diatom-dominated community was also discovered in Transition Season I (May 2022). Note that one diatom species, which is currently identified as *Lampriscus* cf. *shadboltianum*, was suspected either as a new record or new species, due to its unique frustule characteristics that were never described in detail before[1]. The list of 202 species identified so far in this study is listed in Figure 5.14. Note that some of the taxonomic names have not yet been corrected to the most recent ones.

From the phytoplankton dataset, it was discovered that the phytoplankton cell density seemed to increase significantly during the Wet Season (December 2022 and February 2023), which also caused an increase in the trophic level of the waters in Gili Meno. Based on the phytoplankton cell density, the waters in Gili Meno changed from oligotrophic in Transitional Season I (May), Dry Season (August), and Transitional Season II (October), into higher-mesotrophic in the Wet Season (December–February). That condition might be regulated by higher nitrate (NO_3) as well as higher N:P and N:Si ratio in the water columns of Gili Meno during the Wet Season. Although it was difficult to determine, we hypothesize that increasing nutrient input from the land due to surface runoff during the Wet Season supplied the water with nitrate, thus, causing a sharp increase in the phytoplankton cell density. Coincidentally, higher tourism activities in TWP Gili Matra at the end of 2022 and in early 2023 might also have contributed to the increasing N input to the waters. Note that high nitrate seems to correlate well with the higher density of some potentially harmful dinoflagellate genera, such as *Ceratium* and some planktonic *Prorocentrum*. Similarly, higher anthropogenic activities supplying the water with more phosphate, silicate, and nitrogen in the form of nitrites and ammonia, could correspond to the

[1] Currently we are not sure whether *Lampriscus* cf. *shadboltianum* is considered potentially harmful or not, since we have yet found any report on harmful *L. shadboltianum* blooms in other countries. We are aware of paper that describing *L. shadboltianum* as biofouling diatoms on a cruise ship's hull (https://doi.org/10.1080/08927014.2014.974576), but we did not find any definitive conclusion on its harmful effects. Thus, for now, we are not considering that species as potentially harmful.

increase of the potentially harmful genera *Trichodesmium*, *Amphidinium*, and *Chattonella*. All of those potentially harmful genera could cause major problems, particularly the *Chattonella* as it is known as the fish-killer dinoflagellate whose blooms can cause mass fish mortality. Therefore, it will be important to monitor and reduce the nutrient input to the coastal waters to lower the chance of HABs in TWP Gili Matra. This can be done by constructing proper wastewater treatment facilities on the islands which should help to reduce the nutrient load to the surrounding waters.

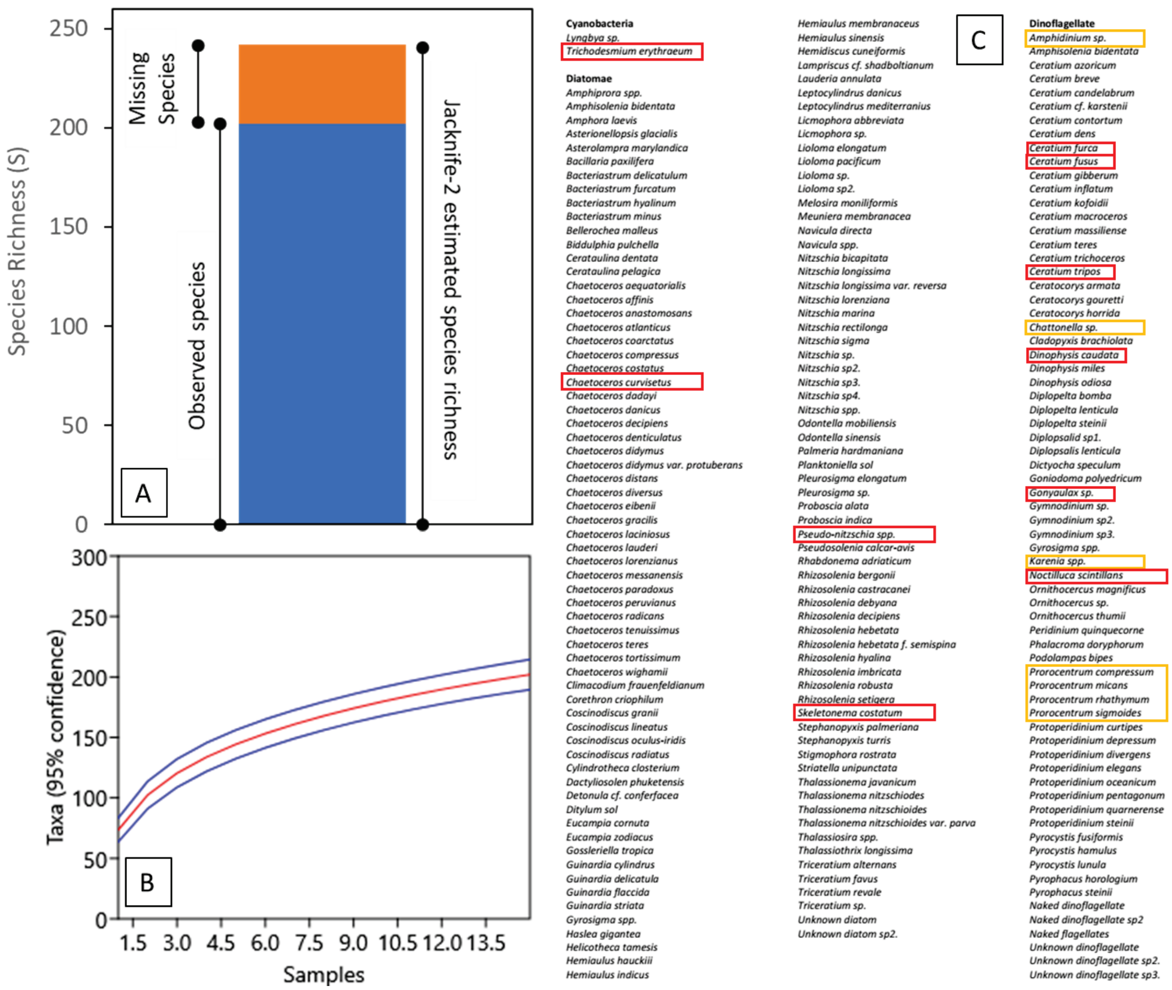


Fig. 5.14 Phytoplankton community data of TWP Gili Matra. (A) comparison between the number of observed species and the estimated number of species based on the Jacknife-2 species richness estimator, (B) Species Accumulation Curve (SAC), and (C) phytoplankton species list. Red boxes indicate species which are known and have records to cause HABs in Indonesia. Yellow boxes indicate HABs species that were reported elsewhere in tropical regions, but no record in Indonesia.

Among the 202 identified phytoplankton species so far, at least 17 species are categorized as potentially harmful due to their records of causing blooms in Indonesia and/or in other tropical countries. Those species are *Trichodesmium erythraeum, Tripos (Ceratium) furca, Tripos (Ceratium) fusus, Tripos muelleri (Ceratium tripos), Pseudo-nitzschia* spp.*, Chaetoceros curvisetus, Skeletonema costatum, Amphidinium* spp.*, Noctilluca scintillans, Karenia* spp.*, Dinophysis caudata, Chattonella* spp.*, Prorocentrum compressum, Prorocentrum* *rhathymum, Prorocentrum micans, Prorocentrum sigmoides, and Gonyaulax* spp. With the exception of *Chattonella* spp., *Karenia* spp., *Amphidinium* spp., and *Prorocentrum* spp., the other potentially harmful species have been recorded to cause HABs events and/or mass fish mortality in Indonesia. Aside from *T. erythraeum, C. curvisetus,* and *Pseudo- nitzschia* spp., the other potentially harmful species were found at very low densities (<10,000 cells/m^3). SEM images of 17 potentially harmful species, and rare and unusual diatoms, are shown in Figure 5.15.

Fig. 5.15 SEM images of 17 potentially harmful species, and rare and unusual diatoms, and their morphological details from an electron microscopy trial taken with Prisma-E (Thermo Science). SEM images were taken under low-vacuum (40–50 Pa) at 5–10 kV acceleration using a Low Vacuum Detector (LVD) or Angular Back Scatter (ABS) detector.

Although phytoplankton cell enumeration has not finished, quick analysis from selected Gili Meno samples shows variations in cell density and diversity between zones in different seasons (Fig. 5.16). So far, the highest phytoplankton cell density in TWP Gili Meno was found at the Core Zone in the Wet Season in February 2023 (3.42×10^7cells/m^3), while the lowest so far was found in the Sustainable Fisheries Zone in Transition Season I in May 2022 (2.32×10^5 cells/m^3) (Fig. 5.16A). As shown in Figure 5.16A, a very high phytoplankton cell density was discovered in February 2023. Although it has not yet reached the blooming threshold (10^9 cells/m^3), based on the total cell density (Fig. 5.16A), it is suggested that the change from oligotrophic (cell density < 4.16×10^6 cells/m^3) to higher-mesotrophic (cell density between $3.14 \times 10^7 – 1.88 \times 10^8$ cells/m^3) is due to the change in water column conditions.

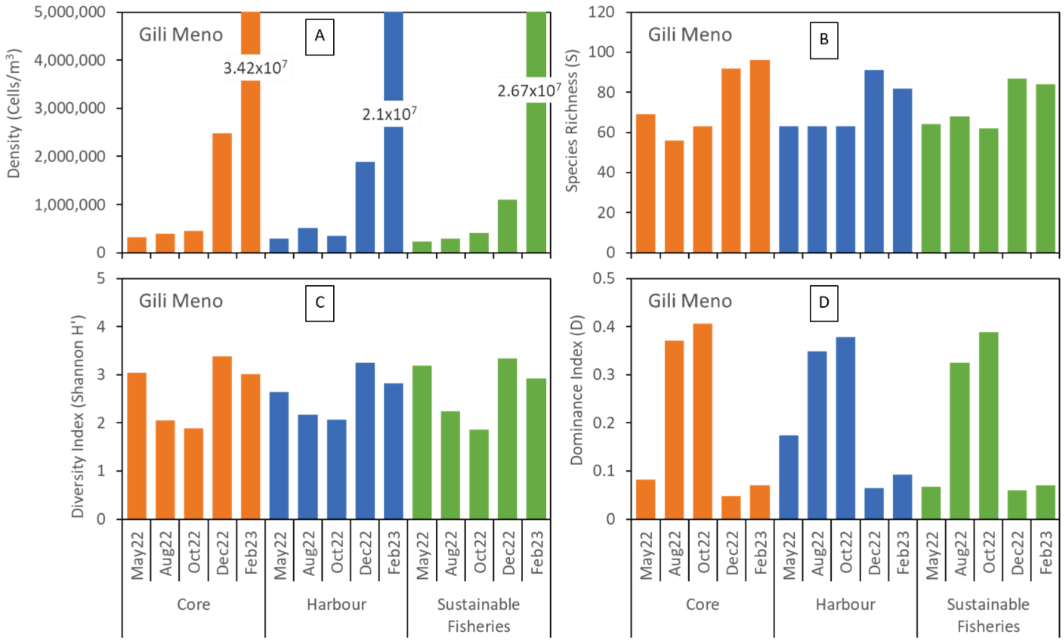


Fig. 5.16 Phytoplankton (A) cell density, (B) species richness, (C) diversity index (Shannon H'), and (D) Dominance Index in TWP Gili Meno from sampling in May (Transition Season I), August (Dry), October (Transition Season II), December 2022 and February 2023 (Wet).

Both cell density and diversity of phytoplankton increased significantly during the Wet Season (December 2022 and February 2023) (Fig. 5.16A, B). Furthermore, the phytoplankton species composition also underwent drastic changes from a cyanobacterial-dominated community in the Dry Season (August 2022) and Transition Season II (October 2022), back to a diatom-dominated community in the Wet Season (December 2022 and February 2023, Fig. 5.17). A similar condition was also found in Transitional Season I (May 2022, Fig. 5.17). Note that the sudden decrease in the dominance index (D) also indicates that there were no species that dominated the phytoplankton community in the three zones of TWP Gili Meno during the Wet Season in 2022 and early 2023 (Fig. 5.16D). On the other hand, the trend also suggests that the shift in the phytoplankton community structure was heavily influenced by seasonal changes, which can alter the physical-chemical conditions in the water column. We assumed that the sharp increase in phytoplankton cell density in Gili Meno during the Wet Season was due to increased terrestrial input from Lombok and the three Gili islands. As a small island, Gili Meno, and the other two Gilis (Trawangan and Ayer), do not have any large rivers, thus the nutrient input into the coastal waters would be caused by surface runoff and domestic wastewater. Note that Gili Matra does not have wastewater treatment facilities, thus untreated domestic wastewater flows directly into the surrounding waters. Additionally, tourist activities have increased in the last few months due to, presumably, the end of the COVID-19 pandemic compared to the early sampling trips (May 2022) in this study. That condition might also be indirectly related to the higher cell density found during the Wet Season in Gili Meno in this study.

From the analysed samples we noted that the phytoplankton species composition underwent drastic changes correlated with seasonal changes. Cyanobacterial domination was observed in August (Dry Season) and October (Transition Season II) 2022. *Trichodesmium erythraeum*, which contributed to over 60% of total cell density in the phytoplankton community, generally dominated the phytoplankton communities in the three zones of Gili Meno (Fig. 5.17). However, the cyanobacterial domination was then overturned by diatoms during the Wet Season (December 2022 and February 2023) (Fig. 5.17). Similarly, diatom domination was also observed in an earlier sampling trip (Survey I) in Transition Season I (May 2022). However, the total phytoplankton cell density was much lower in May 2022 compared to December 2022 or February 2023 (Fig. 5.16A).

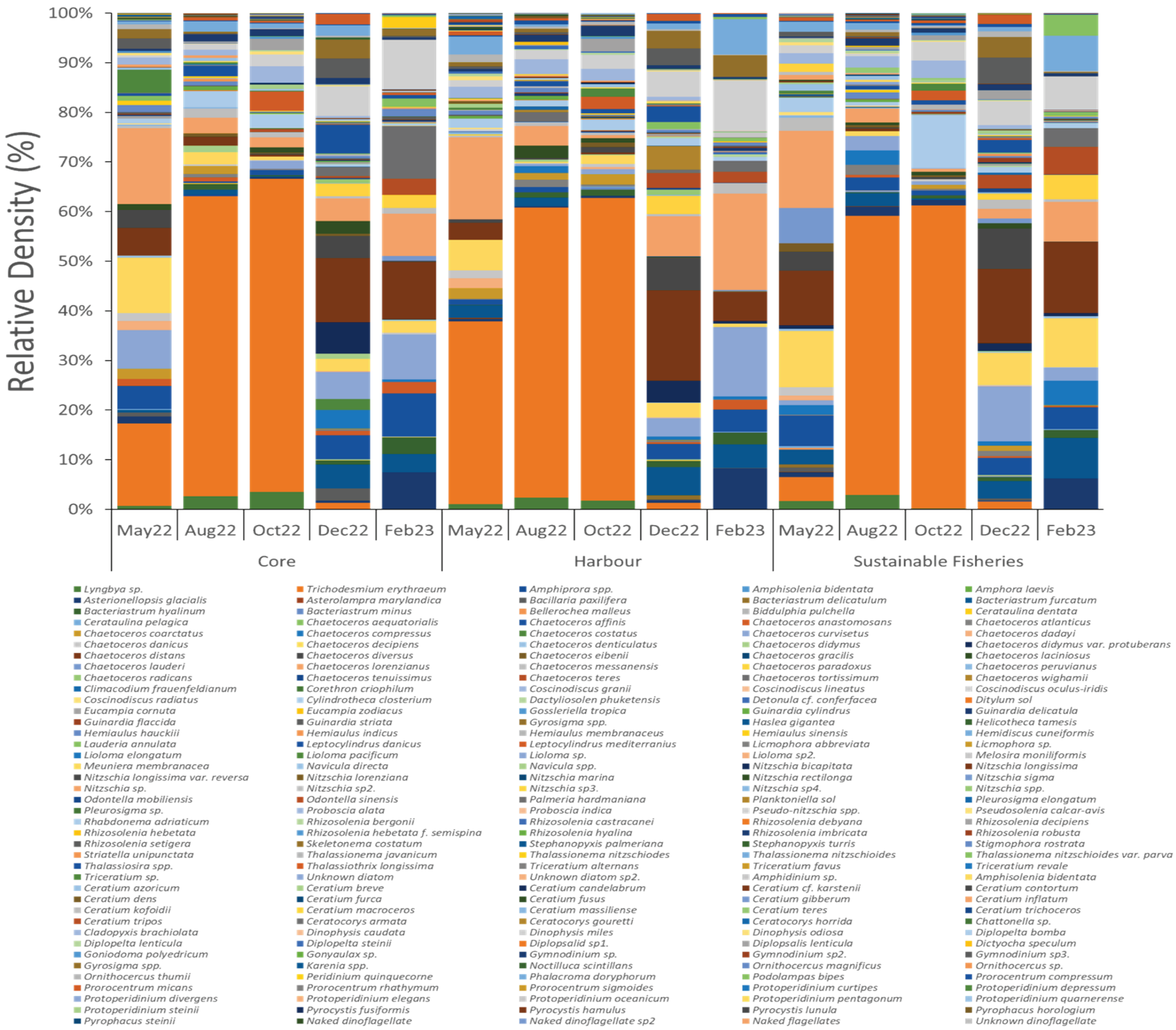


Fig. 5.17 Species composition within the Core, Harbour, and Sustainable Fisheries zones of TWP Gili Meno during Transition Season I (May), Dry Season (August), Transition Season II (October), and Wet Season (December 2022 and February 2023). So far, cyanobacteria *Trichodesmium erythraeum* was found to overtake the diatoms' dominance in the phytoplankton community during the Dry Season and Transition Season II. However, the dominance of cyanobacteria was gone in the Wet Season (December 2022 and February 2023).

A list of the 20 most abundant species found in this study so far is available in Table 5.4. The data also show high variation in the species composition between the three zones in the same season (Fig. 5.17). The most notable difference was the relative density of *T. erythraeum*, in which the cyanobacteria species was detected at the lowest density in the Sustainable Fisheries Zone during Transition Season I (May 2022) and in the Core and Harbour zones during the Wet Season (December 2022 and February 2023).

Table 5.4 List of the 20 most abundant species in TWP Gili Meno during the period of this research (May, August, October, December 2022, and February 2023).

Species	Cell density(cells/m^3)
Chaetoceros distans	9,890,572
Chaetoceros lorenzianus	9,606,480
Pseudo-nitzschia spp.	7,590,784
Chaetoceros curvisetus	7,132,275
Asterionellopsis glacialis	5,977,084
Chaetoceros affinis	5,385,924
Chaetoceros tortissimum	5,214,815
Bacteriastrum furcatum	4,747,304
Chaetoceros decipiens	3,866,384
Thalassionema nitzschioides	3,512,118
Chaetoceros teres	3,149,799
Chaetoceros paradoxus	2,356,656
Bacteriastrum hyalinum	2,133,884
Chaetoceros compressus	1,760,101
*Trichodesmium erythraeum**	1,709,318
Skeletonema costatum	1,635,323
Thalassionema nitzschioides var. *parva*	1,319,934
Chaetoceros anastomosans	1,282,944
Chaetoceros messanensis	1,028,549
Lauderia annulata	962,428

* Cyanobacteria. Aside from *T. erythraeum*, the other most abundant species are from the diatom group.

The nMDS (nonmetric MultiDimensional Scaling) and UPGMA (Unweighted Pair Group Method with Arithmetic Mean) clustering analysis using PAST4 software showed some definite trends in species composition between analysed sites/samples (Fig. 5.18). Based on the Gili Meno data so far, there were at least two distinct groupings due to their similarity (>70%) in the phytoplankton species assemblages. Those two groups consist of sites (i) HarOct22, FisOct22, CorAug22, CorOct22, HarAug22; and (ii) CorDec22, HarDec22 (Fig. 5.19). Note that although the similarity level was slightly below the threshold (<70%), all sites in February 2023 had similar species composition. The only site that was found with very different phytoplankton species composition was the Sustainable Fisheries Zone in May 2022.

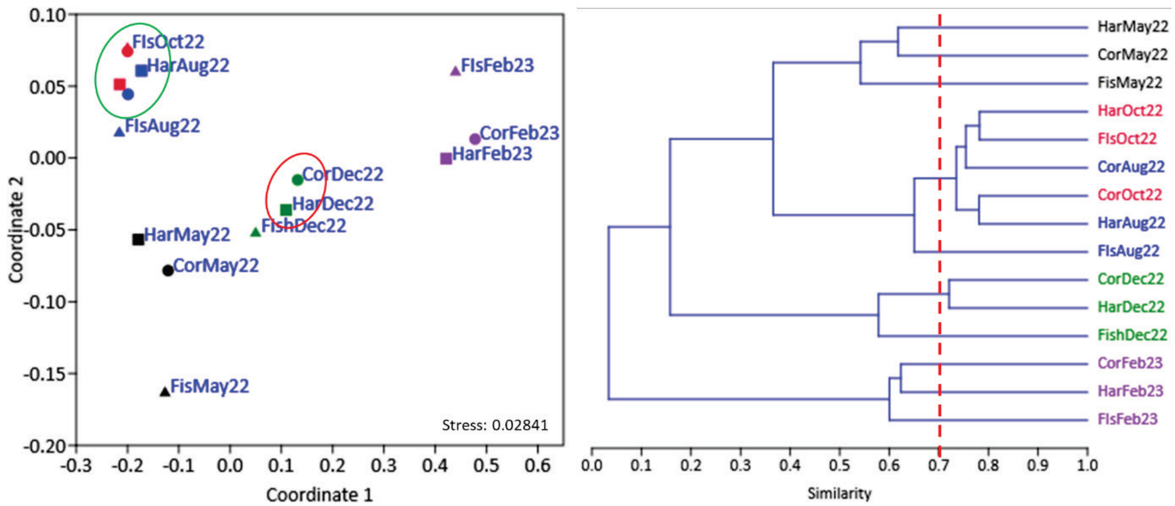


Fig. 5.18 Phytoplankton species assemblages between sites and months were analyzed with (A) nMDS with Bray-Curtis similarities and (B) UPGMA clustering based on the Bray-Curtis index. Cor = Core Zone, Har = Harbour Zone, Fis = Sustainable Fisheries Zone; May22 = May 2022, Aug22 = August 2022, Oct22 = October 2022, Dec22 = December 2022, Feb23 = February 2023.

The reason for the trends found in the nMDS and clustering analysis of Gili Meno phytoplankton communities is not clear as it requires more data to ensure that the trend was also found in other zones and the other two islands. Even so, we suspect that the trend should be similar, in which the shift in the diatoms and cyanobacterial domination occur due to changes in seasons. Note that among all species identified in this study, the five most influential species that drive the groupings, particularly that drive the dissimilarity between sites and seasons, were *T. erythraeum*, *C. lorenzianus*, *C. distans*, *Pseudo-nitzschia* spp., and *C. curvisetus* (Table 5.5). The table also lists the other most influential species.

Table 5.5 Results of SIMPER (Similarity Percentage) analysis showing the 15 most influential species that drive the trend of groupings in the nMDS analysis.

Taxon	Average dissimilarity	Contribution %	Cumulative %
Chaetoceros distans	7.881	10.52	10.52
Trichodesmium erythraeum	7.261	9.69	20.21
Chaetoceros lorenzianus	6.159	8.218	28.43
Pseudo-nitzschia spp.	4.477	5.974	34.4
Chaetoceros curvisetus	4.421	5.9	40.3
Chaetoceros decipiens	3.566	4.758	45.06
Bacteriastrum furcatum	3.512	4.686	49.74
Chaetoceros affinis	3.189	4.256	54
Asterionellopsis glacialis	2.951	3.938	57.94
Thalassionema nitzschioides	2.579	3.442	61.38
Chaetoceros tortissimum	2.419	3.228	64.61
Chaetoceros teres	2.091	2.791	67.4
Chaetoceros paradoxus	1.803	2.406	69.8
Chaetoceros compressus	1.652	2.204	72.01

In this study, a Transformation-based Redundancy Analysis (tb-RDA) model was constructed using a Hellinger-transformed genera/group dataset combined with the untransformed water's physical and chemical parameters. From the analysis, we found that dinoflagellates and diatoms in TWP Gili Meno seemed to be regulated by similar physical and chemical parameters. Both groups were found at higher abundance in nitrate-rich sites or months, which also have higher N:P and N:Si ratios (Fig. 5.19A). Dinoflagellates, in particular, seemed to have a very strong relationship with the N:Si ratio. On the other hand, cyanobacteria tended to be more abundant at sites or months in waters that were oxygen-rich (DO) and had a higher concentration of silicate, ammonia, and nitrite, and higher Si:P ratio (Fig. 5.19A). The tb-RDA analysis, in general, also suggested that the abundance of diatoms was generally driven by the ratio of nutrients instead of the actual concentration of macronutrients (N, P, Si). Additionally, the macronutrient, nitrogen in the form of nitrate, seemed to regulate the cell density of both diatoms and dinoflagellates in Gili Meno. Although unusual, the negative relationship between silicate and diatom cell density (Fig. 5.19A) might have been due to the Si-exhausted water condition during the sampling in February. Thus, the data give an impression that diatoms were more abundant in low-silicate water, where in fact, the silicate-poor water was caused by the blooms of diatoms which quickly exhausted the Si supply in the water column.

At the genus level, there was no definite trend, although the cell density of many phytoplankton genera seemed to be regulated by the concentration of nitrate and the N:P and N:Si ratio in Gili Meno (Fig. 5.19B). Most diatoms are found in the left regions of the tb-RDA biplot, which indicate their stronger correlation with the nitrate-rich waters with higher N:P and N:Si ratio (Fig. 5.19B). Note that the most abundant phytoplankton genera, which were the diatoms *Chaetoceros* and *Pseudo-nitzschia*, seem to have very similar regulating factors. The other abundant genus, *Trichodesmium*, which dominates the community in Dry Season (August) and Transition Season II (October), were more abundant in oxygen-rich waters that were also rich in nitrite, silicate, ammonia, and phosphate (Fig. 5.19B). It was not clear why the concentration of essential macronutrients, such as phosphorus (in phosphate) and silicate, does not seem to regulate the cell density of most phytoplankton genera.

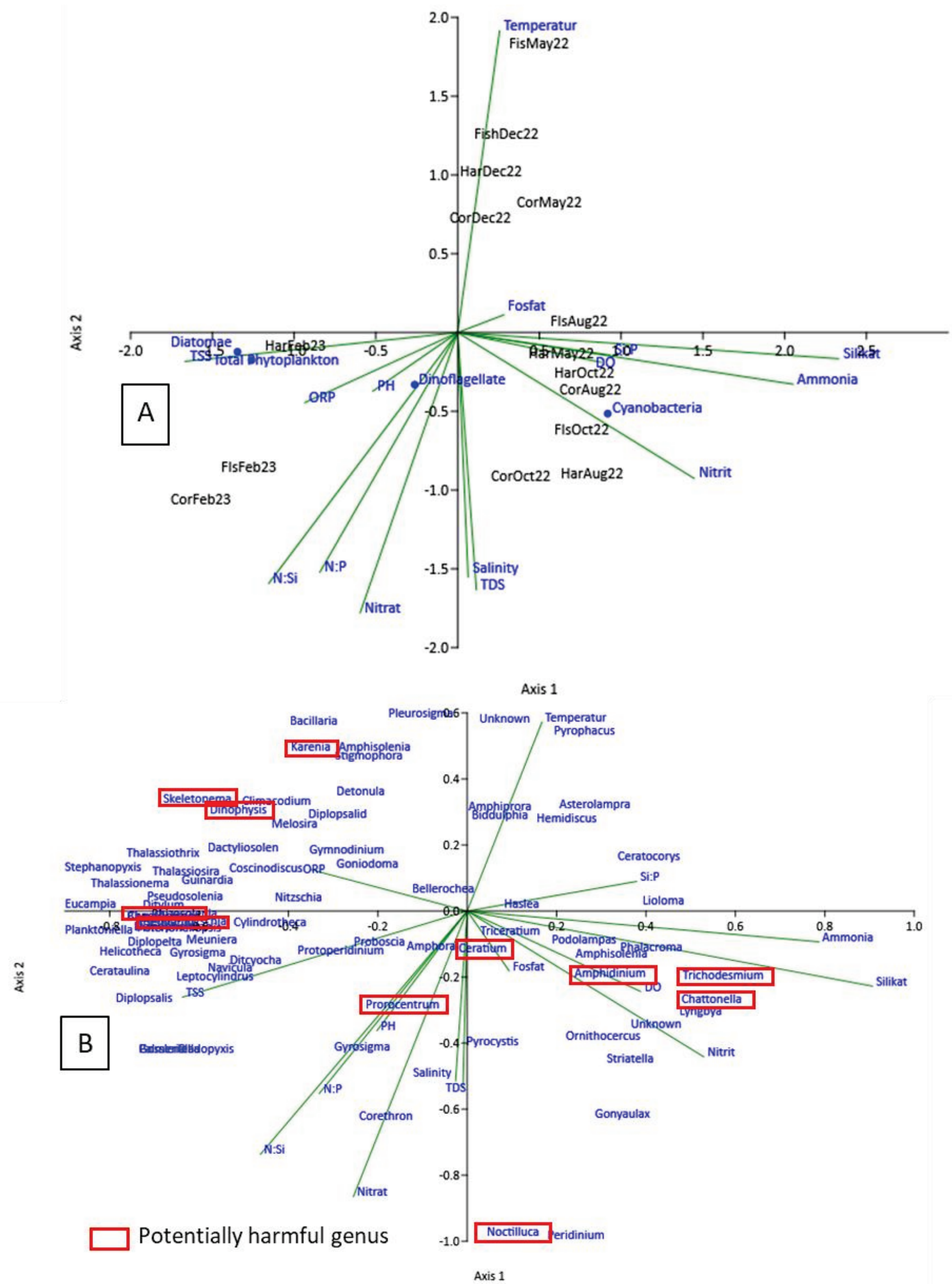


Fig. 5.19 Transformation-based Redundancy Analysis (tb-RDA) biplot showing the trends and relationships between (A) general phytoplankton group, and (B) phytoplankton genera with physical and chemical water parameters in Gili Meno. For those analyses, Hellinger transformation was applied to the group or genera dataset.

5.3.2 Potentially toxic benthic dinoflagellates causing CFP at TWP Gili Matra

Microscopic observation showed six genera which were found in this research, namely *Amphidinium*, *Coolia*, *Gambierdiscus*, *Ostreopsis*, *Prorocentrum* and *Sinophysis* (Fig. 5.20). *Gambierdiscus* (Fig. 5.21B) is the most potentially toxic benthic dinoflagellate due to its toxin content, ciguatoxin. *Amphidinium*, *Coolia*, *Ostreopsis* and *Prorocentrum* are potentially toxic benthic dinoflagellates which are associated with CFP, while *Sinophysis* is a non-toxic benthic dinoflagellate which is commonly found in mangrove areas.

Benthic dinoflagellates were found in any kind of substrate (Fig. 5.20). *Prorocentrum* was the most abundance dinoflagellate, usually observed together with *Sinophysis*, and especially attached on macroalgae and sea grass substrates, in Gili Ayer waters. Meanwhile, *Gambierdiscus* and *Amphidinium* were found in the lowest abundance. *Ostreopsis* and *Coolia* were often found on non-living susbtrates, such as coral rubble and artificial substrate.

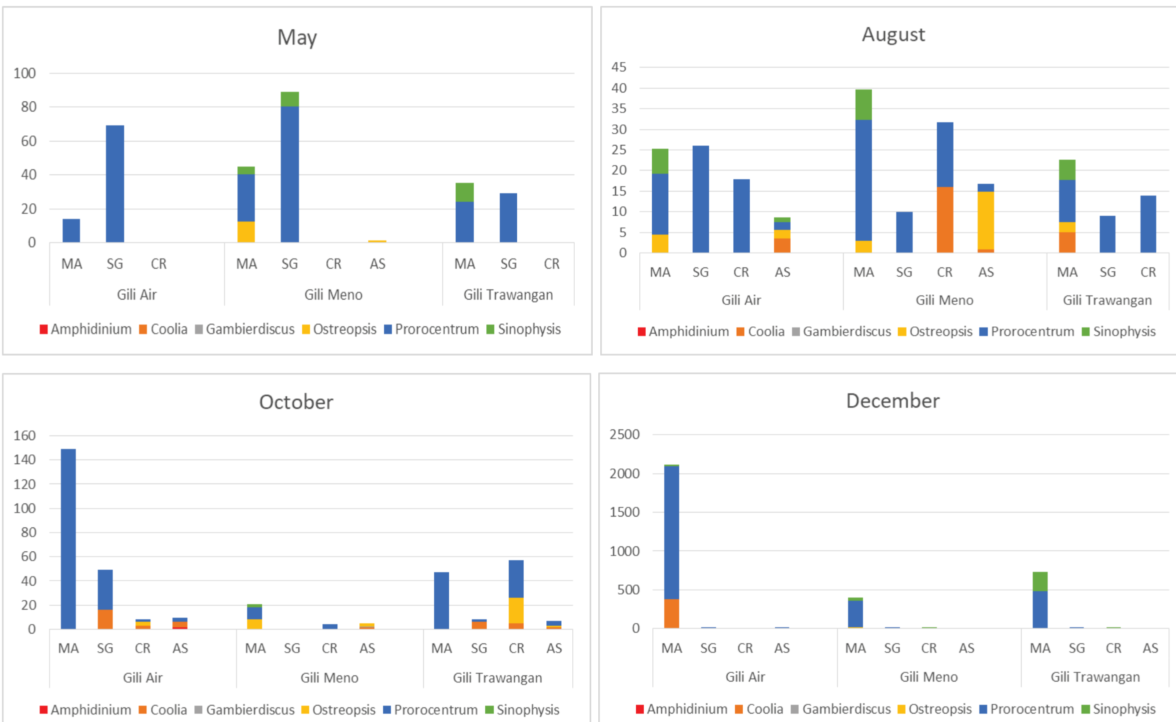


Fig. 5.20 The abundance of benthic dinoflagellates on all substrates in TWP Gili Matra waters (cells/g, cells/cm^2). MA: Macro Algae, SG: Sea Grass, CR: Coral Rubble, AS: Artificial Substrate.

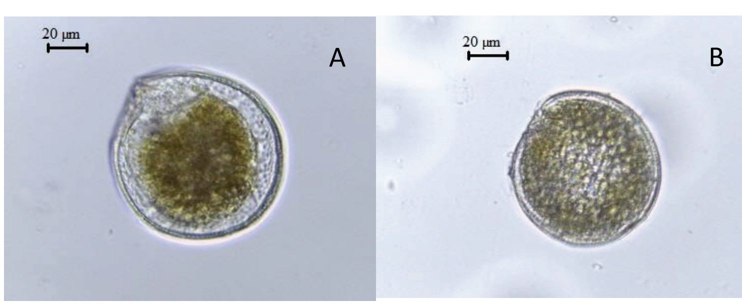


Fig. 5.21 Benthic dinoflagellates observed. A. *Ostreopsis*, B. *Gambierdiscus.* Photomicrograph by Widiarti, 2022.

Samples from February 2023 (Survey V) are still under microscopic analysis, and the data results have not finished yet due to the limitation of time and laboratory facilities. However, from the trend of increasing cell abundance on December 2022, which was dominated by *Prorocentrum* cells (Fig. 5.22), we can expect that several benthic dinoflagellates cells will also experience a population increase.

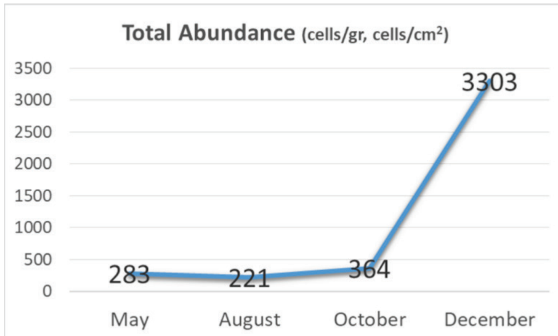


Fig. 5.22 Total abundance of benthic dinoflagellates from May to December 2022.

Benthic dinoflagellate DNA analysis showed that 9 samples from the PCR products provided good DNA bands (Fig. 5.23), which were mainly analyzed from December's samples. Samples from the field usually contain fungal contamination so it was hard to obtain pure DNA from the target cells.

Query covers obtained from Basic Local Alignment Search Tool (BLAST) results showed a low percentage (5–74%, Table 5.6). This could be due to the sequence from benthic dinoflagellates in Lombok waters, which has not been recorded yet in the gene bank, such as the one at the National Center for Biotechnology Information.

Fig. 5.23 Electrophoresis results showing bands of DNA from benthic dinoflagellate species.

Table 5.6 Query and similarity percentage of DNA samples from benthic dinoflagellates.

No.	Names	Query (%)	Similarity (%)
1	4711355_3-6_OST	5	88.46
2	4711356_3-7_PRO	62	67.28
3	4711357_3-8_SNY	74	71.05
4	4711358_3-9_COL	27	74.07
5	4711359_3-10_COL	18	72.00
6	4711361_3-13_GBR	31	77.70
7	4711362_3-14_SYN	33	82.02
8	4711363_3-17_GBR	25	74.24
9	4711364_3-18_SYN	26	76.90

A phylogenetic tree (Figs. 5.24 and 5.25) shows two groups: Group 1, the Gonyaulacoid group, consisting of *Ostreopsis* (OST), *Coolia* (COL) and *Gambierdiscus* (GBR) and Group 2, the Prorocentroid and Dinophysoid groups, consisting of *Prorocentrum* (PRO) and *Sinophysis* (SYN).

E-DNA results in Table 5.7 show that there was a sufficient amount of DNA on the macroalgae and artificial substrate. We still need to determine if it is from the benthic microalgae community, including the targeted toxic dinoflagellates.

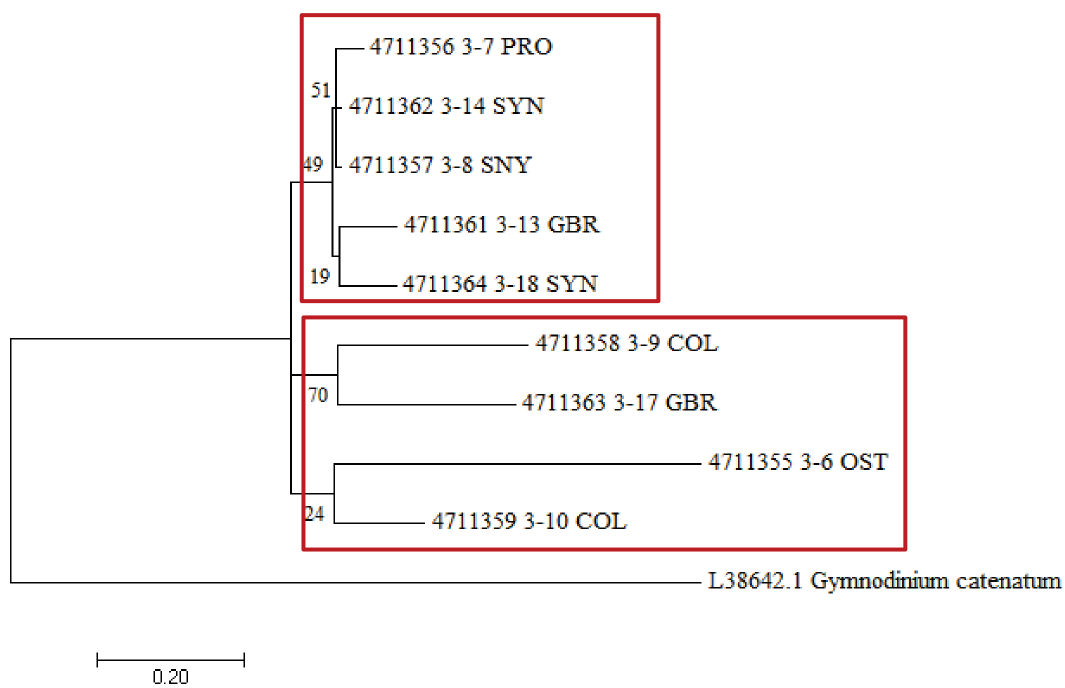


Fig. 5.24 Phylogenetic Tree using Maximum Likelihood (ML). PRO = *Prorocentrum*, SNY = *Sinophysis*, GBR = *Gambierdiscus,* COL = *Coolia*, OST = *Ostreopsis*.

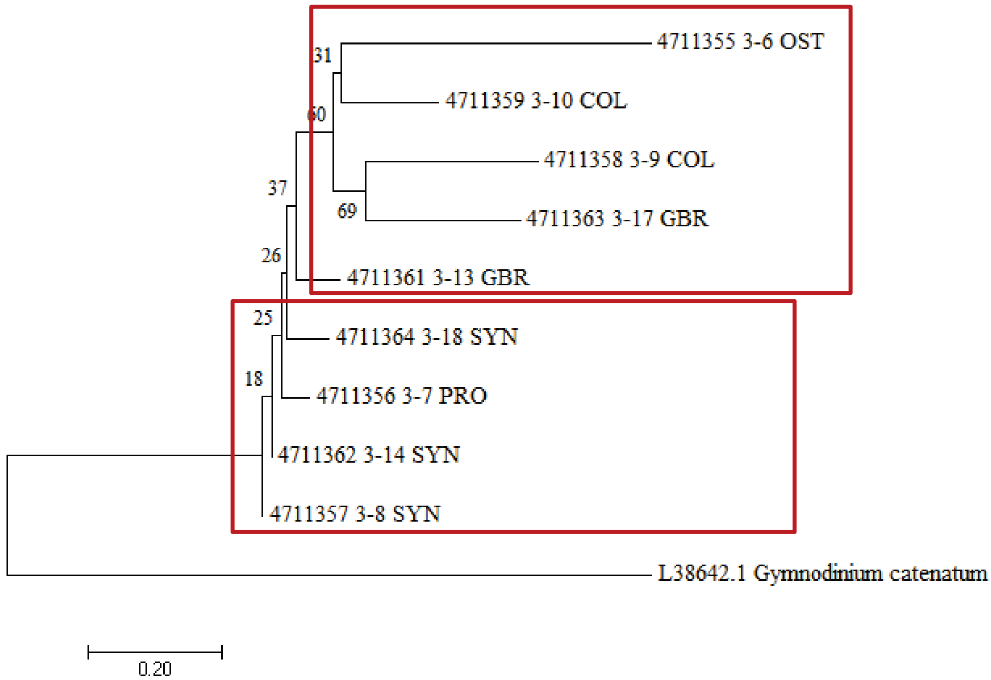


Fig. 5.25 Phylogenetic Tree using Neighbor Joining (NJ).

Table 5.7 E-DNA results for benthic dinoflagellates.

No.	Substrate	DNA concentration (ng/µL)
1	4711355_3-6_OST	5
2	4711356_3-7_PRO	62
3	4711357_3-8_SNY	74
4	4711358_3-9_COL	27
5	4711359_3-10_COL	18
6	4711361_3-13_GBR	31
7	4711362_3-14_SYN	33
8	4711363_3-17_GBR	25
9	4711364_3-18_SYN	26

OST = *Ostreopsis,* PRO = *Prorocentrum*, SNY = *Sinophysis*, COL = *Coolia*. GBR = *Gambierdiscus*

Samples from the Survey V activity in February 2023 are still under microscopic investigation, and the data results are not finished yet due to the limitation of time and laboratory facilities. However, preliminary results show that the samples were dominated by *Prorocentrum* and *Ostreopsis*, especially on the macroalgae substrate (Tables 5.8–5.10).

Table 5.8 Abundance of benthic dinoflagellates on a macroalgae substrate (cells/mL).

	bBenthic dinoflagellate abundance				
Location	*Prorocentrum*	*Sinophysis*	*Ostreopsis*	*Gambierdiscus*	*Coolia*
Gili Ayer	48	3	0	0	3
	4	0	0	0	0
	1	0	0	0	0
Average	**17.7**	**1.0**	**0.0**	**0.0**	**1.0**
Gili Meno	4	5	21	0	0
	1	3	3	0	0
	22	9	20	3	1
Average	**9.0**	**5.7**	**14.7**	**1.0**	**0.3**
Gili Trawangan	7	0	0	1	0
	1	0	0	0	0
	7	1	1	0	0
Average	**5.0**	**0.3**	**0.3**	**0.3**	**0.0**

Table 5.9 Abundance of benthic dinoflagellates on a seagrass substrate (cells/mL).

	bBenthic dinoflagellate abundance			
Location	*Prorocentrum*	*Sinophysis*	*Ostreopsis*	*Coolia*
Gili Meno	0	0	0	1
	0	0	1	0
	0	0	0	0
Average	**0.0**	**0.0**	**0.3**	**0.3**
Gili Trawangan	0	0	1	2
	0	0	0	1
	0	0	0	1
Average	**0.0**	**0.0**	**0.3**	**1.3**

Table 5.10 Abundance of benthic dinoflagellates on an artificial substrate (cells/mL).

	bBenthic dinoflagellate abundance			
Location	*Prorocentrum*	*Sinophysis*	*Ostreopsis*	*Coolia*
Gili Meno	0	0	0	2
	0	0	1	1
	0	0	1	0
Average	**0.0**	**0.0**	**0.7**	**1.0**

5.3.3 Deep (machine) learning for phytoplankton identification using microscopy images

The identification of phytoplankton in Indonesia is mainly done manually by a person with expertise, which is a time-consuming process with many limitations. Therefore, this study aimed to develop automatic identification of phytoplankton using Deep Machine Learning algorithms, such as Convolutional Neural Networks (CNNs), to assist in the process of identification. Machine learning is a division of artificial intelligence (AI) and computer science which focuses on the utilization of data and algorithms to imitate the way that humans learn. Many researchers have introduced machine learning algorithms into microalgae applications and significant results have been gained. The type of Machine Learning algorithms mainly involved in image processing that was used in this study is supervised learning. These operations were a collection of tools for finding and analyzing photograph patterns. Machine learning steps included collecting data, preparing the data, choosing a model, training the model, evaluating the model, parameter tuning, and making predictions.

A pre-trained VGG-16 model was used to construct a CNN model to identify phytoplankton to genus level under five different model scenarios (S) based on phytoplankton images curated from the RCO-BRIN Plankton Image Database. Analysis of a cross-entropy loss and confusion matrix shows that the simple model (S1) and the genus level model (S4) had the best performance with low misclassification. In application trials, the S1 model was able to distinguish groups of diatoms and dinoflagellates with an accuracy of up to 78%, while the S4 model could distinguish the target genera *Ceratium*, *Chaetoceros*, *Coscinodiscus*, *Protoperidinium*, and *Rhizosolenia* to an accuracy of 79%. However, the S4 model suffers from forced classification problems due to its inability to identify images from any non-target genus. Unfortunately, the S5 model built to solve the S4 problem had a much lower accuracy at 54% because the very diverse data were stored in the 'Other' category, which confused the model. Although the CNN model in this study could automatically identify phytoplankton down to the genus level with >75% accuracy, the current limitations in all scenarios need to be resolved before the model can be used in real-world research scenarios. Segmentation results were also compared with manual assessments to calculate performance parameters. The accuracy, 0.970 ± 0.025, gave the highest value while the lowest value was found in the precision parameter, 0.761 ± 0.156.

In the Ciguatera project, the identification of toxic microalgae needs to be done in order to anticipate the occurrence of poisonous microalgae in the Gili Matra area. Samples were collected from TWP Gili Matra (Gili Trawangan Stns 1,3,5; Gili Meno Stns. 6,7,9; Gili Ayer Stns, 12,13, 15) were observed using an Olympus triocular microscope with 400–1000X magnification, connected to a laptop. Some microphotographs have been taken and later they will be used in algal identification using machine learning. The focus of this study was on identification of *Prorocentrum*, an algae species which can cause harmful blooms in many coastal environments as well as in estuaries. The results of some microphotograph images of *Prorocentrum* are provided in Figure 5.26.

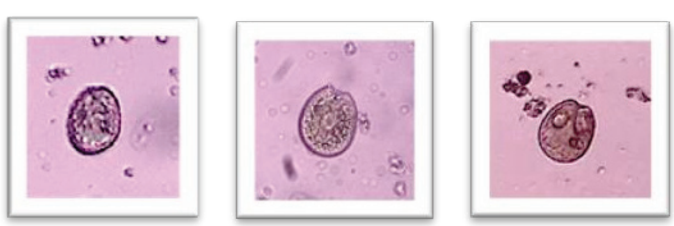


Fig. 5.26 *Prorocentrum* images identified by machine learning.

5.3.4 Water quality of TWP Gili Matra

The water quality of TWP Gilli Matra is influenced by the season which, in turn, affects ocean current and wind patterns. In Indonesia's tropical waters, there are four seasons, namely the Wet/Rainy Season (December–March), the first transition season (Transition Season I) from the rainy season to the dry season (April–May), the Dry Season/Southeast Monsoon (June–September), and the second transition from the Dry Season to the Wet Season/Northwest Monsoon (October–November). Figure 5.27 shows the current and wave patterns in Indonesian waters during the four seasons.

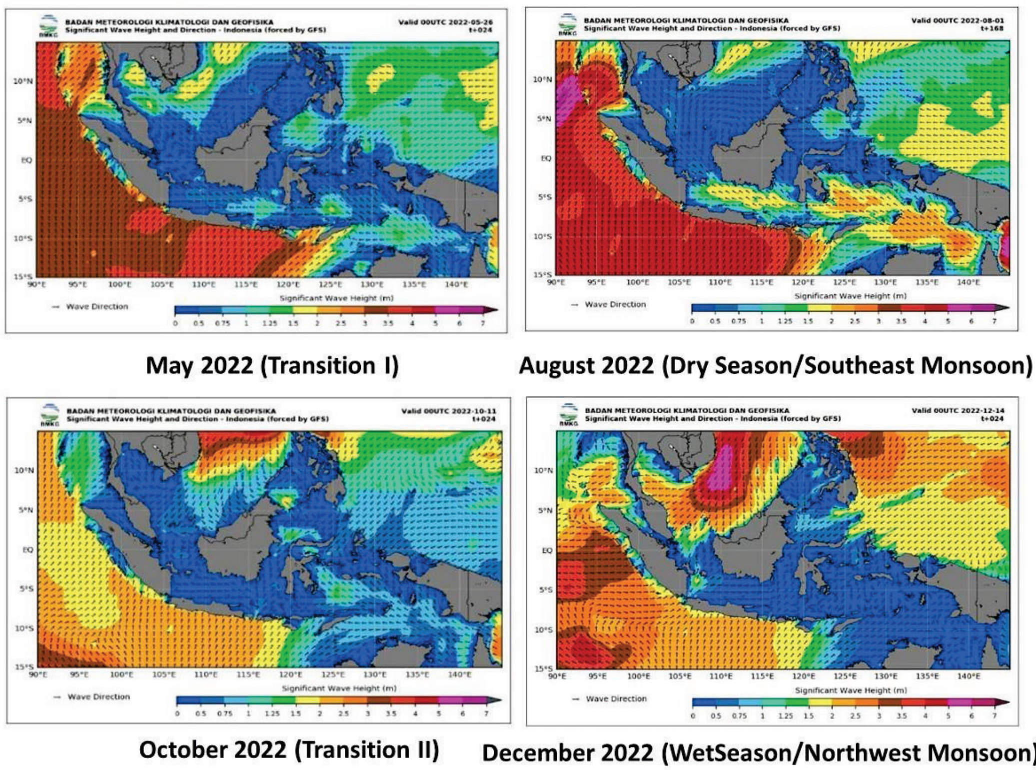


Fig. 5.27 Seasonal variation of the current patterns in the tropical Indonesian waters.

Based on the results of the water quality analysis at TWP Gili Matra (Figure 5.28), water temperature ranged from 28.10–29.93 °C, turbidity from 0.00–0.08 NTU, brightness from 95.63–100.00%, dissolved oxygen (DO) from 4.81–5.44 mg/L, pH from 7.69–8.39, total suspended solids (TSS) from 2.53–15.73 mg/L, Chlorophyll-a from 0.3008–3.3156 µg/L, dissolved inorganic nitrogen (DIN) from 1.48–6.32 mg/L, dissolved inorganic phosphate (DIP) from 0.04–0.08, dissolved silicate (DSi) from 0.33–0.73 mg/L and plankton from 72.94–2730.94 ind/L.

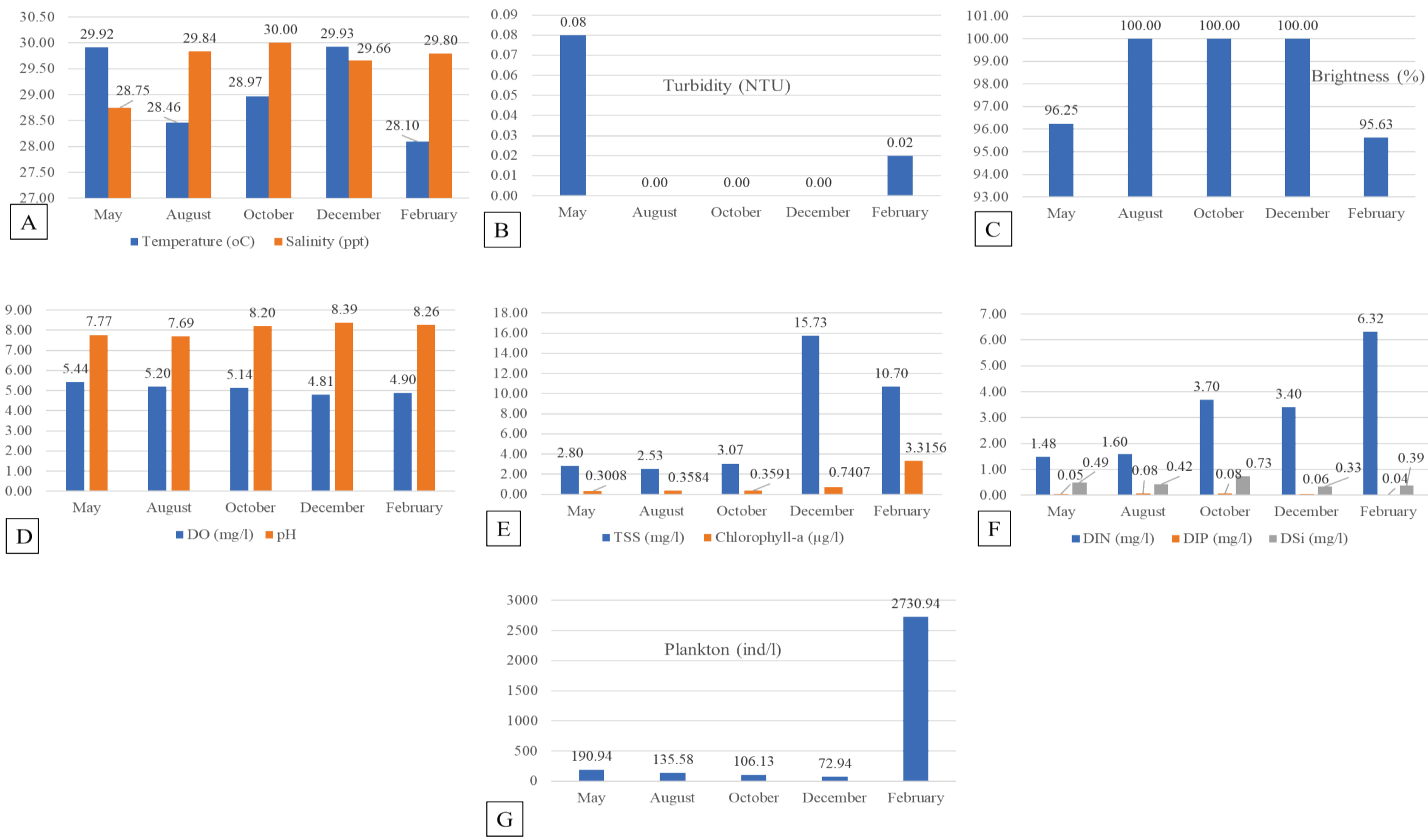


Fig. 5.28 Water quality profiles of TWP Gili Matra taken during the five surveys from May 2022 to February 2023. DO = dissolved oxygen, TSS = total suspended solids, DIN = dissolved inorganic nitrogen, DIP = dissolved inorganic phosphate, DSi = dissolved silicate

5.3.5 E-DNA for fish species diversity assessment at TWP Gili Matra

Coral damage in the TWP Gili Matra area was as high as 75% until 2008 (Ahyadi and Jufri, 2008). Most of the causes were the use of coral for building materials, destructive fishing and tourism activities (*e.g.*, diving), and the consequences of climate change, namely the El Niño phenomenon which contributes to coral bleaching. The widespread bad conditions on Gili Trawangan have reduced the attractiveness of diving tourism (Ahyadi, 2010).

In addition to percent coral cover, baseline data on coral reefs in the form of species diversity and abundance of reef fish are the best indicators to provide early warning of negative or positive impacts from human activities on coral reef ecosystems because they are always moving (*i.e.*, mobile), and need to be sensitive to respond to habitat damage (Gomez and Yap, 1988). In this case, several functional groups of fish, such as corallivores, herbivores, carnivores and planktivores have implications for their respective roles and presence in coral reef ecosystems (Obura and Grimsditch, 2009).

Water samples for e-DNA analysis were collected from 16 locations consisting of four zones, Core, Port, Sustainable Fisheries, Protection, and Utilization zones, in the Gili Matra marine environment (see Fig. 5.4), (Table 5.11). The samples were filtered using 0.45 µm filter paper to ready them for further analysis (DNA extraction to obtain purified DNA, followed by sequencing using MiFish primers).

The samples are ready for e-DNA analysis to identify the types of fish that have the potential to be contaminated with CFP. We are currently waiting for confirmation on the source of additional funding.

Table 5.11 Sample collection from 16 locations in TWP Gili Matra in May 2022.

Zone	Gili Trawangan	Gili Meno	Gili Ayer	Total
Core	St 1	St 6	St 12	3
Harbour	St 3	St 7	St 13	3
Sustainable Fishing	St 5	St 9, 11	St 15	4
Protection	St 4	St 8	–	2
Utilization	St 2, 16	St 10	St 14	4
Total	6	6	4	16

From the results of the fifth survey, the samples that had been collected during Survey V (February 2023), were grouped into three categories: the Gili Trawangan group, the Gili Meno group and the Gili Ayer group (Table 5.12). Samples were grouped based on their position close to Gili Trawangan, Gili Meno and Gili Ayer (see Table 5.2).

Table 5.12 Grouping of samples based on the position of the sampling location at Gili Trawangan, Gili Meno and Gili Ayer.

Location	Sample grouping
Gili Trawangan	Sample numbers 1, 2 and 5
Gili Meno	Sample numbers 3,4 and 10
Gili Ayer	Sample numbers 12, 13 and 14

Sample grouping was carried out to obtain the e-DNA concentration needed when performing High Throughput Sequencing (NGS) analysis which requires DNA concentrations above 10 ng/µL. The DNA concentration and purity of the samples are presented in Table 5.13. Currently these samples are still in the PCR prior to sequencing using the High Throughout Sequencer.

Table 5.13 Grouping of samples based on the sampling location at Gili Trawangan, Gili Meno and Gili Ayer.

Location	DNA concentration (ng/µL)	Purity A260/A280
Gili Trawangan	67.7	1.84
Gili Meno	31.8	1.91
Gili Ayer	44.4	1.85

DNA was extracted from samples collected in Survey I (May 2022), and that would represent the locations of Gil Trawangan, Gili Meno and Gili Ayer according to Table 5.2. The results for each sample are presented in Table 5.14. All samples had a low concentration of DNA, which was below 10 ng/µL, but had a fairly good purity of DNA extract (A260/280), which was above 1.7. Next, a concentration pull-up carried out with modified DNA extraction met the desired DNA concentration and purity requirements after which 16s primary amplification was done. Table 5.15 results show that concentration pull-up was above 10 ng/µL and could be amplified with the 16s primer (Fig. 5.29). The samples are in the process of being sequenced using NGS at the Genetics Science Laboratory. The sequencing process to produce information on the types of fish detected is expected to last for 2 months.

Table 5.14 Results of measuring DNA concentration and purity of e-DNA extracted samples per sample/location in the first survey (May 2022), according to Table 5.12.

Station	DNA Concentration (ng/µL)	Purity A260/A280
1	5.7	1.87
2	4.2	2.58
3	8.9	1.94
4	9.3	2.08
5	5.4	1.72
7	2.4	1.78
9	5.4	1.93
10	4.2	2.09
11	2.4	1.73
12	7.6	1.79
13	3.5	1.99
14	3.7	1.88

Table 5.15 Results of DNA concentration measurements and sample purity from the results of DNA extraction from the first survey (May 2022) samples after being pulled up according to Table 5.12.

Location	DNA concentration (ng/µL)	Purity A260/A280
Gili Trawangan	22.5	1.87
Gili Meno	12.5	1.90
Gili Ayer	21	1.91

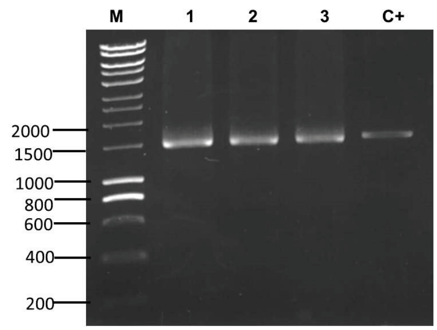


Fig. 5.29 Results of DNA amplification using 16s primer (M = marker, 1 = Gili Trawangan, 2 = Gili Meno, 3 = Gili Ayer, C+ = positive control).

5.3.6 Food safety and traceability of reef fish at TWP Gili Matra and surroundings

To determine the possibility of fish being contaminated with ciguatoxin and to trace the origin of fish (Traceability) in TWP Gili Matra and its surroundings, fish sampling was carried out at two main fish markets (Bintaro and Tanjung) of the North Coast area of Lombok, east of TWP Gili Matra in May 2022 (Survey I) and TWP Gili Matra in August 2022 (Survey II) (Fig. 5.30). The results of the analysis carried out by the Fish Quarantine Standard Testing Center, Quality Control and Safety of Fishery Products, Ministry of Maritime Affairs and Fisheries showed that fish samples of 13 fish species obtained from the two markets as well as from TWP Gili Matra did not detect any ciguatoxin (Tables 5.16 and 5.17. This means that the fish sold at the two fish markets are currently safe for public consumption.

Fig.5.30 Sampling locations of fish in Survey I at the Bintaro and Tanjung fish markets and Survey II at TWP Gili Matra, North Lombok.

Table 5.16 Ciguatoxin analysis results from fish samples at two fish markets (Tanjung and Bintaro fish markets) in North Lombok.

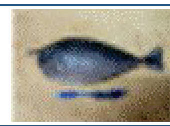
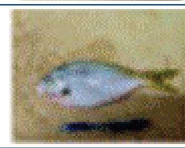
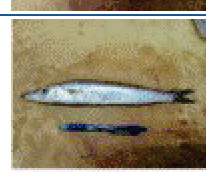
No.	Local/species name of fish	Sampling location (fish market)	Fish photo	Method	Result
1.	Ikan Pogot (Blackbelly triggerfish)	Tanjung		Mouse bioassay	Not detected
2.	Ikan Karang Unidentified	Tanjung		Mouse bioassay	Not detected
3.	Ikan Karang Unidentified	Tanjung		Mouse bioassay	Not detected
4.	Ikan Karang (*Siganus* sp.)	Tanjung		Mouse bioassay	Not detected
5.	Ikan Karang Unidentified	Tanjung		Mouse bioassay	Not detected
6.	Ikan Karang Unidentified	Tanjung		Mouse bioassay	Not detected
7.	Ikan Tuna	Bintaro		Mouse bioassay	Not detected
8.	Ikan Karang (Kakatua)	Bintaro		Mouse bioassay	Not detected
9.	Ikan Karang Unidentified	Bintaro		Mouse bioassay	Not detected
10.	Ikan Barakuda	Bintaro		Mouse bioassay	Not detected

Table 5.16 Continued.

No.	Local/species name of fish	Sampling location (fish market)	Fish photo	Method	Result
11.	Ikan Karang Unidentified	Bintaro		Mouse bioassay	Not detected
12.	Ikan Karang (Grouper)	Bintaro		Mouse bioassay	Not detected
13.	Ikan Karang (*Siganus* sp.)	Bintaro		Mouse bioassay	Not detected

Table 5.17 Ciguatoxin analysis results of fish samples from TWP Gili Matra.

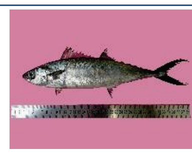
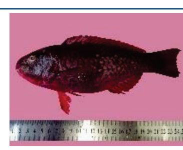
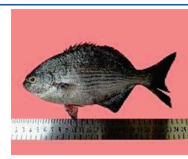
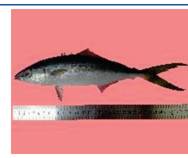
No.	Species name of fish	Sampling location	Fish photo	Method	Result
1.	*Decapterus macarellus*	TWP Gili Matra		Mouse bioassay	Not detected
2.	*Elagatis bipinnulata*	TWP Gili Matra		Mouse bioassay	Not detected
3.	*Heniochus diphreutes*	TWP Gili Matra		Mouse bioassay	Not detected
4.	*Kyphosus cinerascens*	TWP Gili Matra		Mouse bioassay	Not detected
5.	*Oxycheilinus digrammus*	TWP Gili Matra		Mouse bioassay	Not detected
6.	*Caesio caerulaurea*	TWP Gili Matra		Mouse bioassay	Not detected

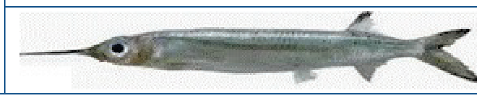
Table 5.17 Continued.

No.	Local name of fish	Sampling location	Fish photo	Method	Result
7.	*Scarus quoyi*	TWP Gili Matra		Mouse bioassay	Not detected
8.	*Scarus tricolor*	TWP Gili Matra		Mouse bioassay	Not detected
9.	*Gymnosarda unicolor*	TWP Gili Matra		Mouse bioassay	Not detected
10.	*Rastrelliger kanagurta*	TWP Gili Matra		Mouse bioassay	Not detected

To find out the distribution chain and the origin of the fish as well as the price of fish circulating in TWP Gili Matra and its surroundings, a survey was conducted at fish landing sites and fish markets (Tanjung and Bintaro) in TWP Gili Matra, through direct interviews with fishers, local traders and restaurant owners. Survey results showed that the fish circulating in TWP Gili Matra and its surroundings, apart from originating from TWP Gili Matra, also came from outside Lombok. Types of fish varied from reef fish to pelagic fish. The process of handling fish in terms of food safety, from fishers to restaurants, was mostly by using ice or in fresh form. Traceability and food safety data from the fish landings and fish markets are given in Table 5.18.

Table 5.18 Fish traceability and food safety details at fish landings and fish markets in Tanjung and Bintaro, Lombok.

Fisher

No.	Fisher's description	Fish species species/ local name	Fish price	Fish Origin	Storage and fresh fish	Photo
1	Ibu Haliyah, Gili Ayer	"Pasok"		Gili Ayer	At the time of survey, the fisher was not going to sea	
		Hemiramphidae (Oras /Julung-julung)	Oras fish sold after salting (preserved)			

Collector

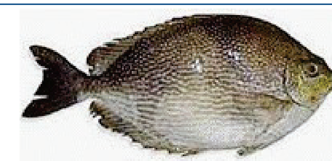
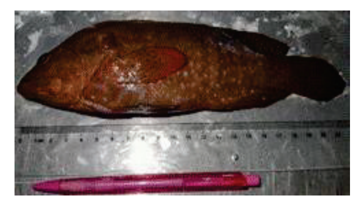
No.	Collector's description	Fish species species/ local name	Fish price*	Fish Origin	Storage and fresh fish	Photo
1	Bintaro Jaya Fish Market, Ampenan, Mataram, Lombok	*Siganus* spp. (rabbit fish)	Rp. 35.000/kg	Lombok – Sumbawa area; the fish came in a styrofoam box, and the ice had melted	No storage; Fish spread on a cement floor, sometimes covered with a plastic tarp	
		Sphyraena spp. (Barracuda)	Rp. 30.000/kg			
		Epinephelus spp. (Grouper)	Rp. 75.000/kg		Condition of the fish is relatively fresh - White eyes - Surface of the fish is still flexible	
		Euthynnus affinis (Tongkol)	Rp. 28.000/kg			

Table 5.18 ***Collector, continued***

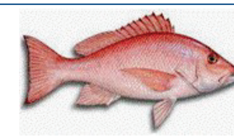
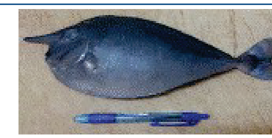
No.	Collector's description	Fish species species/ local name	Fish price	Fish Origin	Storage and fresh fish	Photo
1		*Caranx* spp. (Kuwe)	Rp. 40.000/kg			
		Thunnini spp. (Tuna)	Rp. 35.000/kg			
		Scomberomorini spp. (Tenggiri)	Rp. 75.000/kg			
		Lutjanidae spp. (Barramundi)	Rp. 50.000/kg			
		Trichiurus Lepturus (Layur)	Rp. 30.000/kg			
		Hemiramphidae (Oras /Julung-julung)	Rp. 20.000/kg			
		Naso spp. (Pogot / Unicorn fish)	Rp. 20.0000/kg			
2	Tanjung Market, North Lombok	*Naso* spp. (Pogot / Unicorn fish)	Rp. 17.500/kg			
		Caesionidae spp. (Ekor kuning)	Rp. 40.000/kg			
		Elagatus Bipinnulata (Sunglir merah)	Rp. 35.000/kg			
		Coryphaena Hippurus (Lemadang /Mahi-mahi)	Rp. 20.000/kg			

Table 5.18 ***Seller/Restaurant***

No.	Seller's/Restaurant owner's description	Fish processing	Purchase price	Fish origin	Storage and fresh fish
1	Ibu Dewi – Warung Dewi Gili Trawangan	*Siganus* spp. (Rabbit fish)	Rp. 55.000 / kg	Fresh fish purchased from Tanjung Market – North Lombok	Fish stored in the freezer
		Sphyraena spp. (Barracuda)	Rp. 60.000/ kg		
		Epinephelus spp. (Grouper)		Lombok, using box	Total fish processed: 5 kg per day
		Euthynnus affinis (Tongkol)	Rp.5.000/head, 167 g/head	Fish come from the fishing rods / arrows of Gili Trawangan fishers	
		Scarusspinus (Kakatua)	Rp. 35.000/ kg		
		"Ragi lolo"			
		Coryphaena hippurus (Lemadang/Mahi-mahi)	Rp. 80.000/ kg fillet		
2	Bp Firman – Warung Firda (Firman-Ida) Gili Ayer	"Dengkol"/ Mackerel	Rp. 35.000 rb/bunch, 4–5 fish/bunch	Fish comes from Gili Ayer fishers	All fish are purchased fresh, and stored in the freezer. Notes : Dengkol 2 bunches /3days Unicorns 2 kg/day, Tuna 2–3 kg / 4-5 days, Tilapia 1–2 kg/week
		Naso spp. ("Membilo "/ Pogot / Unicorn fish)	Rp. 25.000/kg 3-5 fish /kg		
		Thunnini spp. (Tuna)	Rp. 35.000/kg 1 fish = 1,5 kg	From Tanjung Market – North Lombok	
		Oreochromis niloticus (Tilapia)	Rp. 35.000/kg 4-5 fish/kg		
3	Resto – Hotel Merumatta Sengiggi	*Lutjanidae* spp. (Barramundi)		From agent	All fish are purchased in the form of fillets Notes : Snapper, 20 kg fillet/day Mahi-mahi 5 kg fillet/day, depending on guest's request
		Coryphaena hippurus (Lemadang /Mahi-mahi)			
		Zeus faber (Dori)			
4	Indira Apriliani – Resto Taliwang , Bintaro Jaya – Ampenan- Mataram, Lombok (Pemilik : Ibu Rusmini)	*Siganus* spp. (Rabbit fish)	Rp.40.000/kg	From Kebon Roek market, Ampenan, Mataram, Lombok The average weight of the fish used is between 250–500g	Fish from the market stored in the freezer
		Oreochromis niloticus (Tilapia)	Rp. 30.000/kg		
		Lutjanidae spp. (Barramundi)	Rp. 45.000/kg		
		Epinephelus spp. (Grouper)	Rp. 55.000/kg		

* in Indonesian rupiahs

The number of people surveyed in May and August 2022 regarding the distribution of reef fish for consumption, their profession and location is given in Table 5.19. A flow chart showing the traceability of reef fish at the survey locations during the two surveys can be seen in Figure 5.31.

The livelihood of some residents on Kerandangan Beach, Senggigi, Batu Layar, West Lombok is fishing. Here, Fishers here go to sea from 3 am to 11 pm. In general, the reef fish caught are mainly red snapper, white snapper, and grouper. The catch is usually sold to collectors from Ampenan and taken to Tanjung Market.

Bintaro Market, Ampenan, is a gathering place for wholesalers, small traders/retailers, and consumers. The fish sold here come from fishing villages, the waters of the Lombok Strait, the Tanjung Fish Market and several other places. Consumers who buy in Bintaro Market are local households as well as restaurant owners. Reef fish sold at the market include snapper, yellow tail fish, baronang fish, grouper, and barracuda.

Dealers at Tanjung Market, Sokong, North Lombok, are generally collectors and small traders/ retailers. The fish sold by these collectors come from Sumbawa, East Lombok, Tanjung Luar, and Java. Most of the consumers who buy at the wholesalers are from small traders/retailers, while the consumers who buy at the small traders come from households. Reef fish sold at Tanjung Market include snapper, baronang fish, grouper, parrot fish, and others. The fish sold in this market are not only fish in whole form but also as filets and other processed methods.

Table 5.19 Location and number of respondents during Survey I (May 2022) and Survey II (August 2022).

Respondents	Location	Number of respondents
Fishers	Kerandangan Beach, Senggigi, Batu Layar, West Lombok, West Nusa Tenggara	1 (Survey I)
Collectors/Wholesalers	Bintaro Market, Ampenan, West Lombok,West Nusa Tenggara	3 (Survey I)
	Tanjung Market, North Lombok,West Nusa Tenggara	6 (Survey II)
Small traders/Retailers	Kebon Roek Market, Jalan Adi Sucipto, North Ampenan, Kec. Ampenan, Mataram City, West Nusa Tenggara	3 (Survey I) 2 (Survey II)
	Tanjung Fish Market, Sokong, North Lombok, West Nusa Tenggara	3 (Survey I)
	Gili Trawangan Village Market,Gili Indah Village, Pemenang District, North Lombok, West Nusa Tenggara	2 (Survey II)
Restaurant	Pantai Gading, South Ring Road, Tanjung Karang, Sekarbela District, Mataram, West Nusa Tenggara	4 (Survey II)
	Bluefin Restaurant, West Sekotong District, West Lombok, West Nusa Tenggara	1 (Survey II)
	Nipah Beach Restaurant, Malacca Village, Pemenang, North Lombok, West Nusa Tenggara	1 (Survey I)

Fish are sold at Kebon Roek Market, North Ampenan, and Gili Trawngan Village Market, North Lombok by small traders/retailers. The fish come from Tanjung Luar, East Lombok, and Bintaro Market, West Lombok. Fish buyers are mostly household consumers. Reef fish sold whole and in the form of filets and chunks include red snapper, white snapper, yellowtail, baronang fish, grouper and barracuda.

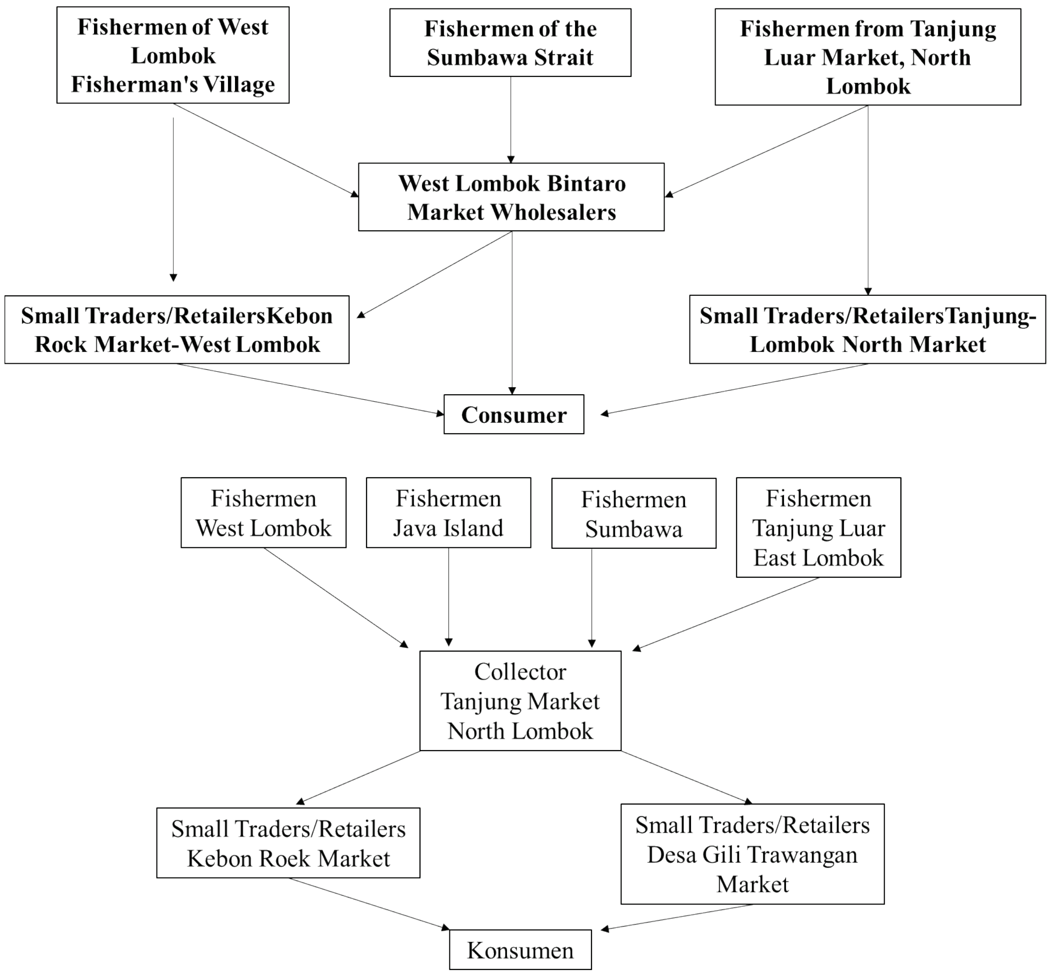


Fig. 5.31 Charts illustrating the traceability of reef fish at survey locations; (top) Survey I, May 2022 and (bottom) Survey II, August 2022.

The restaurant on Pantai Gading (Ivory Coast), Tanjung Karang, Mataram, West Lomok sells several varieties of reef fish. In general, the reef fish sold in restaurants here come from Kebon Roek Market and Bintaro Market, North Ampenan, West Lombok. Reef fish sold include grouper, red snapper, white snapper, baronang fish, parrot fish, yellow tail, and others.

The Bluefin Restaurant in West Sekotong sells several varieties of reef fish as well. In general, the reef fish sold here come from Sekotong and include grouper, red snapper, and baronang fish.

5.3.6.1 Fish freshness organoleptic test results

The organoleptic test value of fresh fish is based on National Standardization Agency of Indonesia (Badan Standardisasi Nasional) SNI 2729-2013. A minimum is 7 for freshness on a range from 1 to 9. The averaged results of the organoleptic value of the freshness of fish sold by wholesalers, retailers and restaurants interviewed during surveys I and II (see Table 5.19) had a values 7 and higher (Table 5.20), indicating that the reef fish sold by the respondents had complied with SNI.

The results of the Gap analysis of conformity for fish freshness (Table 5.21) show that the fish sold by the respondents (Table 5.19) attained a high level of suitability, ranging from 81–100%, *i.e*., suitable, during both surveys I and II. Fish sold in Bintaro Market had the highest level of freshness compared to other markets surveyed during Survey I, which was close to 100%, or 9 (the highest score of the organoleptic test). This is because the fish that are brought in at Bintaro Market are frozen or cold, and during the process of selling the fish they are always splashed with water to keep the temperature down for the cold fish. Bintaro Market is also one of the places where small traders/retailers come to buy fish, so the big traders try to keep the fish fresh for them. Fish sold by collectors in Tanjung Market had the highest freshness level, at 96%, during Survey II. This is because the fish imported to the market came directly from the fishers so they were still fresh and properly stored in frozen or cold conditions. Tanjung Market is also one of the places where small traders or retailers buy fish which will later be resold. The fish served at the Bluefin Restaurant had a higher level of freshness compared to the restaurant on Pantai Gading because the fish at the Bluefin Restaurant were kept alive until ordered by the customer.

The results of the Gap analysis on the suitability of fish handling (Table 5.22) at the respondents' location were not as good as the results of the freshness level analysis. The handling of fish at Bintaro Market during Survey I shows that the level of handling was 'almost suitable', at 66–80%, while at the Kebon Roek Market, Tanjung Market and Nipah Beach restaurant, the level of handling was regarded as 'unsuitable', reaching only 50%, and requires special attention. Fish handling during Survey II at Tanjung Market, Kebon Roek Market and Gili Trawangan Village Market was 'almost suitable', while handling standards at the Pantai Gading restaurant and Bluefin Restaurant were much higher.

Based on the results of the gap analyses, it can be concluded that the reef fish sold at all the markets and restaurants sampled during surveys I and II met the SNI for fish freshness. Fish handling met the SNI at only two locations (two restaurants in Survey II). The other locations need special attention.

Table 5.20 Organoleptic value of reef fish freshness at wholesalers, retailers and restaurants in North and West Lombok, West Nusa Tenggara, based on SNI 2729, during Survey I (May 2022) and Survey II (August 2022).

		Survey I May 2022				Survey II August 2022				
No.	**Criteria**	**Wholesalers at Bintaro Market, Ampenan, West Lombok**	**Retailer at Kebon Roek Market, Ampenan, West Lombok**	**Retailers at Tanjung Market, Sokong, North Lombok**	**Nipah Beach Restaurant, Malacca Village, Pemenang North Lombok**	**Collectors at Tanjung Market, Sokong, North Lombok**	**Retailer at Kebon Roek Market, Ampenan, West Lombok**	**Retailer at Gili Trawangan Village Market, North Lombok**	**Pantai Gading restaurant, Tanjung Karang, West Lombok**	**Bluefin Restaurant, Sekotong Barat, West Lombok**
1.	Appearance									
	a. Eye	8.7	8.7	7.0	8.0	8.7	8.5	7.5	8.5	9
	b. Gill	9.0	9.0	8.3	8.0	9	8	8	7.75	8
	c. Mucus	8.7	9.0	7.7	8.0	8.7	7.5	8	8.25	9
2.	Meat	8.3	8.3	7.7	8.0	8.7	8	8	8	9
3.	Smell	8.7	8.0	7.3	8.0	8	7	7	8	8
4.	Texture	8.7	8.0	7.7	8.0	9	8.5	8	8	8
Average freshness rating		8.7	8.5	7.7	8.0	8.7	7.9	7.8	8.1	8.5

.

Table 5.21 Gap analysis results of conformity value of reef fish freshness at wholesalers, retailers and restaurants in North and West Lombok, West Nusa Tenggara, during Survey I (May 2022) and Survey II (August 2022).

	Survey I (May 2022)			Survey II (August 2022)		
No.	**Actor**	**Conformity percentage (%)**	**Conformity level**	**Actor**	**Conformity percentage (%)**	**Conformity level**
1.	Wholesalers at Bintaro Market, Ampenan, West Lombok	96	Suitable 81–100%	Collectors at Tanjung Market, Sukong, North Lombok	96	Suitable 81–100%
2.	Retailer at Kebon Roek Market, Ampenan, West Lombok	94		Retailer at Kebon Roek Market, Ampenan, West Lombok	88	
3.	Tanjung Market Retailer, Sokong, North Lombok	86		Retailer at Gili Trawangan Village Market Retailer, North Lombok	86	
4.	Nipah Beach Restaurant, Malacca Village, Pemenang	89		Pantai Gading restaurant, Tanjung Karang, West Lombok	90	
5.				Bluefin Restaurant, Sekotong Barat, West Lombok	94	

Table 5.22 Gap analysis results on the suitability of reef fish handling at wholesalers, retailers and restaurants in North and West Lombok, West Nusa Tenggara, during Survey I (May 2022) and Survey II (August 2022).

	Survey I (May 2022)				Survey II (August 2022)			
No.	**Actor**	**Average handling value**	**Conformity percentage (%)**	**Conformitylevel**	**Actor**	**Average handling value**	**Conformity percentage (%)**	**Conformitylevel**
1.	Wholesalers at Bintaro Market, North Ampenan, West Nusa Tenggara	2.7	68	Almost suitable (66 – 80%)	Collectors at Tanjung Market, Sukong, North Lombok	3.1	79	Almost suitable (66% – 80%)
2.	Retailer at Kebon Roek Market, Ampenan, West Nusa Tenggara	1.7	43	Unsuitable (34 – 50%)	Retailer at Kebon Roek Market, Ampenan, West Lombok	2.9	73	
3.	Tanjung Market Retailer, Sokong, North Lombok	1.5	38		Retailer at Gili Trawangan Village Market Retailer, North Lombok	2.8	70	
4.	Nipah Beach restaurant, Malacca Village, Pemenang	1.6	39		Pantai Gading restaurant, Tanjung Karang, West Lombok	3.7	93	Suitable (81 – 100%)
5.					Bluefin Restaurant, Sekotong Barat, West Lombok	3.8	95	

5.3.7 Social, cultural and economic potential of Gili Indah Village at TWP Gili Matra

Field observations and interviews on socio-economic conditions and community activities related to marine resources were carried out for 3 days from August 2–4, 2022 at the TWP Gili Matra (Gili Trawangan, Gili Meno, and Gili Ayer). It was found that most of the people in the Gili Indah Village in Gili Matra archipelago depend on the potential of marine resources, including the tourism and fisheries sectors. Some residents work in various hotels and restaurants in Gili Matra while others work as tour guides, gig drivers, and boat drivers. A small number of the locals work as fishers.

The population of Gili Indah Village consists of 3,561 people, spread over three hamlets totalling 17 neighborhood units (RT) and 935 family heads (KK). The population by gender is nearly equally divided (Table 5.23).

Figure 5.32 shows that 34% of the villagers have elementary school education, followed by 23% who have junior high school education, 11% who have finished senior high school, and 2% who have attained a university degree. People who have not graduated and have not attended school accounts for 30%. Overall, there is high public awareness of the importance of formal education, especially 9-year compulsory education.

Table 5.23 Population in Gili Indah Village.

Village location	Number of households	Number offamily heads	Population by gender		Total
			Male	Female	
Gili Trawangan	7	352	740	747	1487
Gili Meno	4	165	261	273	534
Gili Ayer	6	418	790	750	1540
Total	17	935	1791	1770	3561

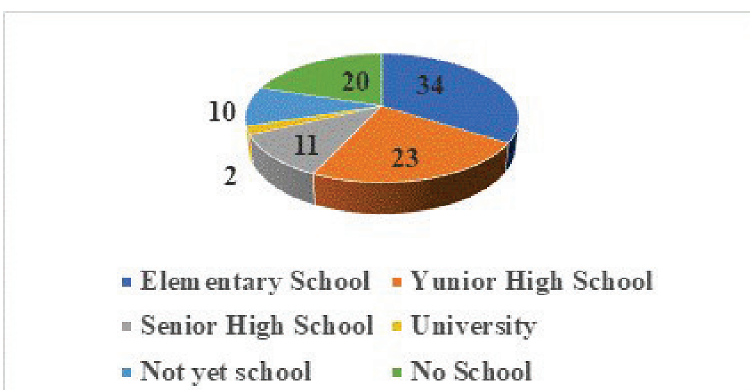


Fig. 5.32 Population of Gili Indah Village by education level.

5.3.7.1 Economic potential

The most dominant livelihoods currently are activities in the field of, or related to, tourism such as transportation, lodging accommodation, cafes, stalls and other tourism service enterprises. Other occupations are in agriculture, especially coconut plantations, while the number of those who are fishers is now decreasing. More than half (54%) of the working community is employed in the labor/private sector, followed by fishers at 16%, farmers by 12%, traders by 11%, farm labor by 3%, breeders by 2%, civil servants by 1%, and others (craftsmen and mechanics) by 1% (Fig. 5.33).

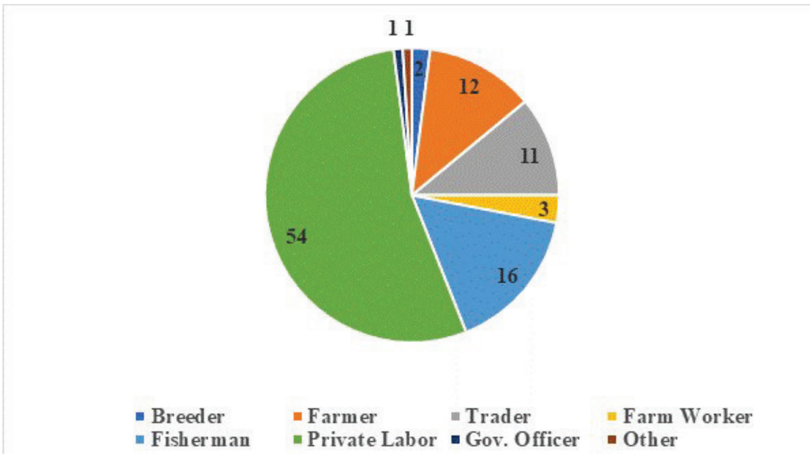


Fig. 5.33 Composition of livelihoods in Gili Indah Village.

5.3.7.2 Tourism activities

Based on the results of research conducted by Kartawijaya *et al*. (2012), the types of activities visitors usually do in TWP Gili Matra are marine tourism, especially diving or snorkeling in coral reef areas, exploring mangrove forests, going on turtle and saltwater lake tours, sunbathing, swimming, and visiting bird parks. Coral reef interest in the form of diving and snorkeling is high, namely 94% and 97.6%, respectively. Snorkeling is more popular than diving because it is easier and less technical than diving, which requires special gear and expertise to do so.

Interest in visiting in mangrove forests is still low due to the lack of advertising and facilities. However, there is high interest in turtle tourism due to the attraction of observing rare and protected species. Bird watching and lake excursions are not currently in great demand by tourists. Sunbathing is one of the most preferred activities (besides diving and snorkeling) by tourists, especially from foreign countries. Sunbathing is usually done at the beach or at the swimming pool around the hotel or lodging, but generally tourists enjoy sunbathing at the beach. Canoeing or tours given in glass bottom boats are additional ways of exploring the coastline. Tourism fishing is an activity that is not exploitive but is limited to certain areas where the fish population and diversity are still quite high. It is done in sustainable fisheries zones (coral and non-coral) around TWP Gili Matra.

5.3.7.3 Community awareness of Ciguatera Fish Poisoning

To determine the public's perception of CFP, 100 community members (95% male and 5% female) in TWP Gili Matra were surveyed. Based on education level, 89% of the respondents had a low level of education, namely elementary school, 8% had senior high school education and 3% had junior high school level. The youngest respondent was 19 years old and the oldest was 72 years.

Occupation

The vast majority of respondents (82%) were fishers, 8% worked in private companies (generally in the tourism service sector), and a small percentage of the rest worked as traders in the non-fishery business sector (Fig. 5.34).

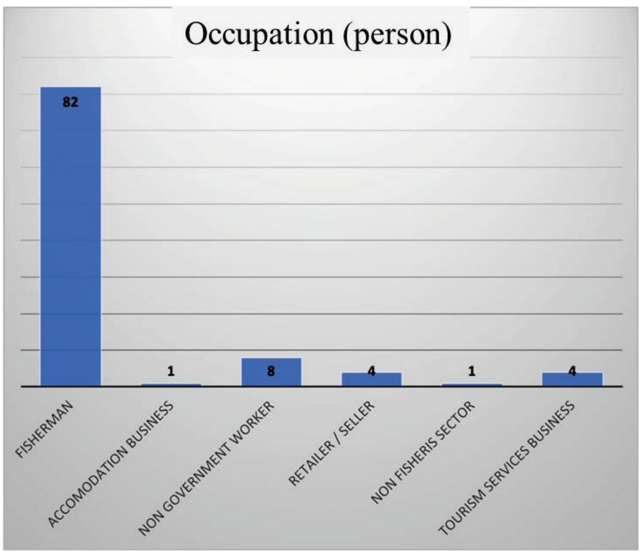


Fig. 5.34 Respondents' occupations. Source: Primary data.

Income

The majority of respondents (87%) had a relatively low income – below 1 million rupiah (~$67US) per month, while only a small minority had an income above 1 million rupiah (Fig. 5.35).

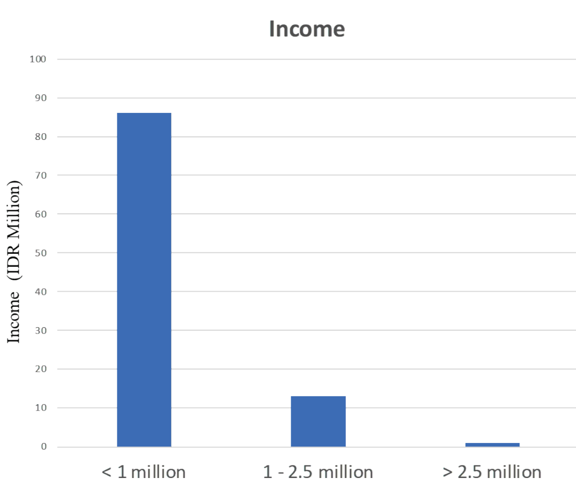


Fig. 5.35 Respondents' family income. Source: Primary data.

CFP awareness

To find out how aware the community was regarding CFP, those surveyed were asked about any characteristics of CFP around the waters of Gili Matra that they might have noticed. One of the characteristics indicating the occurrence of CFP is the change in the color of seawater. They were asked if they had ever seen the sea change color around Gili Matra. Some 69% of respondents stated that they had never seen any change in color but 31% said they had seen the seawater turn brown when it rained (Fig. 5.36). These changes generally occurred in the estuary area where seawater mixed with river water and usually lasted for 24 to 36 hours.

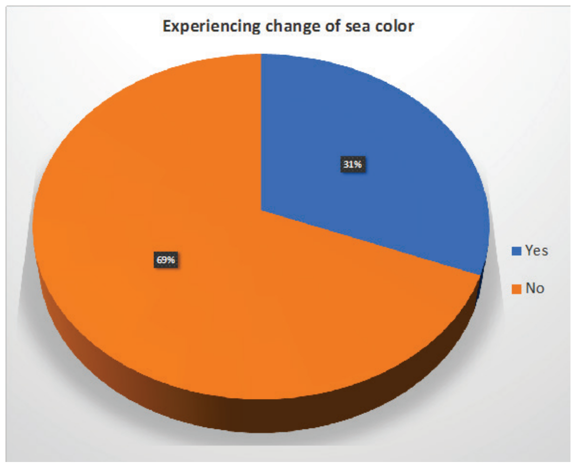


Fig. 5.36 Respondents' experience on sea color change. Source: Primary data.

The second feature of the CFP phenomenon is the sudden death of large numbers of fish (Fig. 5.37). Nearly all of the respondents (97%) stated that they had never seen sudden fish kills. Only 3% had ever seen this phenomenon, which occurred in the 1990s and was caused by potassium which was sometimes used by unscrupulous fishers to catch fish illegally.

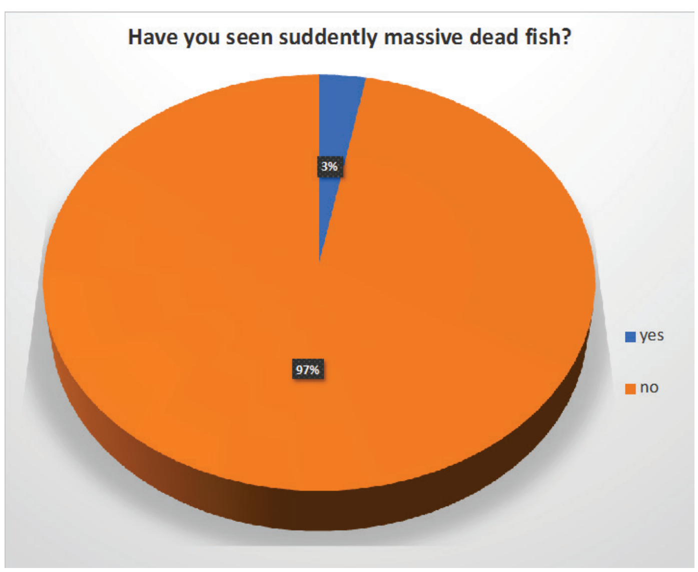


Fig. 5.37 Respondents' experience regarding massive fish kills. Source: Primary data.

The possible effect of CFP on the economy

If CFP occurs among the population, the first thing that would happen is that it would have an impact on jobs related to the marine and fisheries sector. The results of research on Gili Matra found that majority of respondents (82%) would choose to continue working even though they were impacted by CFP. Meanwhile, only 2% of the respondents stated that they would not work at all. Some 12% stated that they would work in a non-fishery sector, and 3% who would continue to work in the fisheries sector but would not go to sea (Fig. 5.38).

The results show that most people were not afraid of CFP and it would not have a significant impact on their work. Thus it can be concluded that the CFP phenomenon is unlikely to have a significant impact on the economy of the fishing communities of Gili Matra.

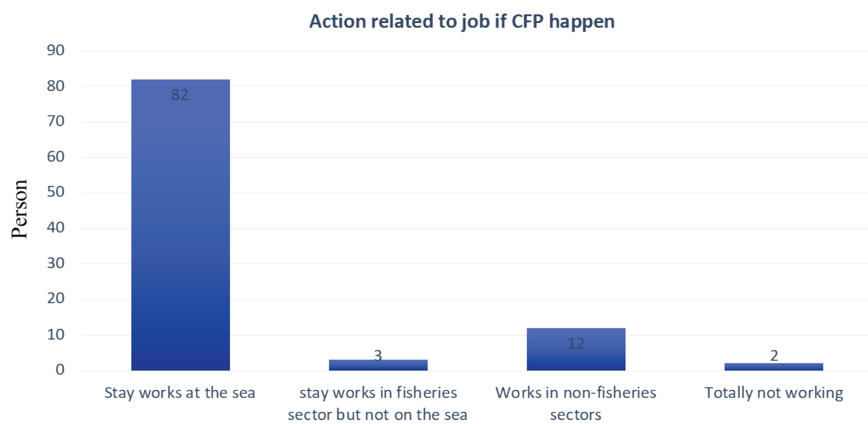


Fig. 5.38 Action related to the existence of CFP. Source: Primary data.

What people need to know

Based on this research, the respondents replied that they had never received any information regarding Ciguatera. The community has never been educated about what CFP is, and what to do if they saw a change in the appearance of seawater or a sudden massive fish die off.

Sixty-five percent of the respondents were interested in obtaining information regarding the causes of CFP, 16% asked for information on the symptoms or characteristics of CFP, 11% on how to deal with it and only 1% wanted to know the impact of CFP (Fig. 5.39). Ninety percent of the respondents thought it was very important to know about CFP, 8% said it was important, and only a small percentage stated that information about CFP was not important.

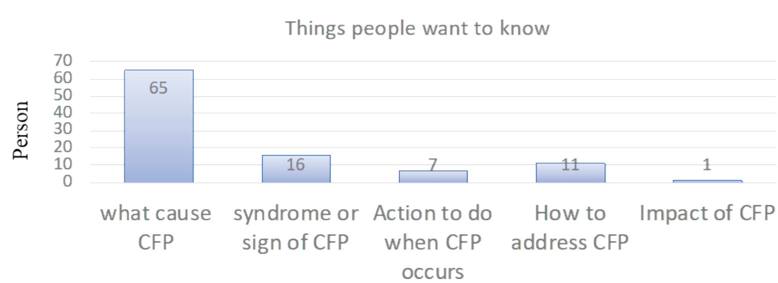


Fig. 5.39 Questions respondents wanted to know about CFP. Source: Primary data.

We feel it is necessary to introduce and disseminate information about CFP to various target groups. This research found that the parties who should be targeted for outreach were fishers, households, religious leaders, and village government officials (Fig. 5.40), while noting that there was much work to be done in educating the vast majority of the community on the importance of CFP (Fig. 5.41).

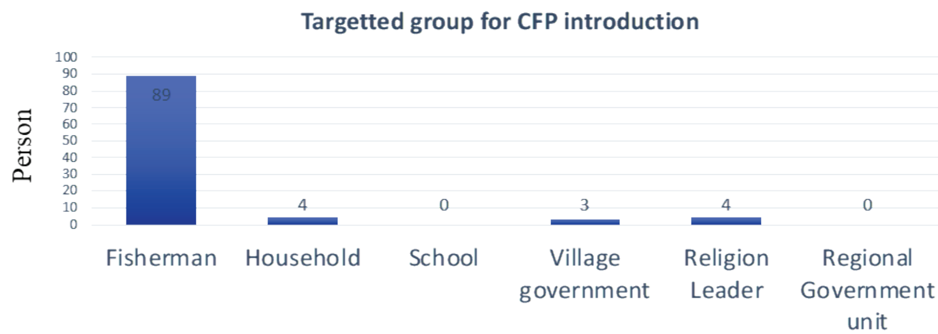


Fig. 5.40 Target groups for CFP instruction. Source: Primary data.

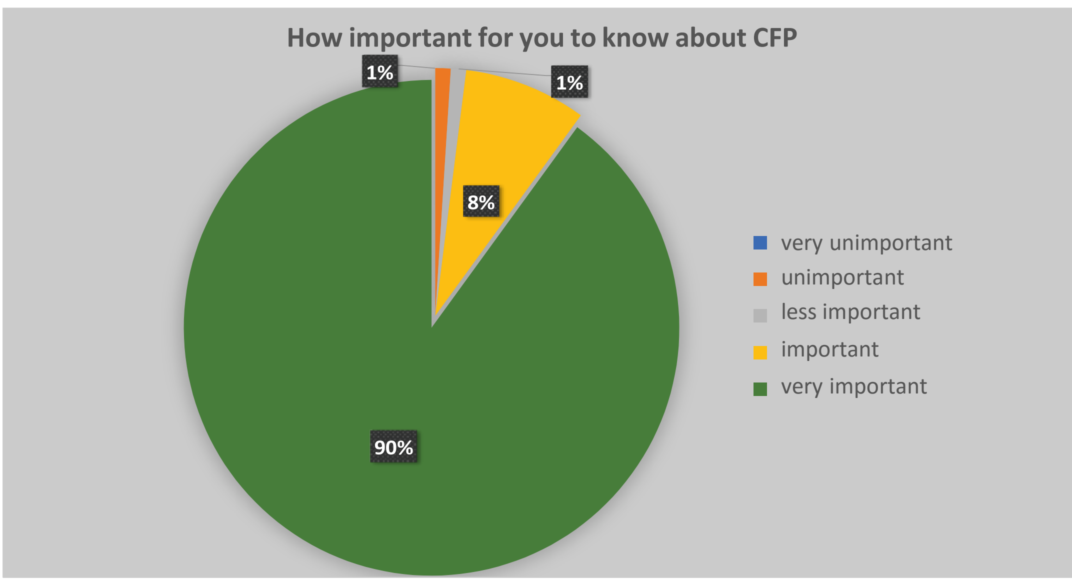


Fig. 5.41 The importance of CFP to the community. Source: Primary data.

Based on the experience of the community around TWP Gili Matra, our research found no incidents that characterize the presence of CFP in the area. Even though the possibility of CFP having a direct economic impact on the community is minimum, it is still necessary to educate the public about this phenomenon to raise public awareness, especially in terms of preventing the occurrence of CFP, so that any socio-economic impacts can be avoided.

6 Community Training and Knowledge Dissemination Workshop—Building Capacity for Coastal Monitoring by Local Small-scale Fishers

It was expected that the project's primary initiatives will be supported by a series of capacity building workshops led by PICES scientists aiming to work with local communities to increase the sustainability of their fishing resources by providing them with CFP information. Due to COVID-19 though, only one training and knowledge dissemination workshop was held close to end of the project, in January 2023, in Lombok.

Discussions with our Indonesian colleagues led to the decision to select the Gili Matra region of Lombok, West Nusa Tenggara (WNT) Province, as a case study site for the project because of existing science-based assets in the area and strong government and local support for efforts towards sustaining the health of coral reef environments. The Gili Matra coastal region has a marine conservation area of 2,273.56 ha, comprising a diversity of important ecosystems, including mangroves, coral reefs, and sea grasses that are vital for protected charismatic and endangered species (*e.g.*, blackfin sharks, whitefin sharks, manta rays, clams, and turtles). However, tourism pressures are increasing on the islands, and this expansion is anticipated to result in decreasing water quality – a trend that has led to increases in CFP in other tropical regions. The tools developed and utilized during PICES-MAFF projects are well suited for assessing and monitoring for these risks. This workshop was intended to inspire new enthusiasm in stakeholders of the region to work towards sustainable management and utilization of their fisheries and other marine resources.

The main objectives of the workshop were to: (1) disseminate information to the broad spectrum of participants about fisheries management and the hazards of benthic harmful algal blooms (particularly CFP) in Indonesian coastal areas, (2) provide technical, hands-on training on the use of smartphone-based tools for monitoring of fisheries resources (FishGIS) and environmental health conditions (HydroColor), and on the use of Planktoscope for quantifying benthic and pelagic phytoplankton, and (3) communicate the consequence of changes to the marine resources on the community fishers.

Two days prior to the workshop were dedicated to field trips. On January 23, the PICES delegation together with the Organizing Committee members travelled by boat to the Ciguatera research location in Gili Matra waters (see Chapter 5 for details). The series of sampling surveys began in association with this project in May 2022, and the current results of this research were presented at the workshop.

On January 24, the PICES delegation visited a seaweed farm in Teluk Ekas (East Lombok) and had an audience with the Regional Secretary of the Governor of the WNT Province, Dr. H. Lalu Gita Ariadi, at the Governor's office (Fig. 6.1). Apart from the PICES delegation and members of the Organizing Committee, this meeting was also attended by the Chancellor of ITI, Head of BRIN's Research Centre for Environment and Clean Technology, and Head of the ITI Cooperation and Public Relations Bureau. The Regional Secretary was accompanied by the Head of the Regional Research and Innovation Agency (BRIDA) and several staff members. The goals of this visit were (1) to thank the Provincial Government for providing invaluable assistance in organizing the workshop in Lombok and to request the Regional Secretary to open the workshop, and (2) to share information about the research activities being carried out and plans for future PICES-MAFF projects in order to draw interest to assist in implementation of these projects.

The 2.5-day workshop was held from January 25–27, at the Merumatta Hotel, Senggigi Lombok, and was organized in close collaboration with ITI (Dr. Suhendar I Sachoemar led the Organizing Committee) and with support from BRIN, the WNT Provincial Government, the University of Indonesia (UI), and Mataram University (UNRAM). More than 90 people attended the workshop, including members of coastal communities from Gili Matra and the surrounding Lombok area, officials and researchers from BRIN, ITI, UI, UNRAM, University of Padjadjaran (UNPAD) and regional agencies and institutions, representatives of the WNT Provincial Government and their Regional Work Units, local NGOs and other community groups, observers of coral reefs and coastal marine ecosystems, and members of the tourism industry.

Fig. 6.1 A group photo after the audience with the Regional Secretary of the Governor of the WNT Province, WNT Governor's Office, Lombok, January 24, 2023.

The workshop began with singing (by all attendees) the Indonesia Raya song and a traditional Indonesian welcome dance performed by UNRAM students. The Opening Session included a report by the Chair of the Organizing Committee (Fig. 6.2, left) and welcome addresses by the Chancellor of ITI (Dr. Ir. Marzan A Iskandar), Co-Chair of the PICES-MAFF Ciguatera project (Dr. Mistutaku Makino), Chancellor of UNRAM (Prof. Ir. Bambang Hari Kusumo), Head of BRIN's Center for Environmental Research and Clean Technology (Dr. Sasa Sofyan Munawar), and Regional Secretary of the Governor of the WNT Province, who officially declared the workshop open (Fig. 6.2, right).

Fig. 6.2 Workshop Opening Session: (left) Dr. Suhendar I Sachoemar presents the report of the Organizing Committee; Regional Secretary of the Governor of the WNT Province, Dr. H. Lalu Gita Ariadi, beats the gong to signal the official opening of the workshop (right).

The welcome addresses were followed by a signing ceremony for a number of Memoranda of Understanding (MOU), Cooperation Agreements (CoA), and Implementation Arrangements (IA) (Fig. 6.3; Table 6.1). These official documents are expected to strengthen support from the government and various institutions and universities in Indonesia for collaborative research with PICES and the sustainability of the observation network after the project is completed. The Opening Session was concluded with a group photo (Fig. 6.4).

Fig. 6.3 Workshop Opening Session: Signing of an MOU between ITI and the WNT Provincial Government (left) and ITI and UNRAM (right).

Table 6.1 Documents on joint activities signed at the workshop Opening Session.

Document type	Collaborators
MOU	ITI and WNT Provincial Government
MOU	ITI and UNRAM
CoA	Research Centre for Environment and Clean Technology, BRIN and Department of Agro-industrial Technology, ITI
CoA	Research Centre for Environment and Clean Technology, BRIN and Faculty of Economic and Business, UNRAM
CoA	Academic, Research and Student Affairs, ITI and Faculty of Food Technology and Agroindustry, UNRAM
CoA	Academic, Research and Student Affairs, ITI and Faculty of Economics and Business, UNRAM
IA	Department of Food Science and Technology, UNRAM and Department of Agro-industrial Technology, ITI
IA	Department of Food Science and Technology, UNRAM and Department of Economics and Development, UNRAM

Fig. 6.4 Group photo of workshop participants taken at the end of the Opening Session on January 25, 2023.

Following the Opening Session were 9 presentations by PICES representatives and Indonesian scientists on the global issue of CFP and the status of local research on ciguatera and benthic dinoflagellates, aquatic environmental quality, e-DNA of marine fish, food safety, and local socio-economic considerations.

The training session began in the afternoon of the first day when all participants learned how fisheries management could provide benefit to the sustainability of their fisheries, the general background of the FishGIS and HydroColor smartphone applications and their purposes for helping to assess the environment, and a description of Planktoscope. The session presented a broad overview of the project assets and set the stage for the second day of the workshop.

On the second day (January 26), participants were split into groups for hands-on training. The first group, consisting mostly of representatives of coastal communities, spent the morning with training on the FishGIS application, and the afternoon with training on the HydroColor application given by Drs. Shion Takemura, Daisuke Ambe, Mitsutaku Makino, Charles Trick, and Naoki Tojo (Fig. 6.5).

Fig. 6.5 Participants learn the FishGIS smartphone applications (first and second row) and HydroColor smartphone application (third row).

The second group, involving fishers and resource managers, gathered to experience the social and economic consequences of environmental changes on fishing activity and financial well-being. Through experience, Drs. Tojo and Trick have recognized that normal "science" presentations are generally ineffective in transferring environmental change information and economic outcomes. Dr. Tojo organized a "fishing game" where the participants would build their own fish-inhabited ocean, and the mentors would remove fish from the future sea based on the possibility that the fish would contain ciguatera (Fig. 6.6). Each working group would then assess the economic value of fishing (lower in all cases), the location of fisheries (pelagic, coastal, or reef), and the effort the fishers would take to fish in the future. The fisher groups realized that the future was uncertain and that their actions influenced the distribution of fish. In addition, the fishers recognized the consequence of having fish contaminated with ciguatera.

Fig. 6.6 Fisheries working groups considering the consequence of environmental changes on the economic value of fishing.

After completing an intense afternoon on the second day of the workshop, certificates were distributed to the FishGIS and HydroColor training participants (Fig. 6.7), and souvenirs were given to the PICES representatives by the Organizing Committee.

Fig. 6.7 Awarding certificates to the training participants by PICES representatives, Drs. Mitsutaku Makino, Naoki Tojo, Shion Takemura and Daisuke Ambe.

Planktoscope is a low-cost microscope platform that allows automated image collection of phytoplankton cells in a simple flow-through system. These images are uploaded to a dedicated server where artificial intelligence software can be trained to identify and quantify the composition of the phytoplankton assemblage. This tool is expected to revolutionize plankton monitoring and is particularly suited to this project. A smaller subset of participants with science background learned the detailed operation of Planktoscope using locally collected plankton samples (Fig. 6.8). The training was given by Dr. Mark Wells and two PhD students, Ethan Li, an experienced Planktoscope operator from Stanford University, and Drajad Seto, a phytoplankton specialist from the University of Maine. On the next morning (January 27), this group was trained in how to disassemble and install components of the Planktoscope system. The Planktoscope training also ended with awarding certificates to the participants.

Fig. 6.8 Participants learn the operation of the Planktoscope.

Also on the morning of January 27, PICES representatives and members of the Organizing Committee met to review the workshop activities (Fig. 6.9). In general, the consensus was that the workshop had proceeded well in all aspects and was widely reported by Indonesian mass media. There was collective hope that this cooperation can be continued.

Fig. 6.9 Evaluation and discussion of the workshop activities by PICES representatives and members of the Organizing Committee on January 27, 2023, at Merumatta Hotel, Senggigi Beach, Lombok.

7 Project Data Management Policy

The long-term security of the data collected during the Ciguatera project must be assured after the project has ended. The data handling considerations for this project are more complex than many other projects because a portion of these data was obtained during surveys funded by the National Research and Innovation Agency of Indonesia (BRIN), through an independent budget (Table 7.1). The data collected during BRIN-funded surveys are considered then to be independent of the PICES Data Management Policy. In addition to natural science data, the Ciguatera project also generates sensitive coastal fisheries data that are of national interest to Indonesia. The ownership of the outcomes of the Ciguatera project, including data, copyright, and intellectual property rights, is outlined in the Project Principles (Appendix 1) and is further expanded here.

Table 7.1 Survey activities in the Gili Matra region.

Survey Dates	Season	Funding Source
May 23–28, 2022	Transition I (Wet to Dry)	PICES
August 1–5, 2022	Dry	BRIN
October 10–16, 2022	Transition II (Dry to Wet)	BRIN
December 12–18, 2022	Wet	PICES
February 20–25, 2023	Wet	PICES

At present, Ciguatera project data are stored either on external cloud-based servers (provided by Google) or in the BRIN Data Repository (Table 7.2). There is on-going discussion on a transfer of these raw and processed data to the Indonesian national repository (Data Repository of Indonesia) for long term storage.

Table 7.2 Storage of Ciguatera project data.

Type of Data	Current Storage Conditions
Data collected by the FishGIS application	External data servers in Indonesia and Japan (raw data) External data server in Japan (data products)
Data collected by the HydroColor application	Importable to external data server in Japan by FishGIS administrator
Data on benthic dinoflagellates	Importable to external data server in Japan by FishGIS administrator
Data from all Indonesian surveys	BRIN Data Repository

All raw data from both BRIN- and PICES-funded surveys currently are shared and managed by BRIN and PICES, and the status of publication of these data will be agreed upon between the Indonesian research group and PICES/MAFF. Although not a PICES member country, Indonesia is a Member State of the Intergovernmental Oceanographic Commission of UNESCO (IOC). The IOC Data Exchange Policy recommends full open access to oceanographic data, but Clause 4 acknowledges the right of Member States and data originators to determine the terms of such exchange in a manner consistent with international conventions. The present agreement is that PICES and MAFF are entitled to access data/information obtained from this cooperation for the purpose of science and technology development. For any data shared with PICES, PICES nevertheless will respect the ownership rights and any restrictions by the Indonesian government, consistent with the PICES Data Management Policy.

The following policy for managing data from the Ciguatera project was developed through close collaboration with PICES Technical Committees on Data Exchange (TCODE) and BRIN representatives:

1. Data gathered as a result of this project activity (hereafter simply termed "data") are used for the Indonesian government and local small-scale fishers and community members to monitor their coastal ecosystems and coastal fisheries for conservation and development.
2. Data will be responsibly managed by PICES to guard against loss and to ensure continued accessibility within each community.
3. The quality assurance of data is the responsibility of the data provider and the community to which the data provider belongs.
4. Any data use (publications, reports, *etc*.) must be acknowledged using a formal citation.
5. PICES will respect the priority rights and any restrictions placed on these data by the data provider and community/organization/government to which the data provider belongs.
6. PICES will respect the terms of use of the applications for data collection used in this project.[1]
7. Any other data will be handled in accordance with the PICES Data Management Policy.

[1] A section on copyright-related issues in a draft FishGIS User Manual states:
- The copyright of the information submitted using FishGIS is reserved solely to the contributor.
- By submitting information using FishGIS, the contributor agrees to the free re-use of this information by PICES, who is responsible for the management and operation of FishGIS.
- PICES may use the submitted information for research activities and other purposes only with the consent of the contributor.

8 Summary and Recommendations

8.1 *Summary of main activities and outputs*

The necessary travel restrictions stemming from the COVID pandemic prevented the implementation of many original plans. Thanks to the vigorous and constructive cooperation with our Indonesia colleagues, alternative activities were conceived and implemented—a welcome measure of successful capacity building collaborations of this and previous PICES-MAFF projects. The revised planning and achievements are listed here.

8.1.1 Project Design Matrix

A Project Design Matrix (PDM) was developed to manage the project more effectively (for details see Chapter 3). The PDM describes the logical structure of the project (the links between activities and objectives) as well as the quantitative data that will be obtained. This framework assists in the planning process, facilitates communication of the "why" and "how" of the project, and provides a basis for assessing the project progression. It is structured to list the Project Goals (to codify the principal objectives), the Project Purpose (the intended impacts and anticipated benefits), the Results/Outputs (the component objectives the project management must achieve and sustain), and the Activities (steps taken to achieve the desired results/outputs). Though we were unable to realize the full benefits from this approach due to pandemic-restricted interactions, applying the Project Cycle Management strategy and the PDM will accelerate progress in future projects.

8.1.2 Observation tools

The 2017–2020 FishGIS project led to the initial development and implementation of the smartphone-based tool (FishGIS application) for fisheries and environmental observations. This tool enables small-scale fishers and community members to collect a variety of data on factors such as water quality status, phytoplankton abundance and speciation, fisheries management data (fish species diversity, size, and abundance), the character, abundance and location of floating garbage (plastics), and Illegal Unregulated and Unreported (IUU) fishing. The Ciguatera project was expected to adapt and refine these smartphone capabilities for measurement and automated reporting and combine them with new automated technologies for plankton species identification.

The revised version of the FishGIS application now is available on Apple Store and Google Play and can be installed on iOS 10 and Android 7 or later smartphone devices. The major modifications include (for details see Chapter 4):

- a reporting scheme that is consistent with ABS (Access to genetic resource and Benefit Sharing) rules of the UN Convention of Biological Diversity;
- an improved user interface;
- a function allowing the direct launch of the HydroColor water quality application from within the FishGIS application;
- a function allowing the direct launch of the Info BMKG application (provided by BMKG – Indonesian government agency for Meteorology, Climatology, and Geophysics) to better incorporate a tsunami early warning notification for remote fishing communities;
- a function to map Ciguatera field survey data and to accumulate fisheries-related data (from photos of fish species in local fish markets);
- a dashboard for data management.

In addition to improvements in the FishGIS application, the project initiated training in the use of Planktoscope, a low-cost microscope platform that allows automated image collection of phytoplankton cells in a simple flow-through system. The images are then uploaded to a dedicated server where artificial intelligence software can be trained to identify and quantify the composition of the phytoplankton assemblage. This tool will revolutionize plankton monitoring and is particularly suited to this project. A successful pilot deployment of several Planktoscopes took place in the Gili Matra region during the January 2023 training workshop.

8.1.3 Field sampling program

Based on recommendations from our Indonesian colleagues, the Gili Matra region (WNT Province) was selected as a case study site. The central factors underlying this selection were the existence of a well-established local fishing community, an active BRIN research station in the area, the capabilities and interest of individuals at the local university (UNRAM), and the strong support for the project by the WNT government.

The initial plan was to have local small-scale fishers and community members in the region carry out field observations and sample collections. However, the pandemic-related delays to the intended on-site training workshops led to shifting the focus to a substantial augmentation of existing BRIN-planned surveys of waters surrounding Gili Matra to expand data collection opportunities. The draft survey design was shared with the PST by our Indonesian counterparts, and modifications to the design were jointly decided. A portion of Ciguatera project funds were re-directed to support a total of five extended surveys conducted in different seasons: May 23–28, 2022 (Wet to Dry Season/Transition I), August 1–5, 2022 (Dry Season), October 10–16, 2022 (Dry to Wet Season/Transition II), December 12–18, 2022 (Wet Season) and February 20–25, 2023 (end of the Wet Season). The smartphone-based FishGIS and HydroColor tools were actively used in these surveys. In addition to water column and benthic samples, fish caught around Gilli Matra or Lombok were purchased for ciguatoxin analysis. Researchers from BRIN and UNRAM also collected fundamental socio-economic data in the area using the same methodology as in the previous PICES-MAFF projects (on-site surveys, questionnaires, and focus group discussions). As a consequence, a valuable initial assessment of water quality, benthic HAB, fisheries data, and socio-economic status was completed in the Gili Matra region (for details see Chapter 5). Analysis of field samples is still ongoing, but preliminary results indicate that the threat of CFP in this area currently is low. These research activities were widely reported by the Indonesian mass media, and two talks by Indonesian scientists were presented at the 2022 PICES Annual Meeting in Busan, Korea.

Considering that one of the main goals of the project was capacity building, partial tuition support was provided to six undergraduate students from UI, UNRAM and ITI (two from each) to participate in field sampling surveys.

8.1.4 Development of a (bow-tie) risk assessment model

The principal objective of the Ciguatera project was to improve and enable the use of smartphone-based tools to enhance the collection of environmental and fisheries data. A key next step is to establish risk assessment strategies to best utilize these data for protecting human health and improving human wellness. As an initial action, a (bow-tie) risk assessment model was constructed that summarizes the connections among coastal environmental conditions, ciguatoxins, human exposure to these toxins and the CFP risk, and demonstrates how the project's activities can prevent, adapt, and mitigate the risks (for details see Chapter 2). This model will be used in project management and capacity building exercises in the new MAFF-PICES project.

8.1.5 Community training workshops

Only one training workshop was held close to end of the project, in January 2023 in Lombok (for details see Chapter 6). This successful workshop was attended by more than 90 members of coastal communities, officials and researchers from BRIN, ITI, UI, UMRAM and provincial institutions, representatives of the WNT Provincial Government and their Regional Work Units, local NGOs and other community groups, observers of coral reefs and coastal marine ecosystems, and members of the tourism industry. The workshop and project goals were widely shared in local and national news reports, and the workshop led to the signing of multiple cooperation agreements among Indonesian national and local government agencies and universities—factors that strengthen support for collaborative research with PICES and the sustainability of the observation network after the project is completed.

8.2 Recommendations for the next step

The most significant lesson from this project is recognition of the critical importance of building a strong relationship and mutual trust of PICES representatives with local counterparts and collaborators. The support gained from local, provincial, and national government agencies and universities played a key role in the approval by MAFF and PICES of a new 3-year project, entitled "Creating a phytoplankton-fishery observing program for sustaining local communities in Indonesian coastal waters" (FishPhytO), in this region starting in April 2023. A major recommendation is to place the highest priority on strategies to further strengthen trust with these local counterparts. For example, working to establish mutually attractive Memoranda of Understanding and Letters of Interest can be effective tools towards this goal. Another priority will be to effectively expand these strategies to link local communities with our Indonesian government and university counterparts so that they become the recognized experts.

It is expected that the new project will use the Gili Matra region as the major case study site to take advantage of 1) the initial field sampling protocols that have been developed, 2) the core network of local people and researchers that has been set, and 3) the current dissemination of knowledge and technologies to local communities and the regional government that can aid in detecting, monitoring and responding to the presence of benthic HABs. We strongly believe that these foundations will help in establishing a sustainable early detection system for protecting human health from benthic HAB impacts, and threats to human wellness from changes in water quality and activities that threaten fisheries resources. Moreover, the observation/awareness/response strategies being created here should be designed so that they are transferable to other coastal regions in Indonesia and elsewhere.

9 References

Ahyadi, H. 2010. Evaluasi sumber daya terumbu karang untuk wisata di Gili Trawangan Propinsi Nusa Tenggara Barat. Desertasi Pascasarjana. Institut Pertanian Bogor, Bogor.

Ahyadi, H. and Jufri, A. 2008. Analisis perubahan ekosistem terumbu karang untuk menunjang pengelolaan kawasan TWP Gili Indah yang Berkelanjutan. Laporan Kegiatan Riset dan Pengembangan Daerah. Badan Perencanaan Pembangunan Daerah, Nusa Tenggara Barat, Mataram. 121 pp.

Burke, L., Selig, E. and Spalding, M. 2002. Terumbu Karang Yang Terancam Di Asia Tenggara (Reefs at Risk in Southeast Asia). World Resources Institute.

Burkholder, J.M. 1998. Implications of harmful microalgae and heterotrophic dinoflagellates in management of sustainable marine fisheries. *Ecological Applications* **8**: S37–S62.

Carr, J.M., Hergenrader, G.L. and Troelstrup, Jr., N.H. 1986. A simple, inexpensive method for cleaning diatoms. *Transactions of the American Microscopical Society* **105**: 152–157, https://doi.org/10.2307/3226387

Chan, T.Y.K. 2014. Epidemiology and clinical features of ciguatera fish poisoning in Hong Kong. *Toxins* **6**: 2989–2997.

Chomérat, N., Bilien, G. and Zentz, F. 2018. A taxonomical study of *Prorocentrum* species (Prorocentrales, Dinophyceae) from Anse Dufour (Martinique Island, eastern Caribbean Sea). *Marine Biodiversity* **49**: 1299–1319.

Cormier, R., Kannen, A., Elliott, M., Hall, P. and Davies, I. M. (Eds.) 2013. Marine and Coastal Ecosystem-based Risk Management Handbook. ICES Cooperative Research Report, No. 317, 60 pp. Doi: 10.17895/ices.pub.5486.

Creed, I., Cormier, R., Laurent, K.L., Accatino, F., Igras, J., Henley, P., Friedman, K.B., Johnson, L.B., Jill Crossman, Dillon, P.J. and Trick, C.G. 2016. Formal integration of science and management systems needed to achieve thriving and prosperous Great Lakes. *BioScience* **66**: 408–418, https://doi.org/10.1093/biosci/biw030.

de Sylva, D.P. 1994. Distribution and ecology of ciguatera fish poisoning in Florida, with emphasis on the Florida Keys. *Bulletin of Marine Science* **54**: 944–954.

Duarte, C.M., Fulweiler, R.W., Lovelock, C.E., Martinetto, P., Saunders, M.I., Pandolfi, J.M., Gelcich, S. and Nixon, S.W. 2014. Reconsidering ocean calamities. *BioScience* **65**: 130–139, https://doi.org/10.1093/biosci/biu198

Dwivayana, T.M.S., Thamrin and Efriyeldi. 2015. Analysis of the abundance of benthic dinoflagellate on the artificial substrate at Padang City waters, West Sumatera. *Jurnal Ilmu Lingkungan* **9**: 122–130, DOI: 10.31258/jil.9.2.p.122-130. (in Indonesian)

Eboni, W., Thamrin and Mubarak. 2015. The distribution of toxic benthic dinoflagellate *Gambierdiscus* sp., *Prorocentrum* sp. and *Ostreopsis* sp. on *Sargassum* sp. in the coastal of Nipah River, Pesisir Selatan Regency, West Sumatra Province. Jurnal Online Mahasiswa **2**: 1–12. (in Indonesian)

FASiD (Foundation for Advanced Studies on International Development). 2001. PCM 手法の理論と活用 (Theory of PCM method and application), 228 pp. (in Japanese)

GEOHAB. 2001. Global ecology and oceanography of harmful algal blooms science plan. SCOR and IOC, Paris.

Gomez, E.D. and Yap, H.T. 1988. Monitoring Reef Condition, p. 171 *In* Kenchington, R.A. and B.E.T. Hudson (Eds), Coral Reef Management Handbook. UNESCO Publisher, Jakarta.

Hallegraeff, G.M. 1991. Aquaculturist Guide to Harmful Australian Microalgae. Publ. Fishing Industry Training Board of Tasmania 25 Old Wharf, Hobart, Tasmania. 7000-CSIRO Div. of Fisheries, Hobart, Australia.

Hernández-Rosas, A, Meave del Castillo, M.E., Díaz-Larrea, J. and Rodríguez, F. 2017. Single-cell PCR amplification of thecate dinoflagellates: a case study of *Tripos* (Dinophyceae). *Journal of Applied Phycology* **30**: 1117–1124, doi: 10.1007/s10811-017-1269-1.

Jeong, H.J., Lim, A.S., Jang, S.H., Yih, W.H., Kang, N.S., Lee, S.Y., Yoo, Y.D. and Kim, H.S. 2012. First report of the epiphytic dinoflagellate *Gambierdiscus caribaeus* in the temperate waters off Jeju Island, Korea: morphology and molecular characterization. *Journal of Eukaryotic Microbiology* **59**: 637–650.

JICA (Japan International Cooperation Agency. 2022. 国際協力機構年次報告書 [JICA Annual Report 2022], 70 pp. (in Japanese)

Katz, A.R., Terrell-Perica, S. and Sasaki, D.M. 1993. Ciguatera on Kauai: investigation of factors associated with severity of illness. *American Journal of Tropical Medicine and Hygiene* **49**: 448–454.

Kohli, G.S., Haslauer, K., Sarowar, C., Kretzschmar, A.L., Boulter, M., Harwood, D.T., Laczka, O. and Murray, S.A. 2017. Qualitative and quantitative assessment of the presence of ciguatoxin, P-CTX-1B, in Spanish Mackerel (*Scomberomorus commerson*) from waters in New South Wales (Australia). *Toxicology Reports* **4**: 328–334.

Laza-Martinez, A., Orive, E. and Miguel, I. 2011. Morphological and genetic characterization of benthic dinoflagellates of the genera *Coolia*, *Ostreopsis* and *Prorocentrum* from the south-eastern Bay of Biscay. *European Journal of Phycology* **46**: 45–65.

Leeuw, T. and Boss, E. 2018. The HydroColor app: Above water measurements of remote sensing reflectance and turbidity using a smartphone camera. *Sensors* **18**: 256.

Lehane, L. and Lewis, R.J. 2000. Ciguatera: Recent advances but the risk remains. *International Journal of Food Microbiology* **61**: 91–125. https://doi.org/10.1016/S0168- 1605(00)00382-2.

Nurhasim, A. 2015. Only 30% of Indonesia`s coral reefs in good condition. Antara. https://en.tempo.co/read/690501/only-30-of-indonesias-coral-reefs-in-good-condition

Obura, D. and Grimsditch, G. 2009. Resilience assessment of coral reefs rapid assessment protocol for coral reefs, focusing on coral bleaching and thermal stress. p. 71. IUCN Resilience Science Group Working Paper Series – No. 5, Gland, Switzerland.

Oktavian, B., Thamrin and Siregar Y.I. 2017. Analysis of epiphytic dinoflagellates on Thalassia hemprichii at Nirwana Beach Waters, Kabung Bay District, Padang City, West Sumatera Province. *Jurnal Online Mahasiswa*. (in Indonesian)

Rachman, A. 2019. Report on Ecosystem and Biodiversity Study for Marine Protected Areas in Lombok, Indonesia: Sub-topic Marine Phytoplankton. Research Center for Oceanography, Indonesian Institute of Science. Jakarta.

Randall, J.E. 1958. A review on Ciguatera, tropical fish poisoning, with a tentative explanation of its cause. *Bulletin of Marine Science of Gulf and Caribbean* **8**: 237–267.

Seygita, V., Thamrin and Siregar, Y.I. 2015. Analisis kelimpahan Dinoflagellata Bentik beracun di PerAyeran Teluk Bayur, Sumatera Barat. *Dinamika Lingkungan Indonesia* **2**: 92–99. DOI: 10.31258/dli.2.2.p.92-99. (in Indonesian)

Skinner, M.P., Lewis, R.J. and Morton, S. 2011. The abundance of potentially toxic epiphytic dinoflagellates and nutrients from Bali and Gili Trawangan, Indonesia. *Marine Research in Indonesia* **36**: 11–23, DOI: 10.14203/mri.v36i2.38

Takemura, S., Makino, M., Kogushi, S., Tojo, N., Wells, M., Trick, C. and Sachoemar, S. 2019. Developing a community-based coastal environmental monitoring system in Indonesia using smartphone app. p. 238. Book of Abstracts, PICES-2019, Victoria, Canada.

Tamura, K., Peterson, D., Peterson, N., Stecher, G, Nei, M. and Kumar, S. 2011. MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution* **28**: 2731–2739.

Tawong, W., Nishimura, T., Sakanari, H., Sato, S., Yamaguchi, H. and Adachi, M. 2015. Characterization of *Gambierdiscus* and *Coolia* (Dinophyceae) isolates from Thailand based on morphology and phylogeny. *Phycological Research* **63**: 125–133, https://doi.org/10.1111/pre.12074.

Terumbu Karang Indonesia. 2014. Biodiversity Warriors, July 5, 2014, kehati.or.id.

Tester, P.A., Vandersea, M.W., Buckel, C.A., Kibler, S.R., Holland, W.C., Davenport, E.D., Clark, R.D., Edwards, K.F., Taylor, J.C., Vander Pluym, J.L., Hickerson, E.L. and Litaker, W.R., 2013. *Gambierdiscus* (Dinophyceae) species diversity in the Flower Garden Banks National Marine Sanctuary, Northern Gulf of Mexico, USA. *Harmful Algae* **29**: 1–9.

Thamrin. 2014. Analysis of benthic dinoflagellate *Gambierdiscus*, *Ostreopsis*, and *Prorocentrum* density on the west coast of Sumatera Island and Bintan Island coast in Riau Archipelago, Indonesia. *In* R.M. Hutauruk, B. Heltonika, R. Karnila, Syawal H. Windarti, Efriyeldi (Eds). Proceeding of 3rd International Seminar of Fisheries and Marine Science. University of Riau, Pekanbaru, 9–10 October 2014.

Widiarti, R. 2002. Dinoflagellata epibentik pada makroalga di rataan terumbu Pulau Penjaliran Barat, Teluk Jakarta. *Sains Indonesia* **1:** 1–9.

Widiarti, R. 2010. Dinoflagellata Penyebab Ciguatera Fish Poisoning (CFP) di PerAyeran Pulau Belitung, Bangka Belitung. Dalam: Prosiding Pertemuan Ilmiah Tahunan ISOI VII 2011: 17–25 hlm.

Widiarti, R. 2011. Dinoflagellata toksik penyebab Ciguatera Fish Poisoning di perAyeran Kepulauan Seribu, Jakarta Utara: Studi awal mengenai distribusi spesies. Dalam: Nababan dkk. (Ed.). Prosiding Pertemuan Ilmiah Nasional Tahunan VIII ISOI 2011, Hotel Sahaid Jaya, Makassar, 25--27 September 2011: 130–139.

Widiarti, R. and Pudjiarto, R.K. 2015. Dinoflagellata Toksik Penyebab Ciguatera Fish Poisoning di PerAyeran Pulau Tidung, Kepulauan Seribu. *Jurnal Ilmiah Ilmu Biologi, Bio Wallacea* **1**(1).

Widiarti, R. and Adi, A.P.W. 2016. The potentially toxic benthic dinoflagellate in Pahawang Besar dan Kelagian Kecil Islands, Lampung. *In* B. Nababan (Ed). Prosiding Pertemuan Ilmiah Nasional Tahunan ISOI XII. Ikatan Sarjana Oseanologi Indonesia, Banda Aceh, 10–12 December 2015. (in Indonesian)

Widiarti, R., Pudjiarto, R.K. and Pratama, I. 2016a. Potentially toxic benthic dinoflagellate in Gili Meno and Gili Ayer waters, Lombok. *In* A.D. Setyawan, Sugiyarto, A. Pitoyo, Widiastuti A. Sutomo and G. Windarsih (Eds.). Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia. Universitas Sebelas Maret, Surakarta, 7 November 2015. (in Indonesian)

Widiarti, R., Pudjiarto, R.K., Fathoniah, I., Adi, A.P.W. 2016b. Epiphytic dinoflagellate on macroalgae which potentially cause Ciguatera Fish Poisoning in Weh Island waters, Aceh. *In* A.D. Setyawan, Sugiyarto, A. Pitoyo, Widiastuti A. Sutomo and G. Windarsih (Eds.). Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia 2 (1). Universitas Sebelas Maret, Surakarta, 23 April 2016. (in Indonesian)

Xu, Y., He, X., Lee, W.H., Chan, L.L., Lu, D., Wang, P., Tao, X., Li, H. and Yu, K., 2021. Ciguatoxin-producing dinoflagellate *Gambierdiscus* in the Beibu Gulf: First report of toxic *Gambierdiscus* in Chinese waters. *Toxins* **13**: 643.

Zhang, H., Li, Y., Cen, J., Wang, H., Cui, L., Dong, Y. and Lu, S. 2015. Morphotypes of *Prorocentrum lima* (Dinophyceae) from Hainan Island, South China Sea: Morphological and molecular characterization. *Phycology* **54**: 503–516.

Appendix 1
Project Principles

1. The overall goal of the project entitled "*Building local warning networks for the detection and human dimension of Ciguatera Fish Poisoning in Indonesian communities*", funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), is to build the capacity of local small-scale fishers and community members to monitor their coastal ecosystems and coastal fisheries to benefit human health in Pacific Rim developing countries. The focus of this project is to detect and monitor *Ciguatera Fish Poisoning* (CFP) in tropical reef fisheries, which globally has the greatest human health and economic impacts of any algal-based poisoning syndromes. The aim of the project is to adapt smartphone-based observation tools developed in the 2017–2020 PICES-MAFF project on "*Building capacity for coastal monitoring by local small-scale fishers*" (FishGIS) to empower Indonesian coastal communities to assess, detect, and minimize their exposure to CFP in community-scale fisheries. The project also is intended to foster partnerships with non-PICES member countries and related international programs and organizations. The MAFF contribution is from the Official Development Assistance (ODA) Fund and therefore, involvement of developing countries in project activities is required.

2. The duration of the project is 3 years, with the ending date set as March 31, 2023.

3. The following organizational principles agreed to by MAFF/JFA and PICES apply to the project:

   - The project will have strong connections and interactions with, and support relevant activities of, the PICES Scientific Committees on Human Dimensions (HD), Marine Environmental Quality (MEQ) (through the Section on *Ecology of Harmful Algal Blooms in the North Pacific* – S-HAB) and Fishery Science (FIS), PICES Technical Committees on Data Exchange (TCODE) and on Monitoring (MONITOR), and the PICES FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) science program (specifically, Research Theme 3 on "*How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?*"). The HD Committee will serve as the parent committee for the project.
   - The project will be directed by a Project Science Team (PST) formed based on principles and procedures detailed in the PICES Policy for approval and management of special projects (Decision 2017/A/7). All the above-mentioned groups and all PICES member countries are expected to be represented on PST.
   - The PST will be co-chaired by PICES members, with one Co-Chair from Japan, representing the Human Dimensions Committee, and the other from the USA, representing the Section on *Ecology of Harmful Algal Blooms in the North Pacific*. These Co-Chairs will provide the geographical balance and the balance of expertise between the human dimension and harmful algal bloom components of the project. The PST Co-Chairs are responsible for the scientific implementation of the project and annual reporting to MAFF/JFA and to PICES Science Board

through the HD Committee. This report should be submitted to JFA within 90 days after the close of each project year ending March 31, and include a summary of the activities carried out for the year, with an evaluation on the progress made, and a workplan for the following year.

4. The following financial principles agreed to by MAFF/JFA and PICES apply to the project:
   - A separate bank account shall be established to deposit the remitted funds.
   - The PICES Executive Secretary or a Project Coordinator designated by the Executive Secretary is responsible for the management of the fund and for the annual reporting on its disposition to MAFF/JFA and PICES Governing Council, through the Finance and Administration Committee, within 90 days after the close of each project year ending March 31.
   - The main elements of the budget are organized into the following categories:
     - Travel and meetings – this category covers travel costs associated with project activities such as field studies, organizational trips, project meetings, workshops, scientific sessions and public events.
     - Contracts – this category covers grants/fees to be paid to consultants and experts employed to implement the project. Tasks and deliverables for contractors are to be determined by the PST Co-Chairs. To support the objectives of the project and to ensure that its activities have minimal impact on the workload of the existing staff of the PICES Secretariat, the Project Coordinator can employ additional staff as required.
     - Publications – this category covers costs associated with publishing findings of the project in special issues of peer-reviewed journals, reports and brochures, and dissemination of these materials.
     - Equipment – this category covers purchases and shipment of equipment for laboratory/field data/sampling processing/analysis, computer hardware/software for the development of database(s) and the project website.
     - Miscellaneous – this category covers expenses associated with the project (mail and phone charges, bank charges, *etc*.) and includes contingencies such as fluctuations in currency exchange rates.
   - Transfers of up to 10% of allocations between the budget categories are allowed based solely on the decision by the PICES Executive Secretary or the Project Coordinator. In special cases, transfers up to 20% between the budget categories can be authorized by JFA. All transfers shall be reported at the end of the fiscal year.
   - A 13% overhead on the annual budget shall be retained by PICES to offset expenses related to the Secretariat's involvement in the project.
   - The interest earned by the fund shall be credited to the project and used in consultation with JFA.
   - Any funds remaining after the completion of every fiscal year of the project shall be reported and disposed of in consultation with JFA.

5. Ownership of the outcomes of the project, including materials, data, copyright and intellectual property rights, will be vested to PICES and the Government of Japan. Either Party may use those outcomes, but will give full credit to their source.

Appendix 2
Project Science Team Members

Daisuke Ambe
(*representing TCODE*)
Fisheries Research and Education Agency
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa, 236-8648
Japan
E-mail: ambe@affrc.go.jp

Seung Ho Baek
South Sea Research Institute
Korea Institute of Ocean Science and Technology
41 Jangmok-1-gil, Jangmok-myon
Geoje, 5320
Republic of Korea
E-mail: baeksh@kiost.ac.kr

Vladimir Kulik
(*representing MONITOR*)
Pacific Branch of VNIRO ("TINRO")
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690091
Russia
Email: vladimir.kulik@tinro-center.ru

Mitsutaku Makino
Project Science Team Co-Chair
(*representing HD*)
Atmosphere and Ocean Research Institute
The University of Tokyo
5-1-5, Kashiwanoha, Kashiwa-shi
Chiba, 277-8564
Japan
E-mail: mmakino@aori.u-tokyo.ac.jp

Shion Takemura
(*representing HD*)
Japan Fisheries Research and Education Agency
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa, 236-8648
Japan
E-mail: shiontakemura@affrc.go.jp

Naoki Tojo
(*representing FIS*)
Faculty of Fisheries Sciences
Hokkaido University
3-1-1, Minato-cho
Hakodate, 041-8611
Japan
E-mail: n.tojo.raven@fish.hokudai.ac.jp

Vera L. Trainer
(*representing MEQ*)
University of Washington
Olympic Natural Resources Center
1455 S Forks Ave.
Forks, WA 9833
USA
E-mail: verat@uw.edu

Charles Trick
(*representing MEQ*)
Institute for Inclusive Health and Well-Being
University of Toronto
1265 Military Trail
Toronto, ON, M1C 1A4
Canada
E-mail: charles.trick@utoronto.ca

Pengbin Wang
Second Institute of Oceanography
Ministry of Natural Resources
36 Baochubei Rd.
Hangzhou, Zhejiang, 310012
People's Republic of China
E-mail: algae@sio.org.cn

Mark Wells
Project Science Team Co-Chair
(*representing MEQ*)
School of Marine Sciences
University of Maine
5741 Libby Hall
Orono, ME 04469
USA
E-mail: mlwells@maine.edu

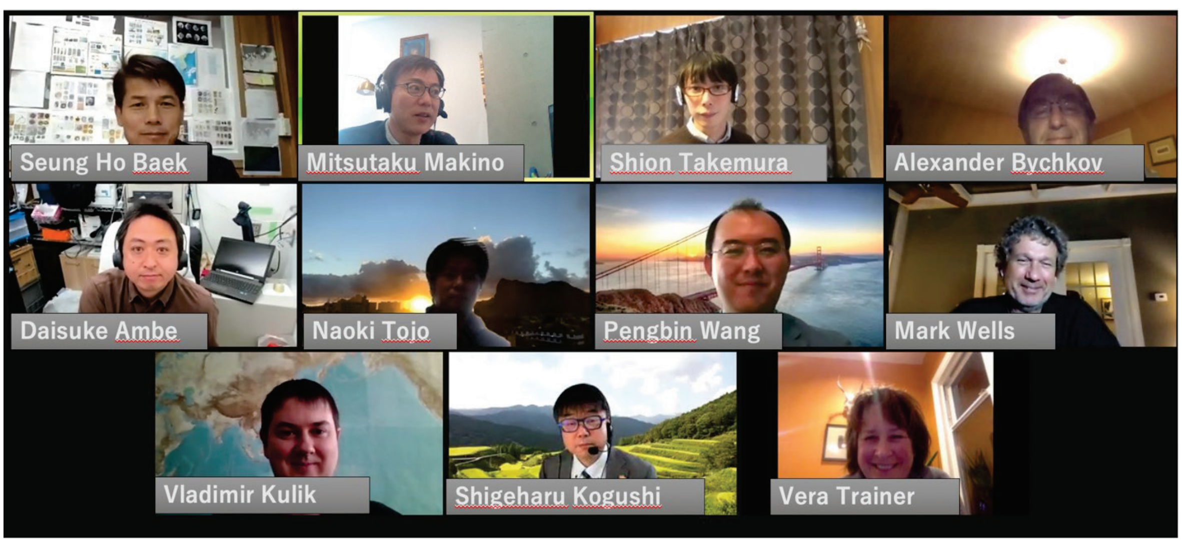
Alexander Bychkov
ex-officio
PICES Secretariat
P.O. Box 6000
Sidney, BC, V8L 4B2
Canada
E-mail: bychkov@pices.int

Appendix 3.1
First Virtual Meeting of the Project Science Team
March 9/10, 2021

The first virtual meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" (hereinafter referred to as Ciguatera) funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held via Zoom videoconference from 16:00–19:00 Pacific Daylight Time on March 9, 2021 (March 10, 2021 in the Western Pacific).

1. WELCOME REMARKS, INTRODUCTIONS AND ADOPTION OF THE AGENDA

The meeting was chaired by Dr. Mitsutaku Makino who called the meeting to order. Dr. Shion Takemura led the introductions of the attendees (*Appendix 1*). The provisional agenda circulated prior to the meeting was adopted without changes and can be found in *Appendix 2*. Dr. Mark Wells served as the rapporteur.



Ciguatera project meeting participants at their first virtual meeting on March 9/10, 2021. Charles Trick missing from photo.

2. SUMMARY OF THE PROJECT

Dr. Makino gave a detailed background to the project beginning with a summary of the previous PICES-MAFF project on "*Building capacity for coastal monitoring by local small-scale fishers*" (FishGIS) to set the stage. This included the basis for capacity building using mobile phones, a review of the current capabilities, and the emphasis of transdisciplinary work and co-design of the project with local communities. He then transitioned into the new project plans, providing a detailed overview of the current project design.

3. REVIEW OF CIGUATERA FISH POISONING

Dr. Pengbin Wang has considerable experience working with *Gambierdiscus* species, and he provided the team with a broad background summary of the dinoflagellate and the known/perceived climate effects on Ciguatera Fish Poisoning (CFP), and harmful algal blooms (HABs) in general.

4. REVIEW OF ORIGINAL WORKPLAN FOR YEAR 1

A summary of the underlying reasons for the workplan was presented by Dr. Mark Wells and discussed by the PST:

- CFP is the greatest HAB problem on Earth… causing substantial health, economic, sociological problems in tropical and subtropical nations.
- CFP is exacerbated by damage to coral reef environments, through either direct human activities or indirectly though climate change stressors.
- Climate change is leading to the expansion of subtropical gyres/environments, increasing the potential range of *Gambierdiscus* species.
- We are beginning to see increases in benthic dinoflagellates, including *Gambierdiscus* in other regions where it is monitored.
- These increases lead to greater bioaccumulation in fish that, in turn, lead to problems for local communities depending on the fisheries for food, and for larger-scale operations transferring fish internationally.

The strategy of the project is to **Assess**, **Detect** and **Avoid** the transfer of contaminated fish to the tables in local communities.

General comments:

- Need to keep in mind the cost in time (fishers cannot lose more than 6 days per year), so engaging them on a volunteer basis must not require lengthy commitments.
- Must realize that fishers have a limited ability to move their fishing grounds. Thus, if CFP is detected in one region, we need to consider how that knowledge should be dealt with.
- Countering this, Ciguatera-free fish may be worth more at the market, so greater distances and lower catch may still be sustainable.
- Need to consider the broader aspects. For example, develop a model case of how they might respond to different types of events.

5. REVIEW OF THE BUDGET STEPS

Dr. Alexander Bychkov provided a detailed summary of the evolution of the project budget with 3 consecutive versions as the extent of the COVID-19 pandemic became clearer—moving funds from travel to equipment and workshop costs, with some carryover to Year 2, with permission of MAFF.

6. CURRENT STATE OF THE FISHGIS APPLICATION

Dr. Takemura gave a summary of the current status of the FishGIS application and the updates to iOS 12 and Android 5.1 or later.

- Currently collected data are uploaded to the cloud server established in Indonesia and then transferred immediately to Japan for processing. This architecture solves the data sharing issues.
- There was some discussion about the logo for the application. It was decided to put FishGIS at the top and move logos of the funding sources to bottom of the screen.
- It was suggested to have a welcome screen without logos, and to not make the logo's hyperlinks, as this increases the number of things on the screen to hit in error.
- There also was discussion about the button to add leading to information about CFP as well as whether to include a map of the region.

7. WORKPLAN FOR YEAR 2

Due to lack of time, the workplan for Year 2 was not discussed. However, one consideration brought up before the meeting was closed was the need to consider paying individuals to collect the data. This approach may be problematic for sustainability after the project ends, but would simplify the need to meet data depth expectations of MAFF.

Appendix 1

First Project Science Team meeting participants

<u>Members</u>

Daisuke Ambe (Japan, representing TCODE)
Seung Ho Baek (Korea)
Alexander Bychkov (PICES, *ex officio*)
Vladimir Kulik (Russia, representing MONITOR)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Shion Takemura (Japan, representing HD)
Naoki Tojo (Japan, representing FIS)
Vera Trainer (USA, representing MEQ)
Charles Trick (Canada, representing MEQ)
Pengbin Wang (China)
Mark Wells (Co-Chair; USA, representing MEQ)

<u>Other</u>

Shigeharu Kogushi (GFL, Japan)

Appendix 2

First Project Science Team meeting agenda

Tuesday, March 9, 2021 (PDT)

1. Welcome remarks, introductions and adoption of the agenda
2. Summary of the project: general framework, objectives and deliverables (Makino)
3. Review of Ciguatera Fish Poisoning (CFP)
4. Review of the original workplan for Year 1
5. Review of the budget steps
6. Current state of the FishGIS application
7. Workplan for Year 2: Outstanding questions, planning for a virtual meeting with Indonesian partners

Appendix 3.2
Second Virtual Meeting of the Project Science Team
July 13/14, 2021

The second virtual meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" (hereinafter referred to as Ciguatera) funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held via Zoom videoconference from 15:00 to 17:00 Pacific Daylight Time on July 12, 2021 (July 13, 2021 in the Western Pacific).

1. WELCOME REMARKS, INTRODUCTIONS AND ADOPTION OF THE AGENDA

The meeting was chaired by Dr. Mitsutaku Makino who also led the introductions of the attendees (see *Appendix 1*). The provisional agenda circulated prior to the meeting was adopted, with the modification that former item 5 (Modifications to the project workplan – suggestions from Indonesian colleagues) be moved up to become item 3 (see *Appendix 2*). Dr. Mark Wells served as the rapporteur.

Ciguatera project meeting participants at their second virtual meeting on July 13/14, 2021. Top, left to right: Alexander Bychkov, Mitsutaku Makino and Mark Wells; Middle, left to right: Vladimir Kulik, Diasuke Ambe and Naoki Tojo; Bottom, left to right: Suhendar I Sachoemar, Arief Rachman and Charles Trick. Pengbin Wang missing from photo.

2. SUMMARY OF ACTIVITIES SINCE THE 2020 PICES ANNUAL MEETING (PICES-2020)

Dr. Makino gave a brief presentation of past PICES-MAFF projects, including the projects on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" (2007–2012), "*Marine ecosystem health and human well-being*" (2012–2017; MarWeB) and "*Building capacity for coastal monitoring by local small-scale fishers*" (2017–2020; FishGIS), and ending with the current Ciguatera project. He emphasized the transdisciplinary approach we have taken of co-design, co-production, and co-delivery with the local people, researchers and government. The current FishGIS application design and operation was reviewed and presented as the foundation for the Ciguatera project.

The overall goal for the project—To build the capacity of local small-scale fishers and community members to monitor their coastal ecosystems and fisheries—was revisited, along with the general strategy to **Assess** the state of local ecosystems, to **Detect** the presence of HAB species, and to **Avoid** the transfer of contaminated seafood to the tables of families.

Given the impact that the COVID-19 pandemic has had on the ability to travel and work in communities, project activities since PICES-2020 have been restricted to modifications of the FishGIS application. Dr. Shion Takemura is leading that effort but was unable to attend the meeting. He nevertheless provided the following information:

a) Support for Operating System (OS) updates by Apple and Google
   - The application will be modified to allow for flexibility in responding to OS updates by Apple and Google.
   - Android 5.1 and iOS 12 or later devices will be supported.

b) Compliance with ABS (Nagoya Protocol on **A**ccess and **B**enefit **S**haring)
   - For the completed FishGIS project, all reported data has been stored on the Japanese server.
   - For the Ciguatera project, reported data will be stored on a server in Indonesia (provided by Google) and then transferred to a server in Japan in real time.

c) Update to the Ciguatera project
   - A function has been added to map Ciguatera's findings.

3. MODIFICATIONS TO THE PROJECT WORKPLAN – SUGGESTIONS FROM INDONESIAN COLLEAGUES

Dr. Suhendar I Sachoemar and Mr. Arief Rachman had submitted a number of suggestions for modifications to the project plan in order to maintain project momentum during the pandemic.

For the **Assess** component, they suggest studying the data and information or reports on research activities that have been carried out by their colleagues in the Kepulauan Seribu (Seribu Islands), Jakarta Bay, Banten Bay and Pelabuhan Ratu or Hurun Bay at Lampung (South Sumatera) to determine additional potential locations for project activities. They will try to pull all these data together from the regions to allow the PST working on a publication of *Gambierdiscus* distribution in Indonesian waters. There was some discussion about how much funding is needed for this effort, which they will look into. It is possible that we might use a portion of the funds already transferred to Indonesia in Year 1.

In terms of **Detect**ion, some of their colleagues have been trained to use the Ciguatera Fish Poisoning (CFP) detection kit produced by the international CFP working group (Monaco, 2018), and may already have some data on the presence of *Gambierdiscus* in the water column and its abundance in other regions (*e.g*., Kepulauan Seribu (Seribu Island), Jakarta Bay, Banten Bay and Pelabuhan Ratu or other waters previously surveyed like Hurun Bay at Lampung (South Sumatera)).

In terms of **<u>Avoid</u>**ance of eating risky fish, there was some discussion about the potential for on-line training (also for the sampling/analyses aspects of the project). The PST recognized that it may be difficult to achieve the project outcomes this way, but we were generally open to the idea of considering this option. Developing on-line training modules may help to increase the sustainability of the program after the project finishes. However, the consensus was to wait and see whether it will be possible to do in-person training in early 2022.

4. BUDGET SITUATION OF FY 2020 AND FY 2021

Dr. Alexander Bychkov gave a summary of the budget status. The PST is waiting to learn if we are able to keep and use the carryover portion of Year 1 budget. The extra funds would go towards travel as appropriate. This would be convenient given that the cost of travel has grown substantially as a consequence of the pandemic.

5. PROJECT DESIGN MATRIX

Dr. Naoki Tojo presented the Project Design Matrix (PDM) that he and Dr. Takemura have been developing with input from the PST since the first meeting. The PDM provides an overall framework of the project and serves also as a tool for evaluating its progress. Each of the categories in the PDM in turn are to have a Plan of Operation (PO) with specific activities. These PO are based on:

- Obtaining insights to the on-site situation in Indonesia from Dr. Sachoemar and Mr. Rachman.
- Aligning plans of the Indonesian counterparts participating in the project with the overall framework.
- Listing and sharing the key hypothesis by PICES experts with the Indonesian counterparts to help design and maintain the surveys and monitoring activities.
- Listing specific needed inputs with consensus by the decision makers.
- Especially important, confirming all efforts/outcomes by PICES experts for not only their own studies but also the contributions for Indonesian locals (capacity development and international cooperation).

Although the current project plans account for many of these aspects, the great benefit of the PDM is that it provides a detailed framework on which to chart progress. Dr. Tojo's suggestion was to consider the insights provided by Dr. Sachoemar and Mr. Rachman at the meeting, and to then focus on developing the key hypotheses, specifying the list of inputs, and to develop the management model and dissemination flow of research findings and the transfer of technologies.

This was the initial presentation of the PDM and PO to the group, and Dr. Tojo made a compelling argument that this shift in our organizational approach was needed to provide a better overview of the project components and intended outcomes, even if it does not result in altering our immediate project plans. The key will be to have multiple options so that PST can be adaptable as conditions change.

The approach discussed is to build capacities through co-working with the local people, researchers and government in Indonesia and through the available dissemination system, with direct communication to local stakeholders. For the project activities:

- Members of the target organization will be trained in the scientific/technical fields;
- PICES and Indonesian experts will enhance capacity of local disseminating personnel (young/assistant officers);
- Locals will have guidance from the officers and occasionally from PICES experts;

- Locals and the community officer will be encouraged as a group to attend the seminars and report their contributions (*e.g*., photos).

Dr. Tojo raised the possibility of bringing Indonesian community leaders to Japan to observe how similar cooperatives are working, and their benefits for the stakeholders.

Dr. Sachoemar felt there was great support in Indonesia for the project and expressed his willingness to undertake the necessary tasks outlined in the PDM, but he will need to evaluate what is possible given the current pandemic conditions. Mr. Rachman also was in full agreement that a PO is needed and has to be established soon to help the Indonesian counterparts start developing a strategy from their side. Dr. Tojo will begin with a draft PO to share with the team that incorporates Dr. Sachoemar's and Mr. Rachman's suggestions for how we might progress under continued pandemic conditions.

6. OTHER BUSINESS

Mr. Rachman noted that CFP is not yet a major problem in Indonesia, and that there are more problems from other HAB species. HAB species have become one of the major research directions in the Federal research budget, and with the drive to increase mariculture production there is strong support for all HAB research in Indonesia. Dr. Pengbin Wang is involved in a new project that includes Indonesia, and he will look at what linkages make sense and perhaps incorporate them in the PDM.

Dr. Charles Trick brought up the issue of research ethics and the need to evaluate how we may get approval for the research. This will include approval from the community members to conduct the study. He will look into how we should proceed about getting this ethics approval to protect the community members and enable the research findings to be published. We also will need to have agreement on responsibilities and expectations of community members participating in the project (essentially, they sign onto the PDM).

The final task was to decide the next meeting near the end of August to maintain momentum in the planning. In the meantime, we will work offline though email to refine the PDM and PO to be finalized by the next meeting.

Appendix 1

Second Project Science Team meeting participants

<u>Members</u>

Daisuke Ambe (Japan, representing TCODE)
Alexander Bychkov (PICES, *ex officio*)
Vladimir Kulik (Russia, representing MONITOR)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Naoki Tojo (Japan, representing FIS)
Charles Trick (Canada, representing MEQ)
Pengbin Wang (China)
Mark Wells (Co-Chair; USA, representing MEQ)

<u>Other</u>

Arief Rachman (LIPI, Indonesia)
Suhendar I Sachoemar (BPPT, Indonesia)

Appendix 2

Second Project Science Team meeting agenda

Monday, July 12, 2021 (PDT)

1. Welcome remarks, introductions and adoption of agenda
2. Brief summary of activities since the 2020 PICES Annual Meeting
3. Modifications to the project workplan – suggestions from Indonesian colleagues
4. Budget situation of FY 2020 and FY 2021
5. Project Design Matrix
6. Other business

Appendix 3.3
Third Virtual Meeting of the Project Science Team
August 30/31, 2021

The third virtual meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" (hereinafter referred to as Ciguatera) funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held via Zoom videoconference from 16:00–18:00 Pacific Daylight Time on August 30, 2021 (August 31, 2021 in the Western Pacific).

1. WELCOME, INTRODUCTIONS AND ADOPTION OF THE AGENDA

The meeting was chaired by Dr. Mitsutaku Makino who called the meeting to order. Following introductions, the attendees reviewed and adopted the provisional agenda circulated prior to the meeting (*Appendices 1* and *2*). Dr. Mark Wells served as the rapporteur.

Ciguatera project meeting participants at their third virtual meeting on August 30/31, 2021. Seung Ho Baek and Vladimir Kulik missing from photo.

2. RECAP FROM THE SECOND VIRTUAL PST MEETING

Dr. Makino conducted a brief recap of the second PST meeting held virtually on July 13, 2021 Pacific Daylight Time (July 14 in the Western Pacific), including a summary of the project, highlighting the progress, and lack of progress, under pandemic conditions. The main point was that the PST might have to reconsider its original plan and reorganize it according the COVID-19 situation. He emphasised the approach using the Project Design Matrix (PDM) and Plan of Operation (PO) as a way forward.

3. UPDATE ON RESEARCH ETHICS ISSUES

Dr. Charles Trick informed members that you cannot publish health studies without an ethics review, though was not sure that we needed one based on our general plan. An ethics review would slow progress, but it would be a great opportunity for the PST to understand why we are doing all the steps in the project. There are two types of community projects: a community-engaged research project (which needs an ethics approval) or community-service research project (which may or may not need ethics approval). While the Guatemala component in the previous PICES-MAFF MarWeB project was more like the first, the Ciguatera project seems more like the second, so it may not require an ethics approval. These deal with commitments of scientists and community in terms of research—the PST is not sure at this point what tack to take and will need to look into this more.

Dr. Suhendar I Sachoemar pointed out that there are ethics codes for engineering in Indonesia, and maybe for other disciplines. He has found a document describing ethical requirements for Indonesian studies (in Bahasa) and will have a translation made for the PST.

The PST should also consider having a Memorandum of Understanding that the ethical standard of the Ciguatera project is acceptable to Indonesia. An ethics review is only required for research on the health of people (*e.g*., drug trials) in Indonesia (Ministry of Health), but if we just collect information from people, then it is not certain if ethical clearance is needed. Dr. Sachoemar and Mr. Arief Rachman will consult with BPPT and LIPI experts. The participants noted that an ethics review was not required in the past with respect to HAB studies. All they needed was permission from local government for survey work (*i.e*., what they were doing and what were they going to do with these data). It was pointed out that for the international project, the PST should ensure that the highest level of standards is followed. We can add steps to a plan approved by the University of Toronto (for example) without having to go through the review again.

There has been a recent reorganization of many Indonesian research agencies to put them under 3 or 4 umbrella organizations, so things may be a bit different from in the past. Dr. Tojo emphasized that we need to meet the "formal" ethical requirements, but it is very important that we remember that the "community" ethical requirements are just as important, even if they not are "needed" in the formal review.

Dr. Vera Trainer commented on the importance of getting community involvement. Is it different if we ask open ended questions *vs*. specific questions? It was agreed that the project would be strengthened by asking open-ended questions, and these will result in different sorts of conversations.

Dr. Trick pointed out that we probably do not need a survey to conduct the work—there is no direct connection between what we are doing and health, other than our faith that we are adding useful information for the community. If clickers are used, we can get information in a conversational way rather than getting specific data (Do not ask "how much fish do you eat?", but "why do not you eat more fish?").

Dr. Shion Takemura indicated that in agreement with ABS (Nagoya Protocol on Access to Genetic Resources and Benefit Sharing) for the Ciguatera project, data are going onto a Google server in Indonesia and then transferred to a server in Japan—this does not violate ethical rules, at least for Indonesia. Dr. Daisuke Ambe commented that the project seems to be ok in the strategy with respect to data access.

It was agreed that Dr. Trick will take the lead on writing an "informal" ethics plan which will be reviewed by a colleague at the University of Toronto (or contract with a company) to get an assessment of whether a full ethical approval should be sought.

4. UPDATE FROM INDONESIA

a) <u>COVID-19 situation</u>

Dr. Sachoemar reported that COVID-19 cases have been dropping in Indonesia as have hospitalizations. Government has secured 200 million doses of vaccine and is targeting 100 million vaccinations by the end of the year. More than 96 million people have had their first dose at this point. All government officers are vaccinated. Students went back to school on August 30. Gradually conditions are getting better, but borders within Indonesia are restricted. The current vaccination rate is high and very good in Jakarta, but has not progressed as well in outlying areas—difficulties in getting vaccines dispersed. The Pandemic Lockdown has four levels in Indonesia; Jakarta is now at level 3—you can travel to other regions if you show evidence of vaccination. Bali is still at Level 4 (high levels of infection), and conditions in Lombok are not known. Indonesians who travel internationally have to quarantine for 1 week, but Dr. Sachoemar did not know whether foreign travellers are allowed into Indonesia yet.

In terms of fishing communities, Mr. Rachman stated that although there are fewer fishers going out because of less demand, and the economy is in a slump, COVID-19 is not stopping them from fishing.

The general hope is that things will be closer to normal by the end of 2021, and there may be some possibility for PST members to travel to Indonesia early next year.

b) <u>Benthic HAB findings</u>

Dr. Sachoemar and Mr. Rachman provided an update on progress being made using existing data on benthic HABs (bHABs) to generate a publication. They compared data on phytoplankton community structure in Jakarta Bay and Pelabuha Ratu and found *Gambierdiscus toxicus* and other bHAB species in the Jakarta Bay water column as well as in Pelabuhan Ratu. This suggests that populations of *Gambierdiscus* and other bHAB species are present in benthic environments in these regions.

Mr. Rachman gave a summary of Pari Islands (Jakarta Bay) sampled seagrass and sandy bottom. A few corals were observed in 2013, but no coral was left (just sandy bottom) in 2019. A standardized screen was used in 2013 and 2019, but they also collected samples from substrates. In 2013, findings included *Prorocentrum* (most abundant), *Gambierdiscus* (sporadic distribution), and *Ostreopsis* (always found in macroalgae, but not always on other substrates). Cell concentrations were much higher (10×) in 2019, particularly in the seagrass beds. This change seems to coincide with a new luxury hotel that has been built on Pulau Tengah. The obvious question is whether this development is related to the increase in *Gambierdiscus*. The island and bay were mainly deserted before the resort was developed, which also has generated a lot of support infrastructure. There are water quality data from 2013, but not most recently. Mr. Rachman has a good contact (Dr. Riani Widart) at the University of Indonesia who has been doing work on bHABs over the last decade. It would be a good idea to get her involved in the project. Researchers are starting back into the field now, but travel to far islands still requires COVID tests, if staying. Questions were raised about linkages with climate change—was there a wider range of sampling sites that could rule out a broader general increase of *Gambierdiscus* in the region? Mr. Rachman said no, they only had the samples from the lagoon region. Asked for more details (*e.g*., same persons doing the sampling, cell counts, and are the methods accepted?), Mr. Rachman explained the methods in detail (which are established methods) and confirmed that he personally had done the species counts and identifications (*i.e*., there is no "sampler" bias in the findings).

5. PROJECT DESIGN MATRIX AND PLAN OF OPERATION

Due to a shortage of time, Dr. Takemura gave only a brief summary of the Project Design Matrix (PDM) "logical framework". He reviewed the relationship between the PDM and the specific Plan of Operation (PO), which covers the actual planned activities. There were 5 steps to developing the PDM and PO: (1) gather thoughts about CFP issues (from PST members and Dr. Sachoemar and Mr. Rachman), (2) address grouping and structuring CFP issues, (3) obtain Objective and Problem Tree, (4) identify goals, purpose, output and activities (PDM), and (5) identify detailed research activities (PO).

6. CLOSING

Dr. Makino closed the meeting with a discussion about the next step. It was agreed that the next virtual PST meeting would be scheduled during the week of September 13 and would be devoted to discussion of the PDM and PO. Dr. Tojo emphasized that the goal will not be to develop a rigid plan, but to think more about using it as a chance to make sure we all are on the same page with expectations. In particular, we all need to consider the expected inputs from the PST and from our Indonesian colleagues. This way, through discussion, we can come to a general consensus of what the project will comprise, and what the expected outcomes will be. Dr. Takemura offered to take on the responsibility for sending out a doodle poll to schedule the next meeting.

Appendix 1

Third Project Science Team meeting participants

<u>Members</u>

Daisuke Ambe (Japan, representing TCODE)
Seung Ho Baek (Korea)
Alexander Bychkov (PICES, *ex officio*)
Vladimir Kulik (Russia, representing MONITOR)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Shion Takemura (Japan, representing HD)
Naoki Tojo (Japan, representing FIS)
Vera Trainer (USA, representing MEQ)
Charles Trick (Canada, representing MEQ)
Pengbin Wang (China)
Mark Wells (Co-Chair; USA, representing MEQ)

<u>Other</u>

Arief Rachman (LIPI, Indonesia)
Suhendar I Sachoemar (BPPT, Indonesia)

Appendix 2

Third Project Science Team meeting agenda

Monday, August 30, 2021 (PDT)

1. Welcome, introductions and adoption of the agenda
2. Recap from the second virtual PST meeting
3. Update on research ethic issues
4. Update from Indonesia
   a) COVID-19 situation
   b) Benthic HAB findings
5. Project Design Matrix and Plan of Operation
6. Closing

Appendix 3.4
Fourth Virtual Meeting of the Project Science Team
September 15/16, 2021

The fourth virtual meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" (hereinafter referred to as Ciguatera) funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held via Zoom videoconference from 16:00–18:00 Pacific Daylight Time on September 15, 2021 (September 16, 2021 in the Western Pacific).

1. WELCOME AND ADOPTION OF AGENDA

The meeting was opened with welcoming remarks to participants and brief comments on the purpose of the meeting (to collectively review the Project Design Matrix (PDM)) by Dr. Mitsutaku Makino, and adoption of the agenda (*Appendices 1* and *2*).

2. REVIEW OF PROJECT DESIGN MATRIX

Dr. Mark Wells led the discussion phase as PST members worked through each section (Overall Goal, Project Purpose, Outputs, and Activities) of the PDM.

The tasks were to review each item in terms of: a) the original plan, and b) revising or limiting the plan due to the COVID-19 situation. Where needed, modifications to the text of the PDM were made as follows. While the majority of the PDM was considered to not need revision, the following changes and additions were made (see also *Appendix 3*).

"Output" section

- Objectively Verifiable Indicators column:
  Item number 1-4 should be modified to read: "At least, informed scientific knowledge is considered with the inclusion of shared local knowledge."
- Objectively Verifiable Indicators column:
  Item number 1-6 should be added: "Scientific information from hypothesis testing are shared with at least one community or stakeholder group by available alternatives for dissemination (*e.g.*, presentations, participatory experiments, and other media)."
- Narrative Summary column:
  As for item number 2, general information about health-related situations (such as occurrence of HAB incidents) can be gathered by local government officials or researchers. Dr. Suhendar I Sachoemar also pointed out the importance of the traceability analysis.

“Activities” section

- Narrative Summary column:
  With respect to item number 1-4, several research hypotheses were discussed, including inputs from Mr. Arief Rachman (*e.g*., relationship between coral reef degradation and bHAB composition). Dr. Naoki Tojo suggested studying relationships between fish stomach contents and Ciguatera Fish Poisoning (CFP). With consideration to the diminishing available time, it was decided that PST members should give greater attention to effective guiding hypotheses after the meeting.
- Narrative Summary column:
  Item number 2-1 should be re-written, replacing “Suggest specific alternatives for local fishermen to sell fishes with reduced CFP risks” with “Describe the distribution of CFP risk along supply chains.” Dr. Sachoemar noted there were some research projects in Indonesia in 2002–2009 dealing with supply chains, and this would be useful information for us to consider.
- The activities 2-1 and 2-2 will be generally difficult but discussions with local community members may offer avenues for progress.

“Input” section

- Given the impact COVID-19 has had on our ability to conduct the “on the ground” aspects of the project, it was suggested that we may have to shift much of our focus to “Detection and Monitoring”, fisheries information, and to the social surveys that give insight to the current status and state of understanding of CFP and other benthic HABs (bHABs).

3. NEXT STEPS

Dr. Wells presented 4 points/activities to be undertaken during the project period (until March 2023). Based on comments from PST members, the texts were brushed up (*e.g*., importance of weather/environmental information), followed by discussion about how to approach these tasks.

1. Data inputs on the presence/absence and distribution of bHAB (*Gambierdiscus*, but maybe including other species presented at the previous meeting as well). Include weather aspects and broader environmental data. These data can be collected from either our original large site (Gili Islands) or elsewhere.
2. Data inputs on fisheries – what species of reef fish, numbers caught, size, *etc*. (FishGIS).
3. Social surveys that provide the needed data/insights to fisheries impacts, or potential fisheries impacts from CFP or other bHABs. We can begin with the surveys developed for the FishGIS project, but what sites would make the most sense and are more feasible logistically? Use adaptive socio-economic survey methodology.
4. Disseminate information about coral reef degradation and CFP/bHABs (if we find low levels), or risk assessment based on early monitoring results.

The following central questions were posed by Dr. Wells with the discussion outcomes listed in italics:

1. MAFF wishes to see a minimum of 1000 data points added to the database by the end of the project. We will not reach this with volunteers only, based on experience in our previous project. Can we arrange to provide economic incentive to a subset of local fishers (20?) to:
   a) Deploy and retrieve the CFP sampling screens (from a buoy), and transfer the samples to a local LIPI representative?
   b) Use the FishGIS application to get water quality data?
   c) Use the FishGIS data to record their catch?

The expectation would be for a minimum of 4 samples a month for the last year of the project. Along with this question,

2. Do we need to purchase hardware (*e.g.*, phones) to enable the above? Would that, combined with pay, be enough incentive for fishers to participate? What is the best way to incentivize local fishers to participate and make reliable contribution of data?
   It was decided that we would pursue means to incentivize local people to collect data (target is more than 1000 data points). However, we need to pay close attention on how to do it (direct payment is not advised), and we will discuss the best way with Dr. Sachoemar and Mr. Rachman.
3. Do we need a research vessel (as listed), or will it be sufficient to use local fishers?
   Dr. Sachoemar and Mr. Rachman will consider this question.
4. Is BPPT willing, in collaboration with other agencies, to start outreach in the communities to provide background information about CFP and benthic HABs? If so, should we prepare a teaching module that BPPT staff and local agencies can use? (on-line module?)
   If the pandemic situation allows, we can conduct a questionnaire survey or other new methods (adaptive socio-economic survey methodology, as Dr. Tojo suggested). Local government officials can help us. Dr. Sachoemar will look into this question to find the right individuals (LIPI and BPPT and local government).
5. Will BPPT staff be able to conduct the socioeconomic surveys in the target communities? PICES would prepare a questionnaire (or more than one).
   BPPT is willing and will consider how to proceed if the pandemic allows.
6. What would the format be for the training components in Japan? Are there funds available in BPPT to partially support this training (*e.g.*, BPPT covers *per diem* and hotel, PICES covers all transportation)? Who would be sent (local BPPT or other agency staff, senior community members)?
   With time running out on the meeting, it was decided that we would consider this question at a future meeting.

Appendix 1

Fourth Project Science Team meeting participants

<u>Members</u>

Seung Ho Baek (Korea)
Vladimir Kulik (Russia, representing MONITOR)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Shion Takemura (Japan, representing HD)
Naoki Tojo (Japan, representing FIS)
Vera Trainer (USA, representing MEQ)
Charles Trick (Canada, representing MEQ)
Pengbin Wang (China)
Mark Wells (Co-Chair; USA, representing MEQ)

<u>Other</u>

Suhendar I Sachoemar (BPPT, Indonesia)

Appendix 2

Fourth Project Science Team meeting agenda

Wednesday, September 15, 2021 (PDT)

1. Welcome and adoption of agenda
2. Review of Project Design Matrix
   "Output" section
   "Activities" section
   "Input" section
3. Next steps

Appendix 3

Project Design Matrix
updated September 15/16, 2021

Project title: Building local warning networks for the detection and human dimension of Ciguatera Fish Poisoning (CFP) in Indonesian Communities
Project duration: April 2020 – March 2023
Target group: BADAN PENGKAJIAN DAN PENGKAJIAN DAN PENERAPAN TEKNOLOGI (BPPT), LEMBAGA ILMU PENGETAHUAN INDONESIA (LIPI) and coordinated organization for dissemination

Narrative summary	Objectively Verifiable Indicators (hereafter, OVI)	Means of Verification	Important Assumptions
Overall goal* *...3-5 years after the Project, monitored by post-project evaluation			
1. Consumers can purchase CFP-risk free fish products from the local community in Indonesia. 2. Socio-economics of coastal communities do not have to fully depend upon products with CFP risks. 3. Many coral bed declines are of interest and understood by local communities in developing nations, including Indonesia.	1. There is more than 1 product or 1 certificate based on the Project activities that can be provided to Indonesian supply chains with information of CFP control. 2. Half of members in target communities improved their socio-economic capacity (*e.g*. capital, income sources) based on efforts based on the technical transfers in the Project. 3a. A Coral ecosystem status is monitored using > 2 biological indicators at least once a season by locals with governmental instruction. 3b. > 2 International publications are published. 3c. > 100 local stakeholders continuously follow the official Social Networks after the termination of the Project.	1. Product or/and certificate with CFP control information. 2. Results of evaluation surveys with questionnaires for locals (Adequate questionnaires will be developed during the Project with observers). 3a. Survey reports by officers, submitted to Ministries. 3b. Publications with authors from Counter Parts (CPs). 3c. Followers of official SNS account (Official SNS should be established during the Project).	
Project purpose* *…evaluated at the Project termination			
Capacities of coastal communities of Indonesia are improved in sustainable manner with less uncertainties and risks from CFP and degradation of coral ecosystem.	1. > 100 of total local fishers participate in the annual meeting for technical transfer and information exchanges (= "general workshop"). 2. Total > 2 small workshops at target communities are held with representing locals (= "local workshop"). 3. More than half of government extension officers and community leaders who participate in general workshop are certificated by BPPT and PICES with more than 70 % of understanding in the technologies and necessary background knowledge (as a good status).	1. Lists of participants from general workshops and local workshops. 2. Certification officialized by BPPT training workshops with scores of exams. (The exam will be provided from PICES expert in the workshop.)	-

Output			
1. The <u>influence</u> of CFP upon <u>human dimensions</u> and <u>ecological</u> <u>sustainability</u> of coastal communities is explained based on specific <u>hypotheses tests.</u> "DETECT and ASSESS"	1-1. >2 scientific reports or other publications on CFP are publicized or presented with quantified impacts/influences (1 for HD, 1 for ecology/biology). 1-2. Test at least 1 hypothesis with available CFP related information. 1-3. The explanation (oral presentations, brochure, and/or other media) in the impacts/potential impacts of CFP are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-4. At least, informed scientific knowledge is considered with the inclusion of shared local knowledge. 1-5. >2 scientific reports or other publication in the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are publicized or presented in PICES (1 for HD, 1 for others. 1-6. Scientific information from hypothesis testing are shared with at least one community or stakeholder group by available alternatives for dissemination (*e.g.* presentations, participatory experiments, and other media).	1-1. Published scientific report/journal articles. 1-2. a. Official agenda with the title of presentations and supplemental brochures. b. Media provided by experts and partner organizations. 1-3. Presentation in the PICES annual meetings.	
2. Fish products distribution in the common supply chains in Indonesia with consideration in potential health risks from CFP. "AVOID"	2-1. >1 scientific reports or other publication in the potential health risks are publicized or presented. 2-2. > 1 model product with CFP controls are produced based on collected information in the Project. 2-3. An integrative warning system is suggested based on the collected information, chemical analyses, and regional oceanography. 2-4. Awareness of the stakeholders increases > 20% from the Project information and activities.	2-1a Published scientific report/journal articles. 2-1b Presentation in the PICES annual meetings. 2-2. Model product with certification and consumers Willingness to Pay (WTP) upon it in the regional markets in the official surveys. 2-3. Warning system with a Geographic Information System (GIS) platform. 2-4. Responses to questionnaires in general workshops and local workshops. (Adequate questionnaires will be developed during the Project with observers.)	
3. Sustainable monitoring continues after the termination of the project. + "POST PROJECT SUSTAINABILITY"	3.1. Members of partner organizations operate monitoring activities at least once a season. 3.2. Members of partner organizations publish the status report of monitoring activities at least once a year. 3.3. Members of partner organizations hold > 2 committee meeting with PICES experts for activities and self improvement in the topic in the Project. 3.4. Saving of actively involved stakeholders, who joined the monitoring >80% of fishing days, maintained or increased during the Project.	3.1. Extension officers report. 3.2. Status report with confirmation of supervisors. 3.3. Agenda and RD* from the meeting. 3.4. Responses to questionnaires in the first and final general workshops. (Adequate questionnaires will be developed during the Project with observers.) *...Record of Discussion	

Activities	Input		Preconditions
1-1. Carry out monitoring activities to obtain sufficient CFP-related data/information. 1-2. Test multiple hypotheses with the available CFP-related data/information. 1-3. Locate and synthesize statistics or reports in CFP impact in terms of human health. 1-4. Conduct background study in mechanisms of CFP issues with priorities with specific hypotheses.	***PICES and MAFF side:*** 1. PICES experts - Proposal(s) in the protocol and design for CFP survey - Smartphone-based monitoring/warning system (technologies, techniques and advice for application) - GIS and database techniques - Practical social mapping methods ("EZU" methodology) 2. Provide software and equipment - Photo-base sampling technologies, including new version of smartphone software (FishGIS) - Necessary survey devices including tablets and CFP survey toolkit 3. Training of Indonesian Counterpart Personnel in Japan Program(s) covering: - Photo-base sampling technologies - GIS and database techniques - Practical social mapping methods ("EZU" methodology) in Japanese fields and case studies - Fees for traveling of the program participants* 4. Costs - Costs for the general workshop* - Costs for community workshop* - Costs for equipment *...based on specific agreement with chief adviser through the Project coordinator of Japanese side	***Indonesian side:*** 1. Counterparts in the field of: - CFP and coral ecosystem survey and analysis - Fisheries Sciences (especially coastal resources) - Food sciences/human health - Socio-economic survey and analysis - IT - Technical dissemination and developmental education (*e.g.*, extension office) 2. Facilities and equipment - Meeting Spaces (Jakarta and Gili Islands) - Web server (BPPT) and the sufficient Internet connections - Fundamental laboratory spaces for on-site research activities - Research vessel and its fuel - CFP survey toolkit - Fundamental experimental equipment, - Part of tablets, cellphone and sim card for dissemination 3. Costs - Operation and maintenance of research vessel - Operation and maintenance of survey tools and devices - Personnel expenses of counterpart personnel - Agreed logistics for officers for workshops - Per-diem and other supports for despatched counterparts for the training program to Japan	Duties and responsibilities of BPPT and LIPI will not be changed.
2-1. Describe the presence of distribution of CFP risk along with supply chains. 2-2. Disseminate knowledge in CFP risks for Indonesian non-fisher stakeholders along supply chains.			
3-1. Visualize measures and the process of problem solving to counterparts of target organizations and local communities in the Project. 3-2. Monitor and provide technical assistance for financial and economic returns/uncertainties to participants (fishers) from the Project. 3-3. Suggest a management system for CFP risk warning with consideration in sustainability by Indonesian sectors. 3-4. Provide technical guidance to maximize the efficiency of fishing activities with CFP monitoring. 3-5. Provide opportunities to disseminate practical knowledge for target local community with consultation by PICES experts. 3-6. Follow data management with related policies in Indonesia.			

Appendix 4

Tentative Plan of Operation
as of September 15/16, 2021

Activities's term: PICES-MAFF Project (2020 2Q–2022 4Q); post-project evaluation (2023 1Q–2025 4Q)

			Activities			Schedule notes	Indonesian Experts	PICES Experts
INPUT	Experts (Short term)	1	CFP survey					
		2	Smartphone based monitoring & warning system					
		3	GIS and database techniques					
		4	Practical social mapping methods/ Socio-Economic Survey					
			Techinical Webiner					
	Training Indonesian counterpart personnel in Japan	1	Photo-base sampling technologies					
		2	GIS and database techniques			Concerning COVID-19		
		3	Practical social mapping methods					
	Provide Software and Equipment	1	Photo-base sampling technologies					
		2	Necessary survey devices including tablets and CFP survey toolkit					
Output 1. The influence of CFP upon human dimensions and ecological sustainability of coastal communities are explained based on specific hypotheses tests "DETECT and ASSESS"	1-1. Carry out monitoring activities to obtain sufficient CFP-related data/information	1-1A	To form task forces and monitoring members works for CFP related information - members who can continuously works and update - In the case of change in members, information need to be transffered			PST meeting and other web base communications		
		1-1B	To design and officialize monitored information flows and information management	B-1	Under COVID-19 situation, chose the adequate sites and approaches for monitoring			
				B-2	Design monitoring and information flow then share the design among the Project members			
				B-3	Build consensus with governmental agencies for monitoring and data-information flow			
		1-1C	To install necessary monitoing tools and infrastructures with techiniques	C-1	Purchase abroad and transport to the sites			
				C-2	Purchase in Indonesia and installed			
		1-1D	To carry out monitoring activities	D-1	Explain the monirring for surveyers	Prepare references		
				D-2	Carry out on-site monitoring	Potential pilot activities →		
				D-3	Evaluate monitoring activities			
				D-4	Improve monitorings			
	1-2. Test multiple hypothesis with the available CFP-related data/information	1-2A	To examine and list focused hypothesis then form **research groups**	A-1	Carry out necessary literature reviews as individuals in the RG			
				A-2	List and share adequate hypotheses* that need to be examined in the project *...Scientifically significant and socioeconomically expeted by Indonesian, including locals	PST; As a summary, Tome workshop with Webinar		
		1-2B	To design and carry out each research actions to test listed hypothesis	B-1	By research group(s), individual research action was designed			
				B-2	Share research designs among the Project members and comform coordinations	Green checks Up to the research interests, plans and coordinations		
				B-3	Discuss and implement solutions of found research challenges in the designed research actions			
				B-4	Carry out each research activity	Continue as further research partnerships		
				B-5	Update information from research activities and add necessary modifications			
	1-3. Locate and synthesize statistics or reports in CFP impact in terms of human health	1-3A	To assemble records from present health monitoring efforts and local knowledges relating CFP	A-1	Collate availble health reports and other information			
				A-2	Collect information from local stakholders (e.g. aboriginal knowledges)	Preparations		
		1-3B	To improve health monitoring system with integraive information* to sustainably collect CFP impacts *...including aboriginal knowledges	B-1	List problems in the present health monitoring system, esp. relating CFP			
				B-2	Discuss and provide suggestions for the improvement based on information from 1-3A activiies			
	1-4. Conduct background study in mechanisms of CFP issues with priorities with specific hypotheses	1-4A	To review literatures and assemble records from present coastal ecosystem status and costal fisheries resources					
		1-4B	To design present coastal ecosystem monitoring efforts	B-1	Evaluate present monitoring activities for ecosystem/resources in the area			
				B-2	Provide expertises for improvement of the present monitoring			
		1-4C	To collect coastal ecosystem status/fisheries resources information from locals, including aboriginal knowledges	C-1	Collect aboriginal knowledges and information in catches and ecosystems from locals	Preparations		
				C-2	Collect information of coral and key species (e.g. Groupers, *Stegastes* spp.) distributions and abundance using a participatory approach	Continue by Indonesian with developed systems		
			To improve coastal ecosystem monitoring system with integraive information* to sustainably collect coastal ecosystem	D-1	Develop integrative database from C-1 and C-2 with supplemental information (e.g. taxon)			

Output	Activity	No.	Sub-activity	Step	Step description	Schedule notes
		1-4D	...status *...including aboriginal knowledges	D-2	Discuss and provide suggestions for the improvement of ecosystem monitorings and fisheries resources monitorings using the integrative database (D-1)	
Output 2. Fish products distribution in the common supply chains in Indonesia with consideration in potential health risks from CFP "AVOID"	2-1. Describe the presence of distribution of CFP risk along with supply chains	2-1A	To assemble records/information from present the common supply chains in Indonesia			Review from the FishGIS info.
		2-1B	To collect supply chain status information from locals, including aboriginal knowledges			Preparations
		2-1C	To improve supply chain system with integraive information* to sustainably fish products distribution *...including aboriginal knowledges	B-1	List problems in the present common supply chains	
				B-2	Discuss and provide suggestions for the improvement based on information from 2-1A and 2-1B activiies	
	2-2. Disseminate knowledge in CFP risks for Indonesian non-fisher stakeholders along supply chains	2-2A	To list potential economic risks from CFP and improving solutions of supply chains in Indonesia then form research groups	A-1	List and share adequate evidences for potential CFP risks from 1-1D, 1-2B, 1-3A, 1-4C and 2-1C activities	
				A-2	Discuss potential economic risks from CFP among research group(s)	
		2-2B	To publish reports of potential economic risks from CFP and improving solution of supply chains based on the results from 2-1C in model communities			
	3-1. Visualize measures and the process of problem solving to counterparts of target organizations and local communities in the Project	3-1A	To specificy measures for CFP issues	A-1	Compare realities in the target communities/supply chains and findings in status and potential risks from actions of 2-2A	
				A-2	Specify realistic measures to resolve CFP issues in the target communities/supply chains based on the synthesis of 3-1A-1	Discussion among experts
		3-1B	To include or inform Indonesian counterparts from target group in every project activities			
		3-1C	To design applications and tools based on user's needs in Indonesian language	C-1	Discuss immidiate revisions over the present prototype by experts	
				C-2	Schedule and coordinate a pilot survey for experimental uses of apps.	
				C-3	Carry out the pilot survey *...Here, the survey does not have to be direct surveys. Prepared forms might be filled based on the surveys by officers or individuals in the target communities	
				C-4	Summarize impressions from the pilot survey with the part of target communities	
				C-5	Finalize the design of the application	
	3-2. Monitor and provide technical assistance for financial and economic returns/uncertainties to participants (Fishers) from the Project HOUSEHOLD: Individual Resources	3-2A	To investigate pre-project value chain of stakeholders in the model communities in the project site	A-1	Schedule and coordinate the on-site survey* *...Here, the survey does not have to be direct surveys. Prepared forms might be filled based on the surveys by officers or individuals in the taget communities	
				A-2	Carry out surveys	
				A-3	Summarize information in **a developmental value chain model**	If reviews were done, we may have some info. Beforehand
				A-4	Share the model outcomes among experts and major outerparts	
		3-2B	To provide advises and techinical assistances from case studies for improvement of value chains in the local fishery sectoir	B-1	Select adequate information to share, based on present VC information	
				B-2	Provide selected information to improve VC of stakeholders around the target communities	
		3-2C	To evaluate post-activity value chain of stakeholders in the model communities in the project site	C-1	Schedule and coordinate the on-site survey* *...Here, the survey does not have to be direct surveys. Prepared forms might be filled based on the surveys by officers or individuals in the taget communities	
				C-2	Carry out surveys	
				C-3	Summarize information in a developmental value chain model and compare to the model from A-3	
		3-2D	To establish annual monitoring of socio economic status of the model communities for post-project evaluation	D-1	Provide methodologies and instructions in 3-2A and 3-2D to Indonesian CPs	
				D-2	Design and officialize the post-project evaluations of VC	
Output 3. Sustainable monitoring continues after the termination of the project + "POST PROJECT SUSTAINABILITY"	3-3. Suggest a management system for CFP risk warning with consideration in sustainability by Indonesian sectors "System"	3-3A	To clarify the expert's TOR, as advisors for CFP management in the Project, in the international commitement			
		3-3B	To provide adequate advices for further management scheme and disseminations for Indonesian governmental counterparts	B-1	Design warning system of CFP risks with tools from the Project	
				B-1	Synsesize suggestions for further system management based on B-1 as well as on findings and measures	
				B-2	Provide advices in the project termination meeting	
	3-4. Provide technical guidance to maximize the efficiency of fishing activities with CFP monitoring	3-4A	To investigate present fishings and their technical efficiencies	A-1	Schedule and coordinate the on-site survey* *...Here, the survey does not have to be direct surveys. Prepared forms might be filled based on the surveys by officers or individuals in the taget communities	
				A-2	Carry out surveys	
				A-3	Summarize information in the parameter of the technical efficiencies	
		3-4B	To suggest and instruct the best CFP monitoring design and frequencies	B-1	Suggest the alternatives to carry out efficient monitoring	
				B-2	Practice the selected alternative for the efficient monitoring	
		3-4C	To evaluate and revise the CFP monitoring design in the proctices in the field	C-1	Evaluate the CFP monitoring with fishers and officers in the target communities	
				C-2	Revise the CFP monitoring with fishers and officers in the target communities	
	3-5. Provide opportunities to disseminate practical	3-5A	To share target community information (with updates from 3-2A) among PICES/Indonesian experts			

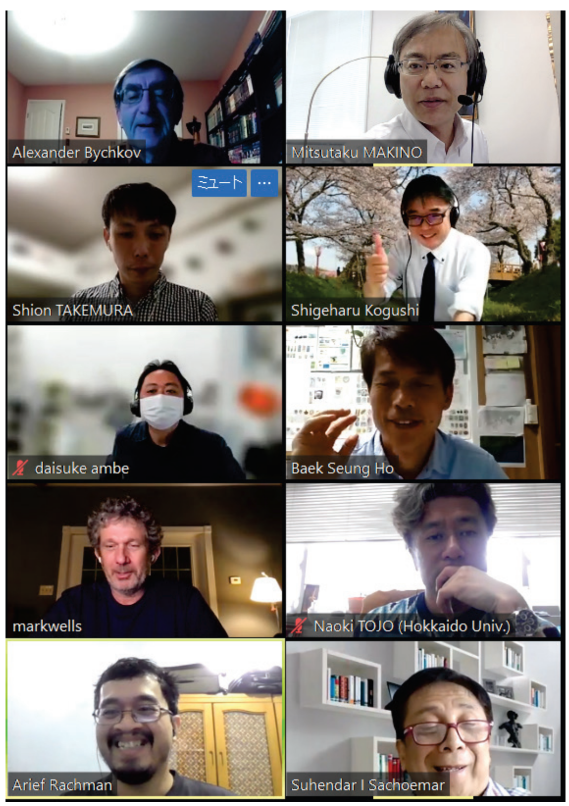
	knowledge for target local community with consultation **by PICES experts**	3-5B	To share information of fishings/fisheries sectors (with updates from 3-4A) among PICES/Indonesian experts			
		3-5C	To hold on-line seminars/techinical sessions in general workshops among experts to practically integrate information of human demantion into marine sciences			
		3-5D	To participate implementation and evaluation of dessiminations for locals to advice based on a common value	C-1	Codevelop agenda for dessimination activities	
				C-2	Codevelop plans for dessimination activities	
				D-1	Participate community workshops and general workshops for locals	
				D-2	Coevaluate dessimination activities	Online communication here
	3-6. Follow data management with related policies in Indonesia	3-6A	**To develop and confirm data and information rule/consensus esp. for research activities (including the protection of private/ethnic information)**	A-1	List necessary risk and issues to be covered	
				A-2	Suggest and confirm complemental rules	
				A-3	Add necessary updates upon the rules	
		3-6B	To have consultations from govermental counterparts in data management			
		3-6C	To implement designed data mangement scheme based on understandings in policies and rules			
		3-6D	To evaluate data menegement and improve based on the policies and consensuses			

Appendix 3.5
Fifth Virtual Meeting of the Project Science Team
April 25/26, 2022

The fifth virtual meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" (hereinafter referred to as Ciguatera) funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held via Zoom videoconference from 17:00–19:00 Pacific Daylight Time on April 25, 2022 (April 26, 2022 in the Western Pacific).

1. WELCOME REMARKS, INTRODUCTIONS, AND ADOPTION OF THE AGENDA

The meeting was opened with welcoming remarks to participants and brief comments on the purpose of the meeting by Dr. Mitsutaku Makino. Following introductions, the attendees (*Appendix 1*) reviewed and adopted the provisional agenda circulated prior to the meeting (*Appendix 2*). Dr. Mark Wells served as the rapporteur.



Ciguatera project meeting participants at their fifth virtual meeting on April 25/26, 2022.

2. SUMMARY OF YEAR 2 ACTIVITIES

a) Current state of the FishGIS application

Drs. Takemura and Kogushi provided a summary of the improvements that have been made to the FishGIS application. These included revamping the appearance of the application to simplify its operation, as well as substantial revision of the software so that older versions of Android (5.1) and iOS (10) are supported. Both of these changes better enable access and use of the application by Indonesian fishers. The test flight version (ver. 1.0) of the revised application will be available on Apple Store and Google Play in mid-May. Collected data are to be stored on a server in Indonesia (provided by Google) and transferred in real time to a server in Japan for data backup. The Indonesian government allows access to these data. It was suggested that the Indonesian National Water Association should be invited to the next meeting in Indonesia to explore how the application might aid in their conversation work.

b) Project Design Matrix and Plan of Operation

Dr. Makino gave a summary of what earlier efforts had added to the Project Design Matrix (PDM), and discussion turned to the draft Plan of Operation (PO). While the initial draft PO has not changed, it is recognized that the pandemic has impacted what is possible. The PST will work to update the PO based on the current activities. The latest PDM and PO are posted under "Products" on the project website. This topic will be an agenda item at the next PST meeting.

c) Memorandum of Understanding with the Institute of Technology of Indonesia

Dr. Makino reviewed the Memorandum of Understanding (MOU) with the Institute of Technology of Indonesia (ITI) signed on March 23, 2022 (JST), and led a discussion on the rationale and structure for developing this formalized collaboration. The MOU provides three primary advantages to the project in that (1) it allows for the smooth communication of project funds between PICES and project counterparts in Indonesia, (2) it enriches the project goals by forging new collaborations with ITI faculty and students, and (3) it helps to provide a stronger foundation for the project that increases the likelihood that project activities will continue beyond the project term. There also is an opportunity to invite faculty of the University of Indonesian (UI) and University of Mataram (UNRAM) to participate in the project. Dr. Sachoemar presented a flow chart of how the planned activities and responsibilities will be spread among the National Research and Innovation Agency (BRIN-Indonesia), ITI and PICES. The broad categories are harmful algal species observations, coastal marine environmental conditions, local human dimension facets, as well as socioeconomic impacts and food safety. The increased span of collaboration among PICES, BRIN, ITI, UI and UNRAM is a significant advance for the project.

3. BUDGET SUMMARY

Dr. Bychkov provided a summary of the project budget, along with the plans for supporting the planned BRIN-funded field program in the Gili Island region, Lombok. This will allow more frequent surveys and thereby give insight to how the water quality and distribution and abundance of toxic benthic organisms changes during the wet, dry and transitional seasons (see 4b for details). After the transfer of funds to ITI, there will be roughly $130,000 CDN remaining for Year 3 activities.

4. WORKPLAN FOR YEAR 3

a) Improvements to the FishGIS application and Terms of Use and Privacy Policy of the application

The following issues were brought up during discussion on improvements to the FishGIS application:

- The logos for BRIN and ITI have to be added to the application, but first a confirmation is needed that we have license to use these logos. The reorganization of Indonesian agencies under the single BRIN umbrella is still working through many issues and while there is expectation that it will not be a problem to include the BRIN logo, given that BRIN is funding part of the work, Mr. Rachman will check.
- The mapping function of benthic toxic algae needs to be improved and adapted for better display of larger datasets. This work is on-going.
- It would be advantageous to link the FishGIS application with data from the Indonesian Meteorological, Climatological and Geophysical Agency (BMKG). This way weather and sea data can be presented in the application, thereby providing fishers another reason to utilize this tool. The linkage also will allow tsunami warning capability to be added to the application. Dr. Sachoemar will discuss this idea with his colleagues at BMKG.
- It would be preferential if users could directly link with the HydroColor application through the FishGIS application. Dr. Wells will contact the HydroColor developer to determine how feasible this might be, or whether it would require significant re-coding of the HydroColor application.
- There is a question about who may "own" the copyright to FishGIS data (Terms of Use and Privacy Policy of the application) – a culmination of many users and providers. There was discussion about what approaches might work. For example, with Twitter the user owns the copyright of data, but allows Twitter *(i.e.*, other users) to access it. Alternatively, Facebook owns the copyright on all data, but gives license to Meta to use these data, which is closer to the situation with FishGIS. Dr. Ambe will discuss this question about data sharing with TCODE. The current feeling among PST members is that a partial sharing structure be developed with some data remaining restricted.

b) Indonesian field sampling program

Mr. Rachman provided a summary of the planned field program, which is a joint collaboration among PICES, BRIN, ITI, UI and UNRAM. He has a 5-year project funded to study ciguatera in Indonesian waters, and this field program is the first of the project. Combining funding from the PICES-MAFF project and from BRIN will allow carrying out the enhanced field program in the Gili Island region, with a total of five 6-day long sampling surveys (2 funded by BRIN and 3 by this PICES-MAFF project). Two surveys are scheduled for May and August 2022, with three more to be conducted through February 2023. The combined surveys are expected to provide measurements across wet, dry and transition periods. The field program is designed to compare human-impacted reef systems to those in a local marine conservation area. Community participation in the first two surveys is restricted due to pandemic regulations so emphasis will be on oceanographic observations (with active use of the smartphone-based FishGIS and HydroColor tools), phytoplankton assemblage composition, and toxic benthic algae distributions. Community participation will be incorporated when conditions permit.

c) Capacity building and knowledge dissemination

Progress on these aspects of the project plan has been very limited due to the inability of PST participation in face-to-face workshops with Indonesian government agencies, universities and local communities. There was discussion about the potential for training and knowledge dissemination workshops in the Lombok and Gili Islands region to be organized in January/February 2023. The COVID and quarantine situation in Indonesia will be monitored while tentative planning steps are taken. If the situation allows, a short visit by a small group of PICES experts will be arranged in late 2022 to facilitate workshop planning.

As a special capacity building initiative, the PST has agreed to support six undergraduate students from ITI, UI and UNRAM (two from each) to participate in the field sampling program by providing them partial tuition (a portion of Year 2 project funds were re-directed for this activity).

d) Collecting data using the FishGIS application

e) Collecting data on fish products distribution in the common supply chains in Indonesia

These agenda items were not discussed due to the lack of time.

f) PST meetings

The next PST meeting is planned to be in-person and to take place on September 22, in conjunction with the next PICES Annual Meeting (PICES-2022) in Busan, Korea. The PST meeting place has not been settled, but is likely to be the PICES-2022 venue. The main objectives for the meeting will be to: (1) review overall progress on the field sampling program in the Gili Island region to date, (2) evaluate the latest version of the FishGIS application (ver. 2.0), (3) initiate planning for a community training workshop to be held in early 2023, (4) discuss the latest Project Design Matrix (PDM) and further steps in the development of this framework, and (5) generate a list of tasks for the preparation of a final scientific report and other project outcomes.

5. OTHER BUSINESS

a) Year 2 annual reports and Year 3 workplan

The Year 2 annual report and Year 3 workplan will be prepared by the Project Co-Chairs in collaboration with the Project Coordinator. The near final draft will be circulated to PST members for comment and revision.

b) Update on the next MAFF project

Given that the current project is going well overall, despite setbacks related to the pandemic, MAFF has expressed a very positive outlook for funding the next MAFF project to build upon this foundation. A final decision will come from the Ministry of Finance, but it is very encouraging news.

Appendix 1

Fifth Project Science Team meeting participants

Members

Daisuke Ambe (Japan, representing TCODE)
Seung Ho Baek (Korea)
Alexander Bychkov (PICES, *ex-officio*)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Shion Takemura (Japan, representing HD)
Naoki Tojo (Japan, representing FIS)
Mark Wells (Co-Chair; USA, representing MEQ)

Other

Shigeharu Kogushi (GFI, Japan)
Suhendar I Sachoemar (ITI and BRIN, Indonesia)
Arief Rachman (BRIN, Indonesia)

Appendix 2

Fifth Project Science Team meeting agenda

Tuesday, April 25, 2022 (PDT)

1. Welcome remarks, introductions, and adoption of the agenda
2. Summary report of Year 2 activities
   a) Current state of the FishGIS application
   b) Project Design Matrix and Plan of Operation
   c) MOU and IA with ITI
3. Summary report of the budget
4. Workplan for Year 3
   a) Improvements to the FishGIS application and Terms of Use and Privacy Policy of the application
   b) Indonesian field sampling program
   c) Capacity building and knowledge dissemination
   d) Collecting data using the FishGIS application
   e) Collecting data on fish products distribution in the common supply chains in Indonesia
   f) PST meetings
5. Other business
   a) Year 2 annual reports and Year 3 workplan
   b) Update on the next MAFF project

Appendix 3.6
Sixth Meeting of the Project Science Team
September 22, 2022

The sixth meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held in person from 09:00–17:00 on September 22, 2022, in the Miami Room at the Hotel Paradise, Busan, Korea, prior to the PICES 2022 Annual Meeting.

1. WELCOME AND ADOPTION OF AGENDA

The meeting was opened with welcoming remarks to participants and brief comments on the purpose of the meeting by Dr. Mitsutaku Makino. Several PST members, Dr. Vladimir Kulik (Russia, representing MONITOR), Dr. Naoki Tojo (Japan, representing FIS), and Dr. Pengbin Wang (China), were unable to attend this meeting. A representative of MAFF/JFA, Dr. Tatsuki Oshima, joined the meeting to learn more about the project accomplishments and future plans. Other invited participants included Mr. Arief Rachman (BRIN, Indonesia), Dr. Suhendar I Sachoemar (ITI and BRIN, Indonesia) and Dr. Moonho Son (National Institute of Fisheries Science, Korea). Following introductions, the attendees (*Appendix 1*) reviewed and adopted the provisional agenda circulated prior to the meeting (*Appendix 2*). Dr. Mark Wells served as the rapporteur.

Participants of the sixth PST meeting held September 22, 2022, in Busan, Korea (l to r): first row – Suhendar I Sachoemar, Mitsutaku Makino, Shion Takemura, and Tatsuki Oshima; second row – Arief Rachman, Alexander Bychkov, Vera Trainer, Seung Ho Baek, Mark Wells, Charles Trick, Daisuke Ambe, and Moonho Son.

2. UPDATE ON YEAR 3 ACTIVITIES

Current state of the FishGIS application

The modified FishGIS application (ver. 1.0) was released in mid-May 2022, and an updated version in early August 2022. New features demonstrated by Dr. Shion Takemura included: a function to map Ciguatera field survey data, and in-application links allowing the direct launch of the HydroColor water quality application and the Info BMKG application (provided by the Indonesian Agency for Meteorology, Climatology, and Geophysics) for a tsunami early warning notification. Discussion then shifted to the principles underlying HydroColor's operation.

Field sampling surveys in Indonesia

Dr. Sachoemar provided a brief overview of the field surveys completed to date in the Gili Matra region (followed by Mr. Rachman's summary below), including the survey site locations and some of the data. Dr. Takemura presented those data that were collected with the FishGIS application during these surveys, including both HydroColor and fish species, along with HydroColor data that were collected 3 years ago.

Photographs of fish from the Gili Matra markets were uploaded in September 2022. These data were used to begin assessing how many fish species are present in a given community. On taking a photo, the FishGIS application brings a screen that asks the type of fish, which highlighted to PST members that it will be necessary to choose common names that are easily recognized by local fishers (rather than genus/species). These names then could be automatically assigned to a genus, which is sufficient at this stage of a developing management program. There was some discussion about the willingness of fishers to display locations where fish were caught, and it was suggested that the coastal region be partitioned into more general "boxes" that can be displayed in the application. (As a side note, Dr. Son explained how they use a smartphone application for the public to record the occurrence of jellyfish, with prizes given to entice public participation—an idea considered early in this project but not implemented as there was concern about sustainability of the effort.) Dr. Takemura then presented a summary of all data collected over time from Indonesian coastal waters in a table, including the name of fish, location, data, and HAB group abundance, and HAB species. It was noted that Indonesians consume ~160 g of fish per day, so there is a high potential for CFP exposure.

There was discussion about the terminology. The term "citizen science" is most often applied to the types of data collection methods used in this project; however, it is more of a "top down" term and did not imply co-development. There was agreement that PST members need to think about this aspect to formalize the project around an approach that then could be a valuable contribution to PICES as a whole (see below).

Mr. Rachman presented an in-depth summary of the field sampling program, co-funded by PICES-MAFF and integrated agencies (biology, chemistry, oceanography, social economic and coastal ecology) within BRIN whose interests align with the PICES-MAFF project. The summary included a detailed list of phytoplankton species, with five harmful benthic species that were present in low numbers. A few of the benthic artificial samplers were not recovered because they could not be found under turbid water conditions. PST members considered approaches to limit this problem, likely by deploying the samplers deeper, so that they are below the wave orbitals. Nevertheless, a benthic species abundance and composition relationship to water quality measures has begun to emerge using data from the recovered samplers. This work included two studies by undergraduates at local universities. PST members suggested that we may wish to look at benthic HAB species consortia, rather than individual species, when assessing risk levels. It also was advised that it may not be necessary to go to detailed taxonomic levels, and that genus abundances might be equally informative in this circumstance. E-DNA analyses of the collected samples awaits new funding, and PST members recommended that the possibility that the project could help support these analyses should be explored.

MOU-related activities

Dr. Sachoemar presented a summary of new research strategic planning in Indonesia to build local warning networks for the detection and human dimensions of benthic HABs. This planning stems from the collaboration with PICES and the accomplishments of the current project. He presented a draft agenda for the planned training and knowledge dissemination workshop scheduled tentatively for January 2023, and suggested that we work to expand the field sampling program to the southern region of Lombok, which has different oceanographic conditions.

3. SUMMARY OF THE BUDGET

Dr. Alexander Bychkov provided a budget status report. The total budget for the project was ~$300,000 CAD, split roughly equally among the 3 years. Year 1 and 2 funds were not spent fully due to the COVID-19 travel restrictions, but we were allowed to carry over funds from Year 1 to Year 2, and from Year 2 to Year 3. Year 3 funds are sufficient to cover this PST meeting, community training and dissemination workshop in January 2023 in Lombok, and a final PST meeting, and perhaps provide some support for e-DNA analyses of a subset of the collected samples.

4. WORKPLAN FOR YEAR 3

FishGIS application – Sharing data and Terms of Use and Privacy Policy

In a continuation of discussion from the morning session, PST members noted that the MOU with BRIN enables sharing of field survey data but there was a question of whether this sharing needs to be formalized for data acquired through the FishGIS application. Dr. Sachoemar responded that he sees no problem with the sharing of data. Data will be protected by passwords, but meta-data will be available for all to see. Those participating in the data collection will have direct access, and others will be required to request permission. The use of data in publications is acceptable as long as Indonesian colleagues have an opportunity to participate in authorships. Dr. Daisuke Ambe reviewed the existing PICES Data Management Policy and explained that the current structure of data sharing meets the PICES policy. A more detailed summary of this aspect will appear in the final report.

It also was decided that the Terms of Use and Privacy Policy of the FishGIS application will need to be finalized by late February 2023.

Planktoscope

A brief summary of Planktoscope and its capabilities was presented by Dr. Mark Wells, and questions from PST members were fielded about how the instrument might be used, and what the benefits will be. The main benefits were the low cost, the ability to collect quantitative data, and the ability to have higher sampling density in remote locations. Operators of the instrument should have a science background and could include Ministry of Fisheries staff at research stations in Indonesia, as one of their responsibilities is to do environmental monitoring. This effort will require workshops, perhaps one per year, to maintain training and to better ensure high quality data. Staff will be included in the January 2023 training workshop.

Indonesian field sampling program

The next surveys in the Gili Matra region are scheduled for the middle of October 2022 (funded by BRIN), December 2022 (funded by MAFF), and February 2023 (funded by MAFF). The same sampling strategies will be used as in the prior two surveys, though there is a need to address how to better ensure the recovery of artificial benthic samplers.

Capacity building and knowledge dissemination workshop

The workshop has been moved to the week of January 23, 2023, due to scheduling conflicts earlier in January. The main objectives of the workshop will be to: (1) disseminate information about fisheries management and the hazards of benthic harmful algal blooms (particularly CFP) in Indonesian coastal areas, (2) provide technical, hands-on training on the use of smartphone-based tools for monitoring of fisheries resources and environmental health conditions, and (3) communicate the consequence of changes to the marine resources on community fishers. A draft plan for the workshop was discussed. According to this plan, participants will be split into groups – one for training on FishGIS and HydroColor applications, and a smaller group for more in-depth training on Planktoscope. An expert from Manu Prakash's laboratory at Stanford University will be invited to join the workshop to lead this latter training.

Data collection with FishGIS application

The FishGIS application will continue to be used during the sampling surveys. The goal is to surpass the threshold of 1000 raw data points. Currently, 300 benthic HAB species data are in hand. There are also samples remaining to be counted from the two previous surveys, and three more surveys are coming. It was decided that all phytoplankton species should be recorded with Planktoscope (not just HAB species) because it may provide better insight to HAB occurrences through community relationships. Machine learning techniques should be developed to accelerate this step. It is worth considering adding macroalgae data collections for monitoring of the general changes in the reef environment. In addition to the surveys, there will be a training exercise in January 2023 that might add further data. Efforts are needed to obtain more photos from the fish markets in the Gili Matra region, and from other Indonesian communities. Dr. Sachoemar also will ask his staff to use the application on general trips for this purpose.

Final PST meeting

The final PST meeting will be held in March 2023 (tentatively planned for March 20–22) in Tokyo or Yokohama. The intent would be to use this meeting as a writing exercise to prepare a draft of the final report.

5. OTHER BUSINESS

Korean smartphone program

Dr. Son summarized the Korean smartphone program to report marine and jellyfish observations (not HABs). Data go to local municipalities and researchers, so the questions can be more focused (*e.g.*, T, S, phytoplankton species, *etc.*). A central person accumulates data and collates all the information from different sites. These data then are used to generate reports (location, problem, magnitude) with linkages to weather data.

PICES Press

A short article on the project appeared in the summer 2022 issue of PICES Press, and the intention is to write an article summarizing the project for the summer 2023 issue of PICES Press.

Next PICES-MAFF project

The next PICES-MAFF project is designed to continue the current project plan and expand the use of the FishGIS application in Indonesia. The pillars of the new project will be use of Planktoscope, and to expand the project to other PICES member countries (China, Korea, Russia, USA), each of which have observed benthic HAB species. Although toxicity data are less available, the presence of these species suggests that observations of their abundance and distribution will be valuable. There also is a need to continue the focus on fisheries, possibly leading to stock assessment in the future; a long-term goal of project efforts.

MAFF strongly supports for this new project and has requested a bit more funding than for the present project. The decision lies with the Ministry of Finance, and the outcome will be known by December 2022.

Several PST members noted that the Ciguatera project could be used as an example of how PICES should be moving in line with the UN Decade of the Oceans for Sustainable Development (UNDOS), bringing communities into the study of marine ecosystems. It was suggested that a slide summarizing the project should be sent to Dr. Steven Bograd (AP-UNDOS Co-Chair) for his plenary presentation at the PICES-2022 Science Board Symposium as an example of how the PICES-MAFF project is a leading force in PICES.

Dr. Makino noted that the Ciguatera project fits well under UNDOS' Goal 14. The emphasis of this goal is transformative ocean science (action and outcome-orientated science, co-design research and deliverables), which is what we did in the previous project and are trying to do in this and the next PICES-MAFF project. The effort here is to work toward co-design and co-delivery on a problem that scientists and community members both know exists. Here, the community contributes to the understanding and the solution of the problem. In this way the project leaves a legacy of action that, with motivation of the community, can continue solving the issue, and we can explore in more detail the motivation strategies to get and keep community involvement. This topic needs to be considered in preparing the January 2023 workshop, and it will be important to have community and regional leaders present. It may also be beneficial for PST members to propose a topic session at the next PICES Annual Meeting on community-based participatory science. The January workshop would be a useful start to gather information about what community members find are the problems they face—what do they need, what problems are they facing in terms of the fishery?

Meeting adjourned at 1730 h.

Appendix 1

Sixth Project Science Team meeting participants

<u>Members</u>

Daisuke Ambe (Japan, representing TCODE)
Seung Ho Baek (Korea)
Alexander Bychkov (PICES, *ex-officio*)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Shion Takemura (Japan, representing HD)
Vera Trainer (USA, representing MEQ)
Charles Trick (Canada, representing MEQ)
Mark Wells (Co-Chair; USA, representing MEQ)

<u>Other</u>

Tatsuki Oshima (MAFF/JFA, Japan)
Arief Rachman (BRIN, Indonesia)
Suhendar I Sachoemar (ITI and BRIN, Indonesia)
Moonho Son (NIFS, Korea)

Appendix 2

Sixth Project Science Team meeting agenda

Thursday, September 22, 2022 (09:00 – 17:30)
Miami Room at Hotel Paradise, Busan, Korea

1. Welcome remarks, introductions, adoption of the agenda, and nomination of rapporteur
2. Update on Year 3 activities
   a) Current state of the FishGIS application
   b) Field sampling surveys in Indonesia
   c) MOU-related activities
3. Summary report of the budget
4. Workplan for rest of Year 3 (discussion coordinated by PST Co-Chairs)
   a) FishGIS application – Sharing data and Terms of Use and Privacy Policy
   b) Planktoscope - High-Throughput Microscope Platform
   c) Indonesian field sampling program
   d) Capacity building and knowledge dissemination activities, including community training workshop
   e) Collecting data using the FishGIS application
   f) Final PST meeting
   g) Other activities until the end of Year 3
5. Other business
   a) Korean smartphone program
   b) PICES Press
   c) Preliminary information about the next PICES-MAFF project

Appendix 3.7
Seventh (Final) Meeting of the Project Science Team
March 16–18, 2023

The final meeting of the Project Science Team (PST) for the project on "*Building local warning networks for the detection and human dimension of Ciguatera fish poisoning in Indonesian communities*" funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), was held in-person on March 16–18, 2023, in Yokohama, Japan.

The main purpose of this meeting was to review and summarize the project for preparation of the final report. Readers are directed to this report for detailed information, and this meeting summary only briefly covers the topics discussed.

1. WELCOME AND ADOPTION OF AGENDA

The meeting began with welcoming remarks and adoption of the agenda. All PST members were attending with the exception Dr. Vladimir Kulik (Russia, representing MONITOR) and Dr. Vera Trainer (USA, representing MEQ). Invitees to this final meeting were two representatives of MAFF/JFA, Dr. Tatsuki Oshima and Dr. Shota Sato, two partners from Indonesia, Mr. Arief Rachman (BRIN) and Dr. Suhendar I Sachoemar (ITI and BRIN), and colleagues from Korea, Ms. Mihye Hwang (Ministry of Oceans and Fisheries), Dr. Dong Wook Kim (NIFS) and Dr. Moonho Son (NIFS). Following introductions, the attendees (*Appendix 1*) reviewed and adopted the provisional agenda circulated prior to the meeting (*Appendix 2*). Dr. Mark Wells served as the rapporteur.

Participants of the seventh PST meeting held March 16–18, 2023, in Yokohama, Japan (l to r): first row – Suhendar I Sachoemar, Pengbin Wang, Mitsutaku Makino, Tatsuki Oshima, Dong Wook Kim, and Mihye Hwang; second row – Alexander Bychkov, Charles Trick, Mark Wells, Naoki Tojo, Daisuke Ambe, Seung Ho Baek, Shoto Sato, Moonho Son, and Arief Rachman. Missing from photo – Shion Takemura.

2. SUMMARY OF PROJECT ACTIVITIES

Smartphone applications modified during the project

Dr. Shion Takemura summarized the revisions accomplished on the three central functions of the FishGIS application: 1) data collection by local fishers, 2) the return of data to a central database where it is calibrated, stored, and analyzed, and 3) results of these data analyses returned to the local fishers. The application languages are now in both English and Bahasa. The central modifications were to revise the data-handling approach to make the project ABS (Access to genetic resources and Benefit Sharing) compliant, update the user interface, better integrate the application with the Indonesian Tsunami Early Warning (BMKG system), and improve the data visualization. Examples were given on how fish images collected from the fish market could be identified and fish size could be estimated by image analysis. The goal in the next project would be to develop automated image analysis methods for fish identification and size determinations.

HydroColor data collected during bloom conditions (Wet Season) and at other times (Dry Season) from the Gili Matra region showed distinct spectral differences (RGB) that were loosely related to chlorophyll concentrations, and provided a demonstration of how HydroColor data could help to understand changes in marine environment.

Project Design Matrix and Plan of Operation

The Project Design Matrix (PDM) is a navigation map for planning, action, assessment, and revision in a project cycle (*Appendix 3*). The Plan of Operation (PO) is a detailed level of the operational plan, with timelines. The development of the project was evaluated on five aspects: relevancy, coherency, impact, efficiency, and sustainability. This evaluation led by Dr. Naoki Tojo was based largely on the January 2023 workshop.

Relevancy — appropriateness of assistance in implementation, who were the beneficiaries, were appropriate adjustments made? Local participants were eager to learn and implement the outputs in their own communities. The goal of the project was to encourage the communities to gain knowledge about ciguatera fish poisoning (CFP) and its possible impacts, the importance of having this knowledge, and how they could organize their community to use this knowledge. Local government was very supportive of the effort. Mr. Rachman noted that every time he goes to the field the local people ask for equipment to help them observe their own environments. Fishers normally think primarily about how to increase catch, but here they showed an understanding of the importance of fisheries sustainability and desire/willingness to be involved in observing these problems to help make changes.

Coherency — How does the project relate to other projects? The project was centered on co-design, was consistent with PICES' objectives and UNDOS' (UN Decade of the Oceans for Sustainable Development) goals. It was a good example of UNDOS' Goal 14.

Impact —did the expected effects (positive or negative) of the project relate to reality in the target years (including utilization of facilities and equipment)? A clearly negative impact would have been finding CFP- compromised regions. Knowledge like this can have a very negative effect on those collecting these data. There needs to be more work done on defining this issue for the next project. The project should be thinking about thresholds of concern (not just present/absence).

Efficiency — comparison of the project input plan, project period, project cost and actual results. There were serious impacts on the project from COVID-based delays. However, there were numerous activities organized by our Indonesian colleagues. PST members expressed their deep appreciation to our Indonesian colleagues for proceeding without our help, making this project a success when it otherwise would not have been. Mr. Rachman pointed out that it was very beneficial to have financial support from the PICES-MAFF project that enabled them to do things that otherwise would not have been possible.

Sustainability — prospects for continuation of the project goals. The signing of multiple cooperation agreements among Indonesian national and local government agencies and universities is a direct outcome of the influence this project has had within Indonesia. These agreements give leverage to provide support. The priority for the next project will be to nurture these interactions through small levels of funding, technical workshops, and community involvement. We must also consider the impacts the project has had on PICES member countries (*e.g.*, Korea is becoming more aware of the issues of CFP).

PST members originally set three hypotheses: (1) degraded reefs can lead to the increased occurrence of toxic conditions, (2) reef degradation associated with nutrient inputs leads to increased macroalgae colonization, and (3) reef fish can be a toxin vector to the community. The findings so far are not sufficient to test hypotheses (1) and (2), but early data suggest that CFP is not a problem yet. A review and assessment of the progress made on the PDM is provided in *Appendix 4*. The pandemic prevented us reaching the point where community members were enabled to collect data. We had to adapt to the existing activities by having data collected in a substantially different way than initially proposed, and this point must appear prominently in the final report.

<u>Memorandum of Understanding and Implementation Agreement with the Institute of Technology of Indonesia</u>

Roughly 96% of the Indonesian population lives in coastal communities, so the potential impact of CFP could be devastating. This recognition was the driving force for PICES to choose Indonesia as a developing Pacific Rim country to implement the project and to enter into an MOU (Memorandum of Understanding) and Implementation Agreement (IA) with the Institute of Technology of Indonesia (ITI) signed in March 2022. Dr. Sachoemar restated the rationale underlying these arrangements and summarized the activities on the Indonesian side over the last year. To keep momentum, he proposed that the first PST meeting and the first training workshop under the new project (see below) be conducted in July 2023, in Lombok. Further, Dr. Sachoemar indicated that ITI is planning to convene the first International Seminar on "Sustainable Coastal Marine Environment Management" in September 2023 and requested that PST members join virtually or in-person to communicate the project goals and activities (what has been done so far and plans for the future) to an audience that is expected to include students, researchers, scientists and engineers from academia, research institutions and industry (~100 people).

<u>Community training and knowledge dissemination workshop</u>

A summary of the workshop held January 25–27, 2023, in Lombok was presented. The FishGIS and HydroColor training sessions followed the same general organization as in the workshops during the previous FishGIS project (2017–2020). Community awareness training for fisheries management, environment and human health was provided and put into the context of the project using a 3E (Environment, Exposure, and Effects) "bow-tie" risk assessment model. Workshop participants played a "fish game", where ~60 fishers drew their favourite fish on pieces of paper that were spread out across the room and outside. Then they "fished" the environment by picking up pieces of paper and were led by the instructor through the fish analyses (this many tuna, that many of that size, *etc*.) to explain fishing success. Some pieces of paper had been marked with predator fish having red dots to represent CFP. Participants came to understand how they could avoid these negative impacts on their livelihoods if they had information about where CFP was prevalent, so that they would avoid fishing in those areas, or limit themselves to certain sizes.

Indonesian field sampling program

A detailed summary was given on the structure and early findings of the field sampling program in the Gili Matra region by our Indonesian colleagues. This summary included a review of the sampling zones (Core Zone, Harbour Zone, Sustainable Fisheries Zone, *etc*.), water column sampling (plankton, nutrient and different water quality parameters), e-DNA collections for fish (but not benthic dinoflagellates), benthic algae sampling (collected natural substrates, deployed artificial substrates), and sample sites (seagrass bed, coral reef). SPATT (Solid Phase Adsorption Toxin Tracking) bags also were deployed for ciguatoxin sampling, although there are limitations to this approach. Some of the fish were sampled for CFP testing in the wild (by spear fishing) and in the market. Analyses showed that toxins were below the detection limit of fish sampled from the market, while results from the wild caught fish are pending. A socio-economic sampling survey was conducted in the Gili Matra region that showed most of the fishers in that region are relatively poor. Approximately 90% of respondents felt that it was very important to know about CFP.

3. SUMMARY OF PROJECT BUDGET

A summary of the project budget was presented by Dr. Alexander Bychkov. The project ends on March 31, 2023, and essentially all of the funds have been used. The total 3-year budget was ~$292,000 CAD. PICES retained 13% as an overhead, leaving an operational budget ~ $254,000. Funds were spent as follows:

- Smartphone application modifications and server maintenance: $60,000
- Support for the Ciguatera Indonesia project (field surveys, e-DNA, tuition for students): $78,000
- January 2023 training workshop: $60,000 (roughly half for Indonesia, half for PST)
- PST meetings (first 5 online, last 2 in-person): $37,000
- Additional funds used for project coordination and miscellaneous: $5,000

The PST members agreed that the remaining amount should be used for preparation of the final report and if any surplus appears, it will be put towards the purchase of a new Planktoscope.

4. DATA POLICY AND USE OF THE FISHGIS APPLICATION BY OTHER ORGANIZATIONS

The project by design acquired data funded from different sources. Dr. Daisuke Ambe presented a TCODE analysis and concluded that the use and storage of data collected with PICES-MAFF funding meets the PICES Data Management Policy.

There was discussion about the use of the FishGIS application by other organizations for non-scientific purposes that are not consistent with the research objectives of the PICES-MAFF project. While it may be appropriate for commercial organizations to pay for data use/storage, it may be beneficial for some commercial organizations to have free access (*e.g*., ecotourism operations). More discussion will be needed to resolve this issue.

5. PROJECT OUTCOMES AND TASKS FOR PREPARING THE FINAL REPORT

An outline of the final report was prepared and writing assignments given for the different sections.

6. CIGUUATERA RESEARCH ACTIVITIES IN CHINA AND KOREA

Short presentations were given about ciguatera research activities in China and Korea by Dr. Pengbin Wang (China), Dr. Seung Ho Baek (Korea) and Dr. Moonho Son (Korea). These presentations illustrated the growing concerns about the emerging threat of benthic HABs in these PICES member countries.

7. INTRODUCTION OF THE NEW PICES-MAFF PROJECT

A new 3-year PICES-MAFF project is expected to begin April 1, 2023 (pending evaluation and approval by PICES) and will utilize the FishGIS application, combine efforts of phytoplankton identification by microscope and Planktoscope, and collaborate with local fishers and research institutes in Southeast Asia (including ITI and BRIN) to create a phytoplankton-fishery observing program for sustaining local communities in Indonesian coastal waters. It will also identify potential research needs for deploying the FishGIS application in PICES member countries. A draft Implementation Plan was presented by Dr. Mitsutaku Makino and supported by the participants. All current PST members indicated their interest and willingness in continuing their involvement in the new project. Plans were decided on preparing a project profile and the principles agreed upon by JFA and PICES that then will be presented to PICES Science Board and Governing Council for approval.

8. DRAFT YEAR 1 WORKPLAN (APRIL 2023 – MARCH 2024)

A draft workplan for the first year of the new project was discussed, and the following activities were considered:

- First training workshop to be organized in July 2023, in Lombok;
- First PST meeting to be held in July 2023, in conjunction with the training workshop in Lombok;
- Joint ITI-BRIN-PICES international seminar on "Sustainable Coastal Marine Environment Management" temporarily scheduled for September 2023, in conjunction with the Second International Conference on Advanced Technology in Chemical Engineering in Jakarta;
- Second PST meeting to be held in October 2023, in conjunction with PICES-2023 in Seattle, USA;
- Second training workshop to be organized in January or March 2024.

There was discussion on how we envision data collection in Year 1, which will be dependent on funding. It was suggested that a training session be arranged for students at the University of Mataram, then bringing them to the Gili Islands to meet with local community members who can assist in sample collection.

The PDM would be revised at the October PST meeting based on information obtained in July, and the data input will be reviewed to find out what is working and what is not.

The goal for the January or March 2024 training workshop would be to build a wider user base, pending sufficient funding. There is a need to add at this workshop training for sample collection, both water column and benthic sampler. High priority must be placed on considering the perspective of local community members to ensure they remain involved.

The PST meeting was closed with thanks from the project Co-Chairs and Coordinator.

Appendix 1

Seventh Project Science Team meeting participants

Members

Daisuke Ambe (Japan, representing TCODE)
Seung Ho Baek (Korea)
Alexander Bychkov (PICES, *ex-officio*)
Mitsutaku Makino (Co-Chair; Japan, representing HD)
Shion Takemura (Japan, representing HD)
Naoki Tojo (Japan, representing FIS)
Charles Trick (Canada, representing MEQ)
Pengbin Wang (China)
Mark Wells (Co-Chair; USA, representing MEQ)

Other

Mihye Hwang (MOF, Korea)
Dong Wook Kim (NIFS, Korea)
Tatsuki Oshima (MAFF/JFA, Japan) [March 16 and March 18]
Arief Rachman (BRIN, Indonesia)
Shota Sato (MAFF/JFA, Japan) [March 16 and March 18]
Suhendar I Sachoemar (ITI and BRIN, Indonesia)
Moonho Son (NIFS, Korea)

Appendix 2

Seventh Project Science Team meeting agenda

March 16–18, 2023
Ankyo Service Center, Yokohama, Japan

Day 1 (March 16, 09:30 – 17:30)

1. Welcome remarks, introductions, adoption of the agenda and nomination of the rapporteur
2. Summary report of project activities
    a) Smartphone applications used/modified during the project (FishGIS, HydroColor)
    b) Project Design Matrix and Plan of Operation
    c) Memorandum of Understanding and Implementation Agreement with the Institute of Technology of Indonesia (ITI)
    d) January 2023 community training and dissemination workshop (Lombok, Indonesia)
    e) Indonesian field sampling program (May 2022 – February 2023)
3. Summary report of the project budget
4. Discussion on project data policy and use of the FishGIS application by other organizations

Day 2 (March 17, 09:30 – 17:30) Recap of Day 1

5. Project outcomes and tasks for the preparation of the final report
6. Presentations on ciguatera research activities in China and Korea (10-15 min each)

Day 3 (March 18, 09:30 – 12:30) Recap of Day 2

7. Introduction a new 3-year PICES-MAFF project
8. Draft workplan for the next 3 years (April 2023 – March 2026)
9. Closing remarks from the project co-chairs and coordinator

Appendix 3

Project Design Matrix designed for the PICES-MAFF Ciguatera project

Narrative summary	Objectively Verifiable Indicators (OVI)	Means of verification	Important assumptions
Overall goal* *...3-5 years after the Project, monitored by post-project evaluation			
1. Consumers can purchase CFP-risk free fish products from the local community in Indonesia 2. Socio-economics of coastal communities do not have to fully depend upon products with CFP-risks 3. Many coral beds declines are of interest and understood by local communities in developing nations, including Indonesia	1. There is more than 1 product or 1 certificate based on the Project activities that can be provided to Indonesian supply chains with information of CFP control 2. Half of members in target communities improved their socio-economic capacity (*e.g.*, capital, income sources) based on efforts based on the technical transfers in the Project 3a. A coral ecosystem status is monitored using > 2 biological indicators at least once a season by locals with governmental instruction 3b. > 2 International publications are published 3c. > 100 local stakeholders continuously follow the official Social Networks after the termination of the Project	1. Product or/and certificate with CFP control information 2. Results of evaluation surveys with questionnaires for locals (Adequate questionnaires will be developed during the Project with observers) 3a. Survey reports by officers, submitted to Ministries 3b. Publications with authors from Counter Parts (CPs) 3c. Followers of official SNS account (Official SNS should be established during the Project)	
Project purpose* *…evaluated at the Project termination			
Capacities of coastal community of Indonesia are improved in sustainable manner with less uncertainties and risks from CFP and degradation of coral ecosystem	1. > 100 of total local fishers participate in the annual meeting for technical transfer and information exchanges (= "general workshop") 2. Total > 2 small workshops at target communities are held with representing locals (= "local workshop") 3. More than half of government extension officers and community leaders who participate in general workshop are certificated by BPPT and PICES with more than 70 % of understanding in the technologies and necessary background knowledge (as a good status).	1. Lists of participants from general workshops and local workshops 2. Certification officialized by BPPT training workshops with scores of exams (The exam will be provided from PICES expert in the workshop)	

Continued

Narrative summary	Objectively Verifiable Indicators (OVI)	Means of verification	Important assumptions
Output			
1. The influence of CFP upon human dimensions and ecological sustainability of coastal communities are explained based on specific hypotheses tests "DETECT and ASSESS"	1-1. >2 scientific reports or other publications on CFP are publicized or presented with quantified impacts/ influences (1 for HD, 1 for ecology/biology) 1-2. Test at least 1 hypotheses with available CFP related information 1-3. The explanation (oral presentations, brochure, and/or other media) in the impacts/potential impacts of CFP are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-4. The explanation (oral presentations, brochure, and/or other media) of the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are made in ALL general workshops and local workshops by experts and members of partner organizations, including perspectives from each area of science. 1-5. >2 scientific reports or other publication in the background mechanisms of CFP issues such as coral ecosystem degradation and change of aquatic fauna are publicized or presented in PICES (1 for HD, 1 for others)	1-1. Published scientific report/journal articles 1-2. and 1-3. c. Official agenda with the title of presentations and supplemental brochures d. Media provided by experts and partner organizations 1-5. Presentation in the PICES annual meetings …"MUST be done anyway" as a comment in the discussion	
2. Fish products distribution in the common supply chains in Indonesia is with consideration in potential health risks from CFP "AVOID"	2-1. >1 scientific reports or other publication in the potential health risks are publicized or presented. 2-2. > 1 model products with CFP controls are produced based on collected information in the Project 2-3. An integrative warning system is suggested based on the collected information, chemical analyses, and regional oceanography 2-4. Awareness of the stakeholders increases > 20% from the Project information and activities	2-1.a Published scientific report/journal articles 2-1.b Presentation in the PICES annual meetings 2-2. Model product with certification and consumers Willingness to Pay (WTP) upon it in the regional markets in the official surveys 2-3. Warning system with a Geographic Information System (GIS) platform 2-4. Responses to questionnaires in general workshops and local workshops (Adequate questionnaires will be developed during the Project with observers)	

Continued

Narrative summary	Objectively Verifiable Indicators (OVI)	Means of verification	Important assumptions
Output			
3. Sustainable monitoring continues after the termination of the project + "POST PROJECT SUSTAINABILITY"	3.1. Members of partner organizations operate monitoring activities at least once a season. 3.2. Members of partner organizations publish the status report of monitoring activities at least once a year. 3.3. Members of partner organizations hold > 2 committee meeting with PICES experts for activities and self improvement in the topic in the Project. 3.4. Saving of actively involved stakeholders, who joined to the monitoring >80% of fishing days, maintained or increased during the Project	3.1. Extension officers report 3.2. Status report with confirmation of supervisors 3.3. Agenda and RD* from the meeting 3.4. Responses to questionnaires in the first and final general workshops (Adequate questionnaires will be developed during the Project with observers) *...Record of Discussion	

Continued

Narrative summary			
Activities	**Input**		**Preconditions**
1-1. Carry out monitoring activities to obtain sufficient CFP-related data/information 1-2. Test multiple hypothesis with the available CFP-related data/information 1-3. Locate and synthesize statistics or reports in CFP impact in terms of human health 1-4. Conduct background study in mechanisms of CFP issues with priorities with specific hypotheses 2-1. Suggest specific alternative for Local fishermen to sell fishes with reduced CFP risks 2-2. Disseminate knowledge in CFP risks for Indonesian non-fisher stakeholders along supply chains	***PICES and MAFF side:*** 1. PICES experts – Proposal(s) in the protocol and design for CFP survey – Smartphone based monitoring/warning system (technologies, techniques and advices for application) – GIS and database techniques – Practical social mapping methods (“EZU” methodology) 2. Provide Software and Equipment – Photo-base sampling technologies, including new version of smartphone software (FishGIS) – Necessary survey devices including tablets and CFP survey toolkit 3. Training of Indonesian Counterpart Personnel in Japan – Program(s) covering: - Photo-base sampling technologies - GIS and database techniques - Practical social mapping methods (“EZU” methodology) in Japanese fields and case studies – Fees for traveling of the program participants* 4. Costs – Costs for the general workshop* – Costs for community workshop* – Costs for Equipment *...based on specific agreement with chief adviser through the Project coordinator of Japanese side	***Indonesian side:*** 1. Counterparts in the field of: – CFP and coral ecosystem survey & analysis – Fisheries Sciences (esp. coastal resources) – Food sciences/human health – Socio-economic survey and analysis – IT – Technical dissemination and developmental education (*e.g.*, extension office) 2. Facilities and equipment – Meeting Spaces (Jakarta and Gili Islands) – Web server (BPPT) and the sufficient Internet connections – Fundamental laboratory spaces for on-site research activities – Research vessel and its fuel – CFP survey toolkit – Fundamental experimental equipment – Part of tablets, cellphone and sim card for dissemination 3. Costs – Operation and maintenance of research vessel – Operation and maintenance of survey tools and devices – Personnel expenses of counterpart personnel – Agreed logistics for officers for workshops – Per-diem and other supports for despatched counterparts for the training program to Japan	Duties and responsibilities of BPPT and LIPI will not be changed. Organizations were reformed during the Project. The agreement with the logical framework (*i.e.*, PDM) should have been revised with necessary modifications

Continued

Narrative summary			
Activities	**Input**		**Preconditions**
3-1. Visualize measures and the process of problem solving to counterparts of target organizations and local communities in the Project 3-2. Monitor and provide technical assistance for financial and economic returns/uncertainties to participants (Fishers) from the Project 3-3. Suggest a management system for CFP risk warning with consideration in sustainability by Indonesian sectors 3-4. Provide technical guidance to maximize the efficiency of fishing activities with CFP monitoring 3-5. Provide opportunities to disseminate practical knowledge for target local community with consultation by PICES experts 3-6. Follow data management with related policies in Indonesia			

Appendix 4

Project Design Matrix — Review and self-assessment

<u>Activities</u>

- 1-1 List as done for the one location (Gili Matra), the target area.
- 1-2 List as not done. The original plan was to study multiple sites which would have enabled testing the hypotheses, but the pandemic prevented this being done so the activity should be listed as modified.
  - We should update the hypotheses/focus from *Gambierdiscus* to toxic benthic algae, as this is more representative of what is being found.
  - We should be selecting sites that enable us to test these hypotheses.
- 1-3 List as partially done. The bioassay used for CTX detection has low sensitivity, so it is not sufficient to say there is no ciguatoxin in the samples. There was discussion about alternate methods for measuring ciguatoxins. An Elisa kit is available but very expensive, and also apparently yields false positives.
- 1-4 List as done.
- 2-1 List as not done because there were no specific alternatives investigated. CFP was not found so there was no alternative to suggest. We also are not really ready for this step… too early in the process. List as not done.
- 2-2 List as done. The January 2023 workshop addressed this issue. A large number of stakeholders (fishers, fish brokers) were present, and a survey was distributed on the issue.
- 3-1 List as partially done. The FishGIS application may help with visualization but not problem-solving. We originally planned to do more, but perhaps the first morning of the January 2023 workshop was a start. We might list this as done if we consider only the Lombok region.
- 3-2 List as not done. Some economic data were collected as part of the survey, but we provided no assistance.
- 3-3 List as partially done. A "management plan" needs to be selected by the local community. However, we did address the risk warning (in the surveys). We provided information about methods to help manage coral reefs and we provided training and information on tools. However, a management plan should have survey protocols, frequency of sampling, *etc*. Even so, we met with the local government to recommend approaches but we needed to create a "system".
- 3-4 List as not done. We did not address fishing efficiency.
- 3-5 List as done. This was the January 2023 workshop.
- 3-6 List as done as discussed above.

<u>Outputs</u>

- Output 2: We did not study the supply chain in across Indonesia, just in Lombok. But Lombok may be a good representative example for many communities. We did not have enough time to go beyond Lombok, given the pandemic delay on the project.
- 2-1 List as done. Including the scientific reports written for BRIN, ITI, and PICES, we have accomplished this output. We also can include presentations at PICES Annual Meetings.
- 2.2 List as not done. We do not have a reliable and fast method for measuring ciguatoxin. Based only on bioassay from market fish, no CFP detected, but we are still waiting for analyses from spear fishing collections. We have to address toxin testing in the next project.
- 2-3 List as not done. FishGIS is a platform that could be used as a warning system, but it is not integrated with risk assessment. The next project should include better assessment approaches to establish risk.

- 2-4 The sense is that we did meet this goal, but we cannot quantify it. We gave a questionnaire at the January 2023 workshop, and there are press releases and interviews. We want to quantify these for the final report. We recognize that there now is an enhanced knowledge about CFP, but we are unable to quantify it.
- 3-1 List as done. Five surveys were done across different seasons. The next task is to utilize the MOU with Lombok as leverage to assist with monitoring activities, though we need to seek new approaches to solidify local sustainability of the project. The MOU is fixed, but the implementation agreement can be modified as needed. We should try to do this for the next project.
- 3-2 List this as done. Reports were published after each cruise.
- 3-3 List this as done. We had 7 PST meetings during this project.
- 3-4 List this as "modified". We were able to hold one in-person workshop but did not have a chance to implement the observation program. We have some economic information but cannot calculate income changes. This output was started but not completed because the pandemic interfered.

<u>Purpose</u>

- We used Lombok as a target area to work with, and by the advances here we can apply the system to the rest of Indonesia
- 1. List as "modified". There were not many fishers at the January 2023 workshop—the list of participants will be included in the final report. The project was designed with the expectation that the economies of these communities relied heavily on fishing (as with previous communities we have worked with). As the Gili Islands fishers have been shifting to tourism, there may not be 100 fishers there now. The lesson here is that we need to have a better idea about our target area before establishing specifics of purpose. However, we had ~100 participants at the workshop, including members of coastal communities, officials and researchers from regional agencies/institutions and universities, local government representatives, and other community groups. So, it can be listed as done if we do not focus only on fishers.
- 2. List as not done. We had only one workshop due to the short travel-possible timeframe.
- 3. List as "modified" and done. Though we did not create an exam for the workshop, all workshop participants received certificates.

<u>Overall goal</u>

- 1. List as not expected. This goal is very difficult to accomplish because we do not have a reliable and rapid method for detecting ciguatoxin. This topic falls under the Food Agency in Indonesia (not BRIN), as they are the ones to certify food. Also, the issue of food safety is different than that for shellfish, where a few can be tested to establish that all are safe. We have to be prepared to sample a larger subset of fish. This goal may not be expected in reality.
- 2. List as not expected. There were no evaluation surveys done.
- 3a. List as expected. It is possible that we might accomplish this goal. Indonesia has 4 seasons (wet, dry, and two transitional), and we can leverage local communities to monitor coral health. There is the additional drive for tourism in the Gili Matra region, and the need to communicate that healthy corals are less likely to have a CFP problem. We are helped by the local government wanting to preserve corals for tourism.
- 3b. List as expected. We need to consider ethics when developing a questionnaire—necessary for publication. International publications require an ethics review, so we should go through one of the PST member universities to ensure that the review will be accepted. We should develop the questionnaire and get it approved early in the next project.
- 3c. List as not expected. We do not have a social network

Appendix 4
Indonesian Survey Team

Name	Institution	Position and field of expertise
Dr. Shinta Leonita, MSi	TIP-ITI	Head of Agricultural Industrial Technology Study Program (TIP), Institute of Technology of Indonesia (ITI) / Responsible for Ciguatera Research Activities
Prof. Dr. Ir. Suhendar I Sachoemar, MSi	TIP-ITI and Research Center for Environment and Clean Technology BRIN	Coordinator of Ciguatera Research Activities / PI Exploration and Expedition Funding BRIN / Expert in Management of Fisheries and Environmental, Coastal and Marine Resources
Arief Rachman, M.Bio.Sc.	Research Center for Oceanography BRIN	Head of the Ciguatera Research Survey Team/ PI Ciguatera Research Activities Home for Biological and EnvironmentalPrograms/ Marine Plankton Expert
Dr. Riani Widiarti	Faculty of Mathematics and Natural Sciences, University of Indonesia	Researcher/Environmental Biologist Benthic Dinoflagellates
Diswandi, S.E., M.Sc., Ph.D.	Faculty of Economicsand Business, University of Mataram	Socio-Economic Researcher/Economistof Natural Resources and Environment
Dr. Ir. Ratu Siti Aliah, MSc	Research Center for Fishery BRIN	Researcher E-DNA Biodiversity Aquatic Biota/Environmental Bioremediation Expert
Hanny Meirinawati, M.Sc.	Research Center for Environment and Clean Technology BRIN	Water Quality Researcher / Aquatic Environmental Quality Expert
Dr. Yuliadi Zamroni, S.Si., M.Si	Faculty of Mathematics and Natural Sciences, University ofMataram	Plankton Algae Researcher and Biologist
Dra. Setiarti Sukotjo,MSc	TIP-ITI	Machine Learning Researcher Identifying Plankton and Dinoflagellates/Marine Biologist
Ir. Muhami, MSi	TIP-ITI	Traceability and Food Safety Researcher/ Biologist
Haryanti, S.Sos., M.M	Research Center for Environment and Clean Technology BRIN	Traceability and Food Safety Researcher/ Socio-Economist and Environmental Management Expert
Muhammad Faza Fadhillah, S.Si., M.M	Faculty of Mathematics andNatural Sciences, University of Indonesia	Researcher/Environmental Biologist Benthic Dinoflagellates
Aryo Caesar Pratomo	Faculty of Mathematics andNatural Sciences, University of Indonesia	Student/ Benthic Dinoflagellates

Emily Arjuna Melani	Faculty of Mathematics andNatural Sciences, University of Indonesia	Student/ Benthic Dinoflagellates
Ekky Ilham Romadhona, SPi	Research Center for Fishery BRIN	E-DNA and Water Quality Researcher /Aquatic Environmental Quality Expert
Novi Megawati, S.Pi.,MSI	Research Center for Fishery BRIN	E-DNA and Water Quality Researcher /Aquatic Environmental Quality Expert
Widia Apriani	Faculty of Economicsand Business, University of Mataram	Student / Biology
Suci Lastrini	Research Center for Oceanography BRIN	Water Quality Technician
Farah Fatikasari	Dept. Agroindustrial Technology-ITI	Student/Food Safety
Muhammad Hendy Abdullah	Faculty of Mathematics and Natural Sciences, University of Mataram	Researcher of Benthic Dinoflagellates