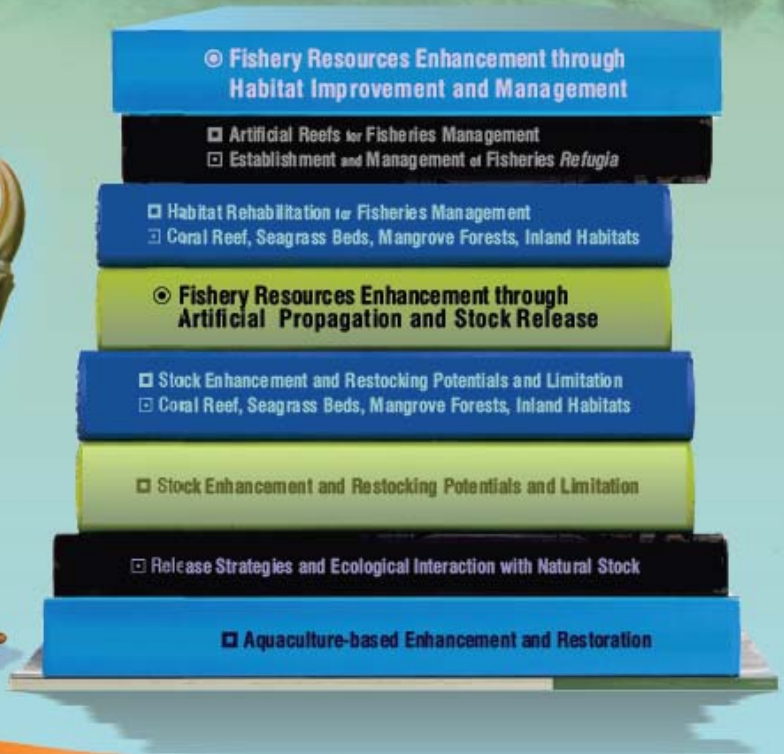
CONSOLIDATING THE STRATEGIES FOR FISHERY RESOURCES ENHANCEMENT IN SOUTHEAST ASIA

Proceedings of the Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region
Pattaya, Thailand 27-30 July 2015



Training Department
Southeast Asian Fisheries Development Center
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Consolidating the Strategies for Fishery Resources Enhancement in Southeast Asia

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Preface

Healthy aquatic ecosystem is a prerequisite for sustainable fisheries production. Southeast Asia is endowed with highly-productive fishery resources sustained by its highly-productive tropical ecosystems such as dense mangrove forests, seagrass beds, extensive coral reefs and riverine systems that run through fertile lands of the region. These ecosystems play critical roles in supporting the life cycle of a broad range of aquatic organisms — from breeding, spawning, and nursing up to growing; as feeding zones of aquatic organisms; and serving as important source of recruitment for wide diversity of aquatic organisms. Nevertheless, we have seen many cases of environmental degradation that comprise one of the causes of decline in wide variety of fishery resources in the region. Environmental degradation and decline of fishery resources are not only caused by natural fluctuations but also due to anthropogenic activities that include continued practice of over-exploitation, illegal fishing, destructive fishing, and environmental destruction, including massive clearance of mangrove forests. Such man-made activities could have economically benefited certain groups of people in a limited period, but in the end, such reckless activities in pursuit of immediate benefit would completely destroy the supporting role of aquatic ecosystems which assures healthiness and sustainability of the fishery resources. As a result, the fishers continue to suffer as their catch continues to diminish not only in terms of quantity but also in size and value, leading to food instability.

The Southeast Asian Fisheries Development Center (SEAFDEC) has been implementing programs in the region that ultimately aim to strike a balance between maintaining a healthy aquatic ecosystem and sustainable development of fisheries through the promotion of responsible fishing practices and ecosystem approach to fisheries management, and upholding stable socio-economic concepts for the sustainable livelihoods of stakeholders, especially the small-scale fisherfolk. One of the most relevant projects pursued by SEAFDEC until 2014 was the Rehabilitation of Fisheries Resources and Habitats/Fishing Grounds through Resources Enhancement. Conducted in Southeast Asia by the SEAFDEC Training Department (SEAFDEC/TD), this project was funded by the Japanese Trust Fund (JTF) of the Fisheries Agency of Japan. With the prospect of carrying out the subsequent phase of the project in 2015 that would emphasize on promoting sustainable fishery resources enhancement measures in critical habitats and fishing grounds, SEAFDEC with support from JTF convened the Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region in Pattaya, Thailand on 27-30 July 2015, in order that the outputs of the project after its completion in 2014 could be shared, while the experiences of the Member Countries on fishery resources enhancement are exchanged. Through such information sharing during the Symposium, the most practical strategies had been compiled while policy recommendations for sustainable fishery resources enhancement in Southeast Asia were developed.

For sharing valuable information that went into this Symposium Proceedings and for providing insights that facilitated the development of policy recommendations, we are most grateful to the experts and representatives from the SEAFDEC Member Countries as well as renowned scientists from Japan and Southeast Asia. We also offer our special thanks to the team from the SEAFDEC/TD for compiling the working papers and presentations, the Symposium Secretariat for keeping track of the records and minutes of the Symposium, and to those who in one way or another, have contributed to the realization of the Proceedings of the Symposium. To the Fisheries Agency of Japan through the Japanese Trust Fund, SEAFDEC is very much thankful for the continued support to its programs and activities, including the printing of this Symposium Proceedings.

Finally, to fisheries managers, fish farmers, fishers, and the rest of the fisherfolk, this publication is for all of you. We hope that our intended target stakeholders would make full use of the Proceedings as reference in undertaking activities that aim towards caring and rehabilitating the fishery resources for the benefit and food security of future generations in the Southeast Asian region.

Hajime Kawamura
Deputy Secretary-General of SEAFDEC,
Japanese Trust Fund Program Manager, and
Deputy Chief of SEAFDEC/TD

January 2016

THE SYMPOSIUM

Opening of the Symposium

The "Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region" was organized by SEAFDEC Training Department (TD) with the cooperation of SEAFDEC Aquaculture Department (AQD) and Secretariat in Pattaya, Thailand on 27-30 July 2015. Supported by the Japanese Trust Fund (JTF), the Symposium served as a forum to exchange the lessons learned and experiences gained from relevant resources enhancement initiatives of SEAFDEC and the Member Countries. The Symposium was also intended to facilitate the sharing of scientific knowledge on fisheries resources enhancement from renowned resource persons from Japan and the Southeast Asian countries.

In his Opening Remarks, the Secretary-General of SEAFDEC, *Dr. Chumnarn Pongsr*i substantiated the statements that although the Southeast Asian region is bestowed with productive coastal waters with rich ecosystems, the same aquatic resources are being degraded due to human activities carried out in pursuit of making proper ways of living.

Under such circumstance, there is a need to have a right balance between responsibly utilizing the aquatic resources for the benefit of humans and the environment, which could be attained through various approaches in sustainable resources conservation and enhancement.

After conveying the desire of SEAFDEC to continue maintaining the health of the ecosystem for food security, the SEAFDEC Secretary-General declared the Symposium open.

Background Information

Considering that most of the fishery resources in the Southeast Asian waters are already in various levels of decline and in an effort to address such concern, SEAFDEC with funding support from JTF, carried out a five-year program on the "**Promotion of Sustainable Aquaculture and Resource Enhancement in Southeast Asia**" starting in 2010. Implementation of the program had been based on two approaches: improvement of critical habitats/nursing grounds of fishery resources; and direct enhancement of fisheries resources through artificial propagation techniques. Under such program was the project on "**Rehabilitation of Fisheries Resources and Habitats/Fishing Grounds through Resources Enhancement**" conducted by TD. Such project served as immediate response to the concerns on the deteriorating coastal and inland ecosystems, and preventing further loss of habitats and eventual damage to the aquatic organisms.

Meanwhile AQD also carried out the project on "**Resource Enhancement of Internationally Threatened and Over-exploited Species in Southeast Asia through Stock Releas**e" which includes the establishment of strategies of stock enhancement through sustainable, responsible and environment-friendly approaches. The significant outputs of the project have also been disseminated to the countries in the region for the promotion of environment-friendly resource enhancement in Southeast Asia. As these projects involved identification of appropriate resource enhancement strategies that could serve as guide for the countries in the region in their efforts towards rehabilitating their respective fishery resources, the "**Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region**" was convened to compile and consolidate the necessary information and technologies that emanate from the project activities. Moreover, heeding the recommendations of the SEAFDEC Program Committee, experiences of the Southeast Asian countries on resources rehabilitation had been exchanged during the Symposium.

Therefore, the Symposium was organized with a two-pronged theme — **Fishery Resources Enhancement through Habitat Improvement and Management**; and **Fishery Resources Enhancement through Artificial Propagation and Stock Release**. Furthermore, based on the outputs of relevant SEAFDEC projects together with inputs from the Member Countries, the Symposium came up with **Policy Recommendations and Strategic Plans for Fisheries Resources Enhancement in the Southeast Asian Region**.

Participation

More than 80 participants representing the SEAFDEC Member Countries, namely: Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam attended the Symposium. The SEAFDEC Secretary-General, Deputy Secretary-General, as well as senior officials from SEAFDEC TD, AQD, Secretariat, the Marine Fishery Resources Development and Management Department (MFRDMD), and Inland Fishery Resources Development and Management Department (IFRDMD) also attended the Symposium. The country presentations served as basis for discussing the approaches adopted by the countries and sharing the countries' experiences in enhancing their respective resources for the benefit of the region as a whole.

Moreover, together with the participation of renowned resource persons and experts from Japan and Southeast Asian countries, the Symposium was able to develop the Policy Recommendations and Strategic Plans for Fisheries Resources Enhancement in the Southeast Asian Region, which could serve as guide for the countries as well as for SEAFDEC in conducting the subsequent phases of the relevant projects that would be carried out starting 2015.

Conclusion of the Symposium

At the end of the Symposium, the strategies and policy recommendations for Theme 1 on Fishery Resources Enhancement through Habitat Improvement and Management, and Theme 2 on Fishery Resources Enhancement through Artificial Propagation and Stock Release, were adopted. These strategies and policy recommendations could be referred to while formulating activities that aim to promote sustainable fisheries resources enhancement.

In closing, the Deputy Secretary-General of SEAFDEC, *Mr. Hajime Kawamura* offered the special thanks to the resource persons and the participants for their great contribution that led to the success of the Symposium.

Specifically, the SEAFDEC Deputy Secretary-General commended the participants for providing updated information on fisheries resource enhancement measures being promoted in their respective countries. Such information would be useful to strengthen the efforts of SEAFDEC in ensuring that activities on fishery resources enhancement would benefit the Southeast Asian countries.

After thanking also the secretariat of the Meeting for their support and cooperation, the SEAFDEC Deputy Secretary-General declared the Symposium closed.

THE SYMPOSIUM THEMES

Theme 1: Fishery Resources Enhancement through Habitat Improvement and Management

Sub-Theme 1-1: Artificial Reefs for Fisheries Management

Sub-Theme 1-2: Establishment and Management of Fisheries *Refugia*

Sub-Theme 1-3: Habitat Rehabilitation (Coral Reefs, Sea Grass Beds, Mangrove Forests, Inland Habitats)

Theme 2: Fishery Resources Enhancement through Artificial Propagation and Stock Release

Sub-Theme 2-1: Stock Enhancement and Restocking: Potentials and Limitations

Sub-Theme 2-2: Release Strategies and Ecological Interaction with Natural Stocks

Sub-Theme 2-3: Aquaculture-based Enhancement and Restoration

THE SYMPOSIUM PROGRAM

26 July 2015 (Sunday)	
1000-1500	Arrival of Participants at Symposium Venue
1500-1630	Pre-registration
27 July 2015 (Monday)	
0815-0830	Guests and Participants Seated
	Opening Session
0830-0900	o Opening of the Symposium by SEAFDEC Secretary-General
0900-0945	o Keynote Paper: **Improvement of Stocking Effectiveness** *Prof. Dr. Hiroshi Fushimi*, Faculty of Life Science and Engineering, Fukuyama University, Hiroshima, Japan
0945-1000	o Introduction of the Framework and Arrangements of the Sessions *Dr. Yuttana Theparoonrat*, SEAFDEC/TD, Thailand
1000-1030	Coffee Break
	Theme 1: Fishery Resources Enhancement through Habitat Improvement and Management
1030-1100	o Introductory Paper: **Overview of Current Status and Trends on Fisheries and Issues on Resources Enhancement in Southeast Asia** *Dr. Somboon Siriraksophon*, SEAFDEC Secretariat, Thailand
1100-1230	**Session 1 (Sub-Theme 1-1: Artificial Reefs for Fisheries Management)** ❖ Introduction of Session by Session Facilitator: *Mr. Bundit Chokesanguan*, SEAFDEC/TD ❖ Report of Successful Cases in Southeast Asian Region - **Artificial Reefs Management and Development in Malaysia** *Mr. Ahmad Zuwairi Zainudin*, Department of Fisheries Malaysia - **Royal Initiative Project: Coastal Fishery Resource Rehabilitation in Pattani and Narathiwat Provinces, Thailand** *Dr. Kamonpan Awaiwanont*, Department of Fisheries, Thailand
1230-1330	Lunch
1330-1430	**Session 1 (Sub-Theme 1-1: Artificial Reefs for Fisheries Management)***, cont'd* ❖ Pilot Study Presentation: **Environmental Survey Studies on Artificial Reefs in Rayong Province, Thailand: Technical Assistance in a Pilot Site for Suitable Designs of Resource Enhancement Practices** *Dr. Yuttana Theparoonrat*, SEAFDEC/TD ❖ Presentation by Resource Person: **Artificial Reefs Contribute to Marine Resources Enhancement** *Dr. Sadamitsu Akeda,* National Research Institute for Fisheries Engineering, Fisheries Research Agency, Japan

1430-1530	**Session 2 (Sub-Theme 1-2: Establishment and Management of Fisheries *Refugia*)** ❖ Introduction of Session by Session Facilitator: *Dr. Somboon Siriraksophon*, SEAFDEC Secretariat ❖ Report of Successful Cases in Southeast Asian Region - **Effectiveness of Blood Cockle Refugia: a Case in Community Fisheries Prey Nub 2, Sihanoukville, Cambodia** *Mr. Yos Chanthana*, Fisheries Administration, Cambodia - **Establishment of Marine *Refugia* in Malaysia: Conservation and Protection of Wild Penaeid Shrimp Stocks in Baram, Sarawak, and Wild Lobster Population in Tanjung Leman, Johor** *Mr. Mohd Ghazali bin A. Manap*, Department of Fisheries Malaysia
1530-1600	Coffee Break
1600-1700	**Session 2 (Sub-Theme 1-2: Establishment and Management of Fisheries *Refugia*)**, *cont'd* ❖ Report of Successful Cases in Southeast Asian Region - **Identification and Establishment of Fisheries *Refugia*: Experience in the Philippines** *Mr. Noel Barut*, National Fisheries Research and Development Institute, Bureau of Fisheries and Aquatic Resources, Philippines - **Development of Fisheries *Refugia* through Closed Seasons and Areas in the Gulf of Thailand** *Mr. Pirochana Saikliang*, Department of Fisheries, Thailand
1800-2100	Welcome Dinner
28 July 2015 (Tuesday)	
0830-1000	**Session 2 (Sub-Theme 1-2: Establishment and Management of Fisheries *Refugia*)**, *cont'd* ❖ Report of Successful Cases in Southeast Asian Region - **Fisheries Stock Enhancement: an Important Measure Towards Sustainable Development of the Fisheries Sector of Viet Nam** *Ms. Nguyen Thi Phuong Dzung*, Directorate of Fisheries, Ministry of Agriculture and Rural Development, Viet Nam ❖ Presentation by Resource Person: **Fisheries *Refugia*: A Regional Initiative to Improve the Integration of Fisheries and Habitat Management** *Dr. Somboon Siriraksophon*, SEAFDEC Secretariat
1000-1030	Coffee Break
1030-1230	**Session 3 (Sub-Theme 1-3: Habitat Rehabilitation (Coral Reefs, Sea Grass Beds, Mangrove Forests, Inland Habitats))** ❖ Introduction of Session by Session Facilitator: *Dr. Tetsuo Yanagi*, International Center for Environmental Management of Enclosed Seas, Japan ❖ Report of Successful Cases in Southeast Asian Countries - **Habitat Rehabilitation with the Participation of Community Fishers in Cambodia** *Mr. Lieng Sopha*, Fisheries Administration, Cambodia. - **Resources Conservation and Enhancement in Nam Houm Reservoir, Lao PDR** *Mr. Akhane Phomsouvanh*, Department of Livestock and Fisheries, Lao PDR

	❖ Report of Successful Cases in Southeast Asian Countries (*cont'd*) - **Inland Fisheries Habitat Management of Myanmar** *Ms. Nilar Kywe*, Department of Fisheries, Myanmar - **Critical Fish Habitat Management to Secure Marine Fisheries Production in Indonesia** *Dr. Andhika Anjaresta*, Marine Conservation Use, Ministry of Marine Affairs and Fisheries, Indonesia - **Restoration and Enhancement of the Fisheries in Philippines Lakes and Reservoirs** *Dr. Adelaida L. Palma*, National Inland Fisheries Technology Center, Bureau of Fisheries and Aquatic Resources, Philippines
1230-1330	Lunch
1330-1500	**Session 3 (Sub-Theme 1-3: Habitat Rehabilitation (Coral Reef, Sea Grass Bed, Mangrove Forests, Inland Habitats))**, *cont'd* ❖ Report of Successful Cases in Southeast Asian Countries (*cont'd*) - **Coral Reef Rehabilitation and Restoration: Experience of Malaysia** *Mr. Albert Apollo Chan*, Department of Marine Parks, Ministry of Natural Resources and Environment, Malaysia - **Habitat Conservation and Resources Enhancement in Seagrass Beds in Sriboya Island, Krabi Province, Thailand** *Dr. Nopporn Manajit*, SEAFDEC/TD ❖ Presentation by Resource Person: **Seagrass Bed Restoration by Fishermen at Hinase in Japan** *Dr. Tetsuo Yanagi*, International Center for Environmental Management of Enclosed Seas, Japan
1500-1530	Coffee Break
1530-1700	**Plenary Discussion on Strategies and Ways Forward for Theme 1: Fishery Resources Enhancement through Habitat Improvement and Management**
29 July 2015 (Wednesday)	
	Theme 2: Fishery Resources Enhancement through Artificial Propagation and Stock Release
0800-0830	o Introductory Paper: **Fishery Resources Enhancement: An Overview of the Current Situation and Issues in the Southeast Asian Region** *Dr. Ma. Junemie Hazel Lebata-Ramos*, SEAFDEC/AQD, Philippines
0830-1000	**Session 4 (Sub-Theme 2-1: Stock Enhancement and Restocking: Potentials and Limitations)** ❖ Introduction of Session by Session Facilitator: *Dr. Felix G. Ayson*, SEAFDEC/AQD ❖ Pilot Site Study Presentation: **Community-Based Stock Enhancement of Abalone, *Haliotis asinina* in Sagay Marine Reserve: Achievements, Limitations and Directions** *Dr. Nerissa D. Salayo*, SEAFDEC/AQD

	❖ Report of Successful Cases in Selected Countries - **Potentials and Limitations of Stock Enhancement Programs in Japan** *Dr. Tetsuo Fujii*, Fisheries Division, Japan International Research Center for Agricultural Sciences, Japan - **Success of Fish Stock Enhancement and Restocking in Inland Waters of Indonesia** *Dr. Endi Setiadi Kartamihardja*, Research Center for Fisheries Management and Conservation, Agency for Marine and Fisheries Research and Development, Indonesia - **Current Status of Fish Stock Enhancement in Thailand** *Dr. Suchart Ingthamjitr*, Kampaengsaen Campus, Kasetsart University, Thailand
1000-1030	Coffee Break
1030-1200	**Session 5 (Sub-Theme 2-2: Release Strategies and Ecological Interaction with Natural Stocks)** ❖ Introduction of Session by Session Facilitator: *Dr. Takuro Shibuno*, SEAFDEC/AQD ❖ Pilot Study Presentation: **SEAFDEC/AQD Stock Enhancement Initiatives: Release Strategies Established** *Dr. Ma. Junemie Hazel Lebata-Ramos*, SEAFDEC/AQD ❖ Report of Successful Cases in Selected Countries - **Stock Enhancement of Portunid Crabs in Japan** *Dr. Yasuhiro Obata*, National Research Institute of Fisheries and Environment of Inland Seas, Fisheries Research Agency, Japan - **Approaches in Rebuilding Sea Urchin and Sea Cucumber Populations in the Philippines** *Dr. Marie Antonette J. Meñez*, Marine Science Institute, University of the Philippines
1200-1300	Lunch
1300-1500	**Session 6 (Sub-Theme 2-3: Aquaculture-based Enhancement and Restoration)** ❖ Introduction of Session by Session Facilitator: *Dr. Evelyn Grace de Jesus-Ayson*, SEAFDEC/AQD ❖ Presentation by Resource Person: **Aquaculture-based Restoration and Stock Enhancement of Tiger Shrimps in the Philippines** *Dr. Jon P. Altamirano*, SEAFDEC/AQD ❖ Report of Successful Cases in Southeast Asian Region - **Aquaculture-based Enhancement and Restoration of Giant Clam in Thailand** *Dr. Jintana Nugranad*, Department of Fisheries, Thailand - **Aquaculture-based Enhancement and Restoration of Many-colored Abalone Resources (*Haliotis diversicolor* Reeve, 1846) in Bach Long Vi National Marine Protected Area in Viet Nam** *Dr. Hoang Dinh Chieu*, Directorate of Fisheries, Fisheries Administration, Viet Nam
1500-1530	Coffee Break
1530-1700	**Plenary Discussion on Strategies and Ways Forward for Theme 2: Fishery Resources Enhancement through Artificial Propagation and Stock Release**

30 July 2015 (Thursday)	
0800-1500	Fisheries Resources Enhancement Site Visit at Kung Kraben, Chantaburi, Thailand
1530-1700	**Adoption of Strategies and Policy Recommendations** Facilitators: *Dr. Chumnarn Pongsri* and *Dr. Yuttana Theparoonrat*
1700-1730	Closing the Symposium
1830-2100	Farewell Dinner

Poster Exhibition

Arranged in a space outside the Symposium venue, the poster exhibition displayed the activities carried out by SEAFDEC and ASEAN-SEAFDEC Member Countries on priority issues relevant to fishery resources and stock enhancement. Running simultaneously with the Symposium, the Exhibition was intended to provide information to guests and participants on the issues.

POLICY RECOMMENDATIONS AND STRATEGIC PLANS OF ACTION

Fishery Resources Enhancement through Habitat Improvement and Management

Issues/Challenges	Recommendations	Strategic Plan of Action
Artificial Reefs Management	➢ Best practices on installation of artificial reefs (ARs) should be promoted to ensure the protection of aquatic species during their life cycle and allowing them to reach optimum size. ➢ Planning and deployment of ARs should be undertaken, taking into consideration the following: • Clear purpose of ARs, *e.g.* resources enhancement; • Results from relevant feasibility studies, including cost-benefit analysis, socio-economic analysis, financial analysis, among others; • Involvement of researchers, policy makers, fishing communities, local government units and other stakeholders in the planning process; • Results of site suitability evaluation, *e.g.* existing corals/fishes, seabed conditions, oceanographic conditions, water circulation patterns; • Choice of AR design(s) that should suit seabed conditions and purpose; and • Certainty that installed ARs does not create pollution to the marine environment. ➢ ARs should be regularly monitored (over time, and seasonally) using appropriate parameters, *e.g.* conditions of ARs, primary productivity, abundance and diversity of aquatic species (fish, macro benthos, etc.). The impacts of ARs on environmental conditions, *e.g.* water current, turbidity, and sedimentation among others should also be monitored. ➢ Regular monitoring and evaluation of the effectiveness of AR programs should be conducted (for short-medium and long-term) by comparing various indicators before/after or within/outside ARs. Correlation of the abundance of species inhibiting the ARs and other environmental factors, *e.g.* bottom condition, water current/condition, should also be established.	➢ Developing Regional Guidelines on Best Practices for Installation of the Artificial Reefs (ARs)

Issues/Challenges	Recommendations	Strategic Plan of Action
	➢ Cost-benefit analysis of AR deployment program(s) should be conducted, taking into consideration the resources, environmental and socio-economic benefits that could be gained from the program(s). Data to be collected could include investment costs (ARs construction and deployment), fisheries production by fishing gear and fishers' incomes before and after ARs deployment, and other ecosystem services.	
	➢ Implementation of AR program(s) should be integrated with other fisheries management measures, *e.g*. fishing regulations that include among others, prohibition of encroachment of commercial fishing activities, establishment of conservation/fishing zones, to ensure that resources are utilized in sustainable manner. Stakeholders' consultations on the management of ARs should be conducted to elaborate responsibility of stakeholders and fishers in the management plan.	➢ Integrating fisheries management measures/principles in AR management programs
	➢ AR programs could be implemented in the coastal and offshore (if necessary) areas to ensure that the life cycle of both of demersal and pelagic species is sustained.	➢ Integrating ARs in policies and plans for coastal and offshore fisheries resources conservation, management and development
	➢ A list of expertise on ARs and available resources should be compiled for reference and usage by the countries.	
Integrating Fisheries and Habitat Management	➢ Fisheries *refugia* could be implemented to complement the existing conservation/management measures, by integrating it with the fisheries objectives of protecting critical life cycle, *e.g.* spawning, nursing, broodstock aggregation, and migratory routes of species targeted for management.	➢ Promoting the establishment of fisheries *refugia* as a tool for integrating fisheries and habitat management
	➢ Selection of site(s) for fisheries *refugia* should be based on scientific information and local knowledge especially in identifying the areas that are natural habitats for critical stages of the life cycle of species targeted for management, *e.g.* spawning, nursery grounds, broodstock aggregation, migratory routes. The area of the Fisheries *Refugia* should be manageable by concerned stakeholders.	➢ Conducting scientific research programs and stakeholders consultation to support the identification of suitable sites and establishment of fisheries *refugia* for target species, and coming up with scientific evidence that harmonize with local knowledge to serve as basis for developing appropriate management measures
	➢ Regulations on fishing activities in the *refugia* (*e.g.* restriction of harvestable size, fishing seasons, fishing gears/methods) should be enforced taking into account up-to-date scientific data (*e.g.* spawning season, size at maturity, larval study), which should be relevant and correspond to the activities of host communities.	

Issues/Challenges	Recommendations	Strategic Plan of Action
	➢ Community participation should be optimized for the establishment and management of fisheries *refugia* (*e.g.* identification of suitable sites, establishment/implementation of management measures including MCS) and collaboration with relevant government agencies at local/national levels should be strengthened so that the fisheries *refugia* could be as self-sustaining as possible.	➢ Ensuring the sustained participation of key stakeholders in the planning, sites selection and development of management measures for fisheries *refugia*
	➢ Sub-regional cooperation should be strengthened for the establishment of fisheries *refugia* for management of trans-boundary species (*e.g.* Indo-pacific mackerels) that move across the EEZs of more than one country.	➢ Enhancing regional and sub-regional collaboration for the establishment of fisheries *refugia* system for transboundary fish stocks management
Degradation of (fish) habitats in the Southeast Asian region	➢ Fish habitat restoration priorities in different water resources in the region should be reviewed.	➢ Making habitat restoration a priority at national levels
	➢ Effectiveness of habitat restorations and resources enhancement in inland water resources such as lakes should be determined through the following methodologies: • Conduct of baseline studies • Harmonization of legal and juridical mandates of authorized agencies, including local governments responsible for water resources • Pooling of government funds and resources • Mobilization of local communities and/or other stakeholders • Application of technical tools to reconstruct the fisheries • Improvement of buffer zones ➢ Habitat restoration should be implemented through suitable co-management arrangements taking into consideration the importance of the ecosystem ➢ The "Satoumi Concept" could be considered as one of the Integrated Coastal Management approaches for habitat restoration. Remarks: Developed by Japan, the "Satoumi Concept" is a form of unified management system for land and sea, where management mechanisms for coastal waters move inland, one step away from integrated coastal management so that land and sea are brought under a unified management policy. In short, the "Satoumi Concept" is meant for environmental conservation of coastal areas in harmony with human interaction on land.	➢ Developing the best practice guidelines on habitat restoration for different water resources such as inland and marine, in conjunction with fisheries resources enhancement programs

Issues/Challenges	Recommendations	Strategic Plan of Action
	➢ Enhancement of fish populations in restored habitats could be carried out by applying appropriate techniques such as installation of ARs, establishment of fisheries *refugia*, restocking, and/or mangrove reforestation, etc.	➢ Rebuilding sustainable fish populations in restored habitats
	➢ Since indigenous knowledge is crucial for habitat restorations, applicable only in most cases for specific areas and the culture of local communities, science and indigenous knowledge should be combined to ensure the effectiveness of habitat restorations.	➢ Undertaking baseline studies based on indigenous and scientific knowledge
	➢ Impact assessment of lost natural habitats (*i.e*. coral reefs, sea grass and sea beds) due to human activities (irresponsible fishing or pollution) should be conducted as well as raising the awareness of stakeholders on the importance of habitats to humans and fishes.	➢ Conducting impact assessment of lost natural habitats, and raising the awareness of stakeholders on conservation and protection of the natural habitats

POLICY RECOMMENDATIONS AND STRATEGIC PLANS OF ACTION

Fishery Resources Enhancement through Artificial Propagation and Stock Release

Issues/Challenges	Recommendations	Strategic Plan of Action
Potentials and Limitations of Stock enhancement and Restocking		
➢ Selection of species and release area considerations • Lack of species and site specific protocols/guidelines for successful stock enhancement/restocking • Techniques (specific to stock enhancement) for ex-ante impact assessment and monitoring (biological, environmental, social and economic) are not available	➢ Stock enhancement and restocking activities should take into consideration the following: • Development of species- and site-specific strategies to ensure success of activity; - Give high importance to availability of scientific information/biology of the target species. - Ensure appropriate choice of species – benthic over pelagic and migratory species - Provide adequate preparation/rehabilitation of receiving habitats to ensure likelihood of success. - Give preference to marine reserves as release sites for managed monitoring and harvesting.	➢ Developing Regional Guidelines or criteria for feasibility assessment and improvement and disseminating the Guidelines to Member Countries [**Note**: the Guidelines will take into considerations the elements for higher success of restocking and stock enhancement covering the technical (choice of species, biology/life cycle of species, sustainable supply of quality seeds/stocks), environmental (suitability of site), social/institutional (involvement and strong support of local communities, local government agencies and research institutions), and economic aspects (funds)]. ➢ Formulating a 'Strategy or Framework for Sustainability of Stock Enhancement Initiatives' and disseminating this Framework to Member Countries
➢ Strategy to ensure sustainability of activities and gains/benefits achieved from stock enhancement is not yet developed ➢ Although benefits from stock enhancement and restocking are urgently needed and appreciated, the technical capabilities and financial resources of most Member Countries could be limited	• Active involvement of the local people (especially the fisherfolks) in the planning, implementation and monitoring activities, with understanding that the objectives of the activity and its long-term sustainability will largely depend on their continuous active involvement and participation; • Well-defined governance arrangements, and access and harvest rights through consultations with various stakeholders in enhancement/ restocking activities;	

Issues/Challenges	Recommendations	Strategic Plan of Action
Potentials and Limitations of Stock enhancement and Restocking		
	• Conduct of cost-benefit analysis of release and stock enhancement activities; • Implementation of long-term planning with all stakeholders to ensure availability of sufficient funds and manpower resources; • Participation of the local government units and their assured commitment to adopt and sustain stock enhancement initiatives (with donor funds) beyond project completion date; • Creation of supplemental and alternative livelihood strategies to encourage fisherfolks' participation and compliance to regulations; • Promotion of multi-stakeholder involvement and embedding conflict management in all phases of stock enhancement activity (including planning for and prioritizing a bottom-up approach in policy & regulation formulation); • Implementation of regulations and networking with enforcement agencies for protection of released stocks and management of recaptures; and • Implementation of activities, in conjunction with other management and conservation measures, to ensure that resources are utilized in sustainable manner.	

Issues/Challenges	Recommendations	Strategic Plan of Action
Release strategies and ecological interaction with natural stocks		
➢ Lack of release protocols/guidelines (specific to stock enhancement) Capacity of Member Countries on ecological risk assessment and effective monitoring needs to be assessed and strengthened	➢ Assess the initial status of the community structure of the release site and monitor over time to determine the effects of interaction with the released stocks ➢ Determine the appropriate size of release of stocks to ensure high survival, avoidance of predators and economic efficiency ➢ Conduct proper behavioral conditioning of stocks prior to release ➢ Promote regular and long-term continuous monitoring to determine effectiveness ➢ Develop effective marking techniques for stock enhancement • Determine appropriate tags for proper identification of released stocks and for effective long- term monitoring ➢ Based on needs of Member Countries, enhance their capacity on the application of decision-making tools for stock release (*e.g.* ecological risk assessment tool)	➢ Establishing release protocols/guidelines based on scientific findings and in accordance with existing policy instruments/ regulations ➢ Implementing effective institutional frameworks, policy instruments for the release of stocks, monitoring and enforcement mechanisms at national and local levels ➢ Developing and implementing capacity building programs on the application of decision-making tools for stock release
Aquaculture-based Enhancement and Restoration		
➢ Genetic, health and biodiversity considerations • Indiscriminate stocking or translocation of non-indigenous species/stocks poses adverse genetic and health risks	➢ Importance of the genetic and health information of species should be well recognized to minimize genetic effects, transfer of diseases and protect biodiversity	➢ Formulating mechanism that will ensure that stocks for release are healthy/disease-free (for instance, thru health certification) and will not pose genetic risks

Issues/Challenges	Recommendations	Strategic Plan of Action
Aquaculture-based Enhancement and Restoration (cont'd)		
		➢ Strengthening IEC (information, education and communication) activities to enhance public awareness on genetic and health risks related to stock release and the need for precautionary measures following relevant Guidelines developed and promoted by FAO
➢ Lack of seed production techniques and facilities intended for enhancement and restocking activities	➢ Increase government investments and solicit donor contributions for aquaculture R&D and related facilities to support wide-scale and high-impact stock enhancement and restocking initiatives	➢ Fostering strong collaboration among R&D institutions, national and local government, and local communities on initiatives that will support wide-scale and high-impact stock enhancement and restocking initiatives

KEYNOTE PAPER

The Symposium was set into motion by the Keynote Presentation of *Prof. Dr. Hiroshi Fushimi* from the Faculty of Life Science and Engineering, Research Institute of Marine Bio-resources of Fukuyama University in Hiroshima, Japan. His paper on **Improvement of Stocking Efficiencies** jump-started the foregoing discussions on stock enhancement as means of sustaining the fishery resources for human consumption. With emphasis on actual stock enhancement activities in rural areas, his presentation also broached the concept of "Area-Capability" as means of harmonizing ecosystem health with the welfare of humans to pave the way for enhancing the sustainability of the ecosystems and livelihoods of people in coastal areas.

Prof. Dr. Hiroshi Fushimi presenting his Keynote Paper

Dr. Fushimi mentioned that the various tools for fisheries management including control of fishing effort and gear that have been promoted, the objective of which is to obtain sustainable yield, take into account the fact that yield is dependent on the fluctuation of recruitment levels. Therefore, it has become imperative to undertake enhancement activities to strike a balance between yield and recruitment levels.

Dr. Fushimi cited as an example the enhancement of *kuruma* prawn stocks in Hamana Lake in Shizuoka Prefecture, Japan as a model for stock enhancement in rural areas following the Area-Capability Cycle. He added that having a thorough understanding of the species' life cycle and habitat sequences would address the bottlenecks in the population dynamics of species targeted for enhancement. Equipped therefore with adequate knowledge on the basic biology and distribution of the *kuruma* prawn (*Penaeus japonicus*), a pilot project on stock enhancement was carried out in Hamana Lake with the involvement of fishermen's associations from the surrounding villages, especially in releasing the prawn larvae. Such collaboration resulted in improvements not only in terms of recruitment but also yields of the prawns. Seeing such positive results, fishers in the areas have henceforth been engaged in the stock enhancement activities, and have taken over the activities after the completion of the pilot project.

During the ensuing discussion, Dr. Fushimi reiterated that the conduct of studies to improve scientific knowledge on the life cycle of species targeted for stock enhancement would be necessary, likewise the need to examine all the parameters relating to environmental conditions and human activities, as these could create impacts on the dynamics of the target species.

SEAFDEC Secretary-General Dr. Chumnarn Pongsri congratulating Prof. Dr. Hiroshi Fushimi after his Keynote Paper presentation

In addition, obstacles caused by fluctuations of stocks after releases should be kept under control, especially when and where such obstacles occur in the life cycle of the target species, Dr. Fushimi added. Keeping such obstacles at bay would lead to better understanding of the concerns in natural recruitment, prevent any obstruction of the species' life cycle, and facilitate the development of appropriate and effective stock enhancement technologies and strategies that ensure the sustainability of the species.

Dr. Fushimi also cited that since difficulties in obtaining knowledge on the life cycle of some species still prevail, it is therefore necessary to address such concern prior to embarking on any stock enhancement of particular species.

Improvement of Stocking Efficiencies

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Introduction

This paper focuses on the principal idea or theory of stock enhancement, and the future prospect of "how to continue the actual activity of stock enhancement in rural areas," based on the concept of "Area-Capability". It should be recalled that an excellent article of Beverton and Holt (1957) on the Dynamics of Exploited Fish Population Dynamics, is the most important reference to be able to understand the effect of fisheries activity of humankind on the fishery resource species. The catch equation of Beverton and Holt (1957) is therefore the principal guiding idea for exploited fishery resources dynamics.

The main parameters of the equation are, ***F*** as the fisheries mortality, ***M*** natural mortality, a_c age of first caught, and ***K*** growth coefficient of von Bertalannffy's growth curve. ***M*** and ***K*** are determined by natural conditions and apart from human activity. However, ***F*** and a_c are decided by fisheries activities. So, the measuring tool for fisheries management is by controlling fishing effort and gear. Also, it is easy to understand that ***Y*** yield is dependent on fluctuation of ***R*** recruitment. Nevertheless, studying the basic biology and distribution of resource species is also an essential effort to clarify the dynamics of target species. In reality, yield (***Y***) is fluctuating from year to year and could suffer from recruitment fluctuation. It is therefore necessary to find the way of getting more stable yield. To get the effect of fluctuation of ***R***, **Y/R** is used for developing fisheries management practice.

$$Y = FW_\infty R \exp\{-M(a_c - a_r)\} \sum_{n=0}^{3} \frac{\Omega_n \exp\{-nK(a_c - a_0)\}}{F + M + nK} \times [1 - \exp\{-(F + M + nK)(a_d - a_c)\}]$$

Where, $(a_c \leqq a < a_d)$

$$\Omega_0 = -\Omega_3 = 1, \quad -\Omega_1 = \Omega_2 = 3$$

Life Cycle of Coastal Fishery Resources

Fig. 1 shows the schematic explanation of the life cycle of fishery resources organisms, such as giant clam, sea cucumber, penaeid shrimp, and spiny lobster. There are common pattern in the life cycle. In general, the life cycle of fishery resources organisms consists of benthic phase and pelagic phase.

Usually, larval period has pelagic phase as planktonic life and at the end of pelagic life, larvae attain metamorphose stage and settle to the bottom. So, larval migration or transportation success affects the individual number of settlement and recruitment.

In other words, survival in pelagic phase and success of settlement would affect the abundance of the fishery resource organisms. Thus, settlement success which is a bottleneck of the population dynamics of fishery resources should be addressed and/or enhanced.

As a researcher at the stock enhancement center, *Prof. H. Fushimi* was in-charge of the *kuruma* prawn release activity

Prof. Fushimi cited that:

After everything was finished, fishers knew how and what to do for Kuruma prawn intermediate culture. There was no need to explain everything to them.

Working together is the key to improve confidence of scientific data.

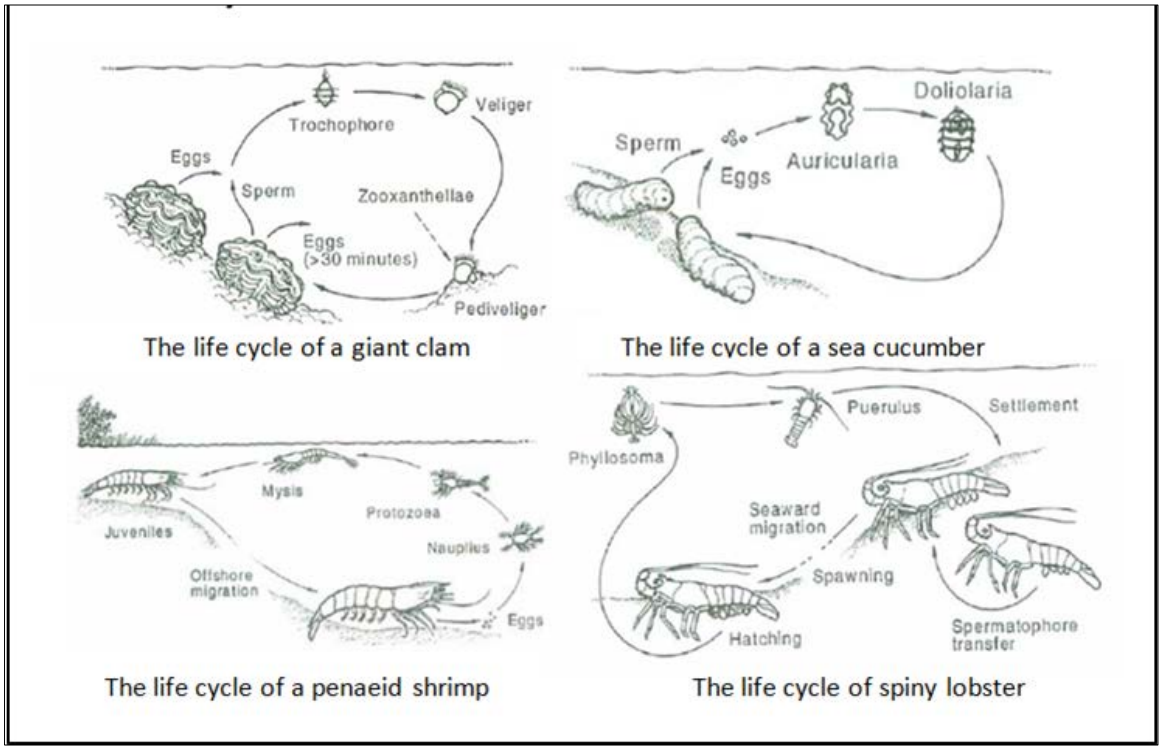

Fig.1. Schematic diagram of life cycles of some organisms

Fig. 2 shows a schematic explanation of the life cycle of *kuruma* prawn. In the early spawning season, April to May, old broodstocks spawn in deep open sea areas, and the hatched-out larvae spend planktonic life and are transported by water current. The postlarvae migrate to immediate coastal zones, and then settle in tidal flats. These areas are very important as nursery ground of larval *kuruma* prawn. After attaining 3 cm in body length (BL), the larvae move to shallow areas, 4-6 m in depth connecting the coastal zones. Here, the adult *kuruma* prawn become sexually mature and start to mate. After mating, the adult migrate to shallow open sea connecting the shallow areas, and then spawn in shallow open sea during July to August, *i.e.* late spawning season. Hatched-out larvae also spend planktonic life and settle during August to November. After first spawning, young broodstock migrate to open sea. From this schematic explanation of the life cycle, it is easy to understand the importance of habitat sequences. Without habitat sequences, *kuruma* prawn could not complete their life cycle.

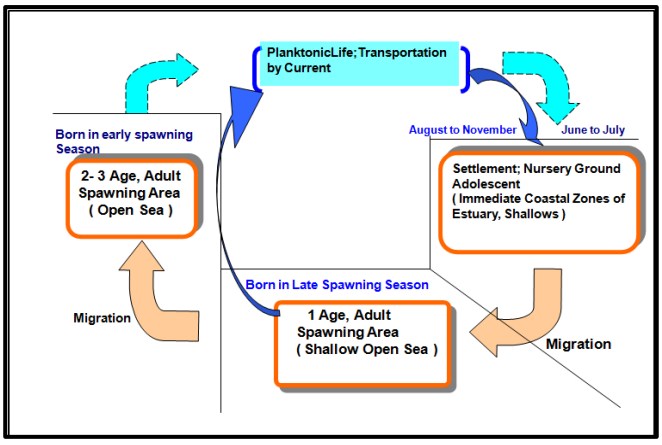

Fig. 2. Schema of the life cycle of *kuruma* prawn (Adapted from Kurata (1986))

Reclamation of Coastal Areas in Japan

In Japan, severe land reclamation occurred during the era of industrial areas construction and development in 1960s. As a result, the yield of coastal fishery resources markedly declined from 1960s to 1970s. Moreover, as large beach and seagrass habitats had been reclaimed, costal fishery resources lost their habitats and deteriorated. Habitat sequence is an essential condition of completing the life cycle of coastal resources destroyed by severe land reclamation. The Federal Government therefore conducted a public project on stock enhancement of fishery resources, as compensation for fishermen (**Fig. 3**). Known as *Tsukuru Gyogyo* in Japanese, stock enhancement centers were established in each Prefecture under this project.

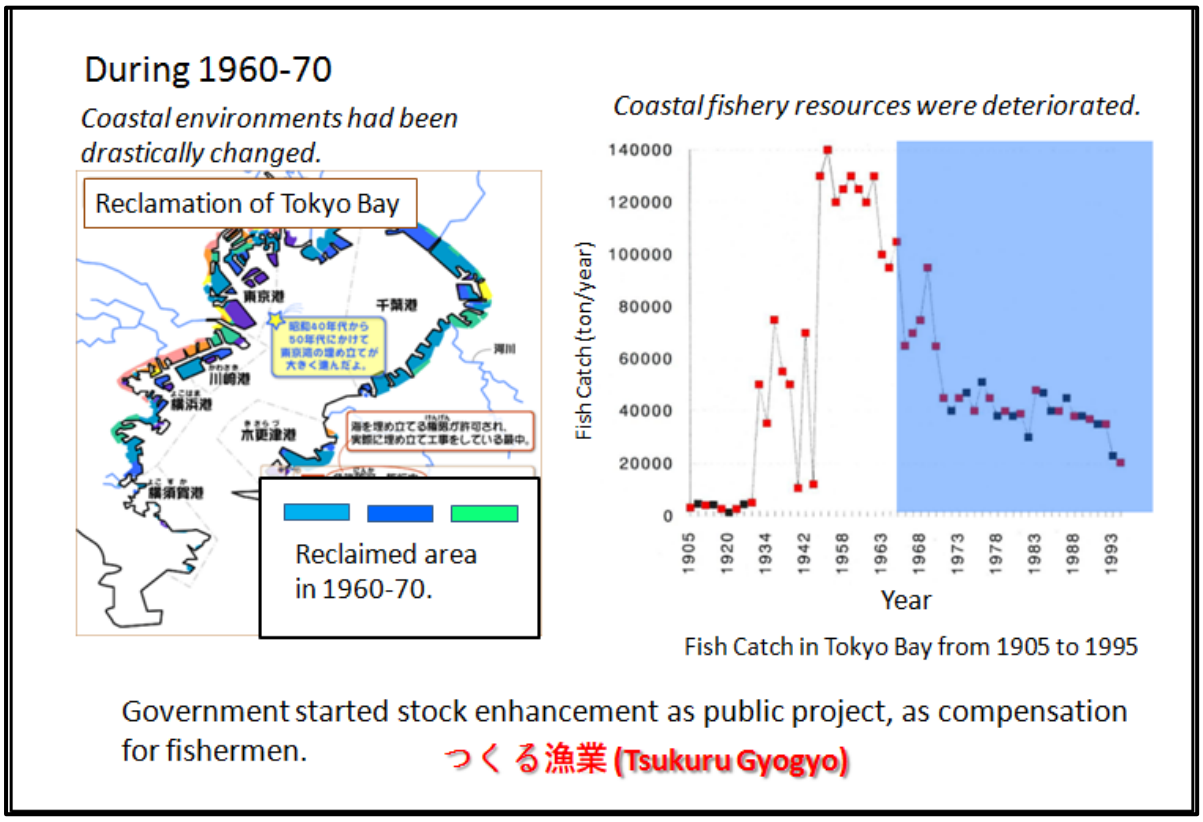

Fig. 3. Reclamation of Coastal Area in 1960s to 1970s

Case Study of Good Practice of Stock Enhancement: Hamana Lake

Stock enhancement of *kuruma* prawn in Hamana Lake in Japan has been successful (**Fig. 4**). Hamana Lake is located in Shizuoka Prefecture, central Pacific area of mainland Japan. Fishermen's association of 7 villages around Hamana Lake had been conducting larval prawn releases as stock enhancement for more than 20 years by themselves. The fishermen also conduct environmental monitoring and conservation activities.

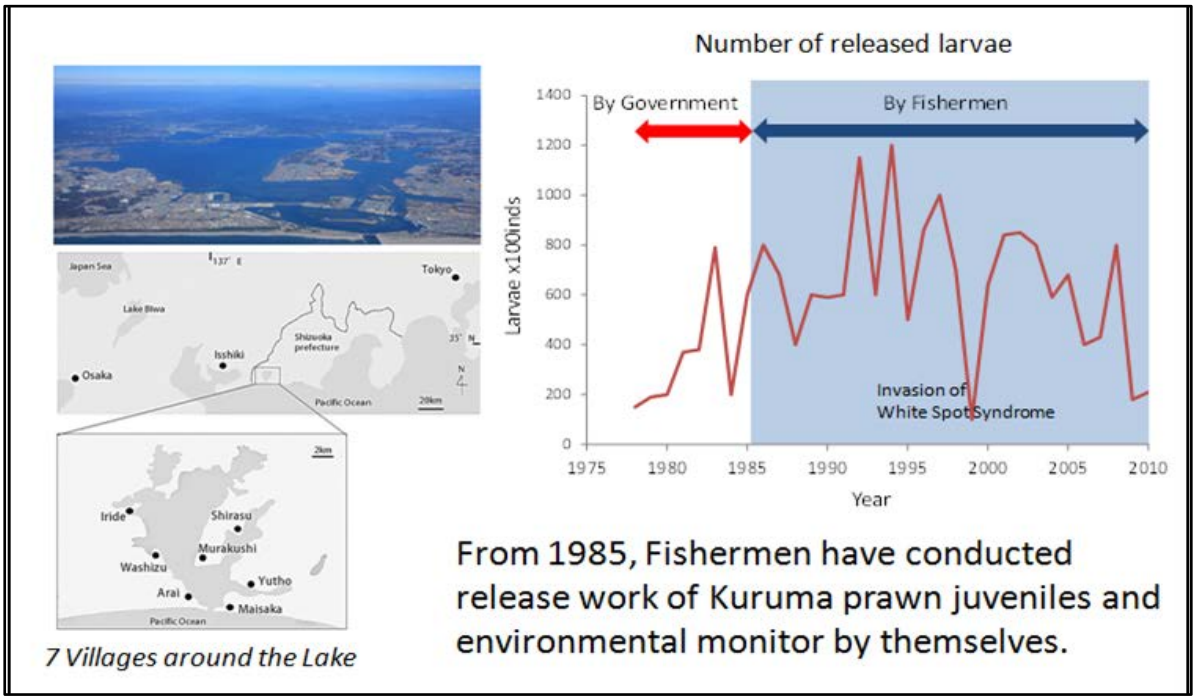

Fig. 4. Good stock enhancement practice in Hamana Lake, Japan

Model of Recapture Process for Hatchery-raised *Kuruma* Prawn Postlarvae in Shonai-ko, Lake Hamana

Fig. 5 shows the plan for detecting stock enhancement efficiency and the driven model to determine the recovery of released juveniles. The yield of each cohort is determined using the model. The Kuruma Prawn Stock Enhancement Technology at Hamana Lake, and mathematical model for evaluation of stocking effectiveness had been established. The stock enhancement of *kuruma* prawn by releasing hatchery-raised juveniles had improved the recruitment. Thus, the yield had increased corresponding to the amount of juveniles released. Fruitful results of many research studies are published as scientific papers. But, scientific papers were not the only driving power for continuing stock enhancement activities. What is the driver of continuing stock enhancement activity by fishermen themselves? This could be gleaned from the life of fishermen in local communities. Why fishermen wanted to continue stock enhancement activity by themselves? This leads to the history of Kuruma Prawn Stock Enhancement Project with special reference to the relationship among fishermen and researchers or local government staff.

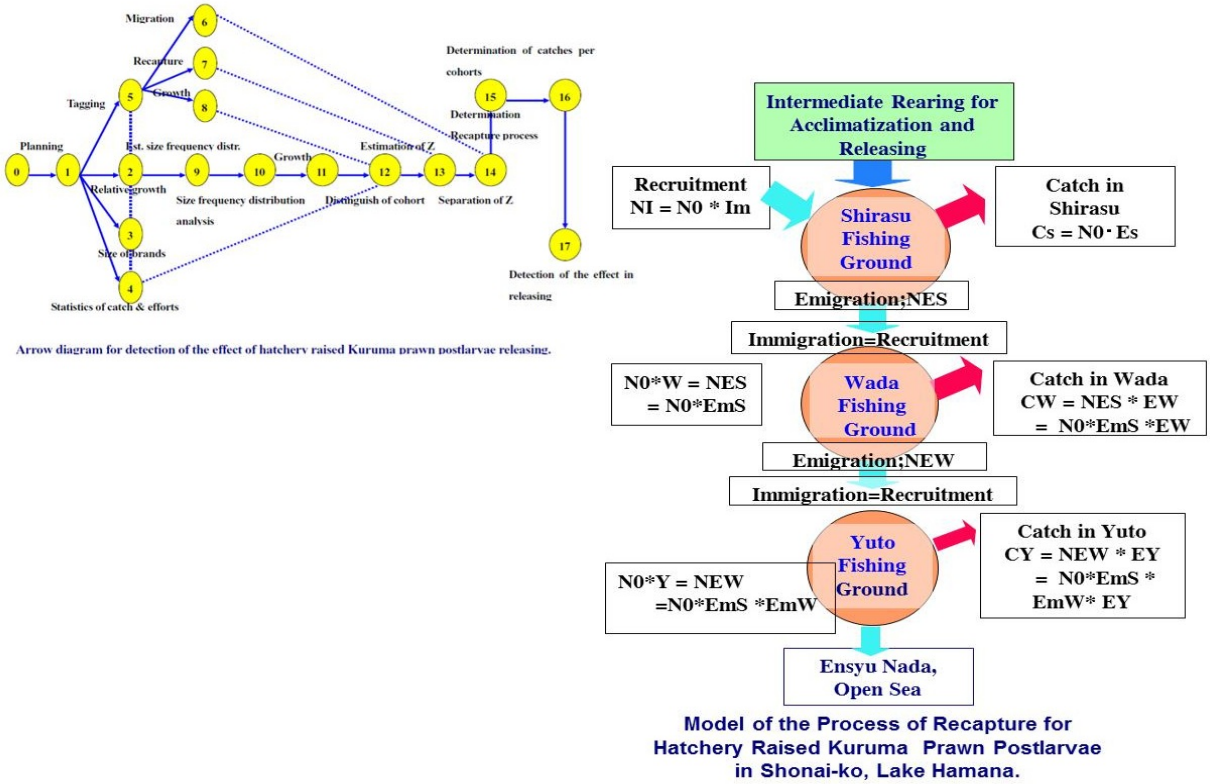

Fig. 5. Recapture for hatchery-raised *kuruma* prawn postlarvae in Shonai-ko, Lake Hamana

What Changes Had Occurred?

In the case of Hamana Lake, *kuruma* prawn was selected as target species for stock enhancement because *kuruma* prawn is the area's most economically-important species. In the initial stage of the project, there were no appropriate aquaculture technology of prawn, and environmental information was quite limited, even if it was necessary to come up with release schedule and sites. Researchers working for the stock enhancement center carried out several environmental studies and technology improvement on their own. Any kind of collaboration and trusts could not be extended by the fishermen around lake. However, two years later, researchers and young fishermen living in Shirasu Village (**Fig. 6**) started collaborating with the center, and succeeded in releasing 3 million larvae and 10 million larvae in the following year. As a result, catch of small prawn drastically increased. Then, other villagers also participated in the stock enhancement project, and released 14 million larvae. Results had indicated that in the beginning, population of the small prawns increased around the mouth of the Lake. Some fishermen living at the mouth of the Lake caught much small prawn, except those from Shirasu. Two years later, and on their own initiative, such fishermen terminated their activity of catching small prawn, and joined the stock enhancement project.

All activities including intermediate aquaculture, environmental assessment, catch statistics and post-harvest were conducted with the collaboration between fishers and researchers. Although this public project was terminated after 5 years, the fishermen from 7 villages took over the release work as their own activity, after the project. The evidence of impacts from conservation activity on the life of fishermen is necessary to change their minds and attitude. Although data could be used as evidence, working together is the key to improve the coinfidence of scientific data and conservation activities. Therefore, "after everything was finished, fishers knew how and what to do about *kuruma* prawn intermediate culture. There was no need to explain anything to them."

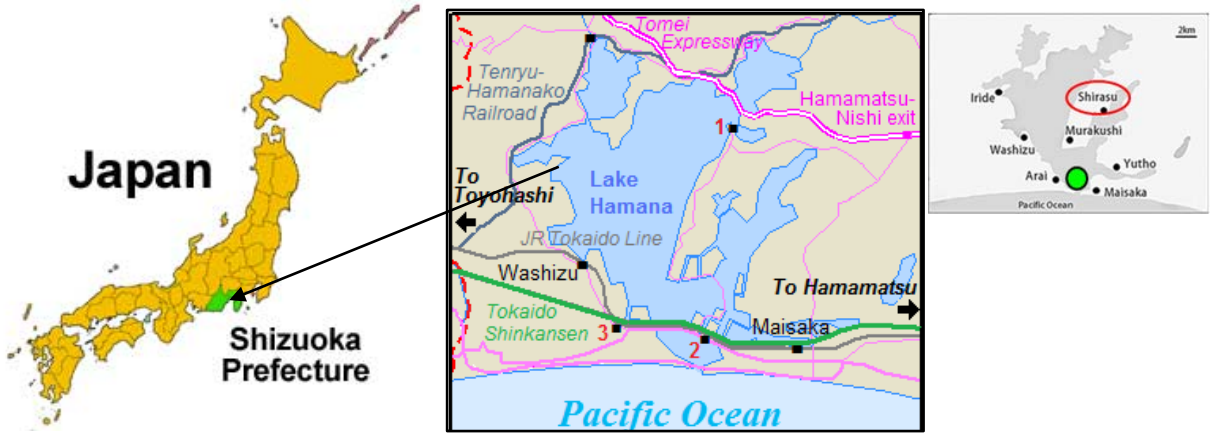

Fig. 6. Map of Japan showing Shirasu Village near Lake Hamana in Shizuoka Prefecture, Japan

Lessons Learned

From several case studies on stock enhancement project, many important aspects have been suggested. These include the following:

- New technology is key for establishment of communities
- Community activities make scientific data collection possible
- Scientific data improve community's understanding of nature
- Evaluation from other stakeholders sustains community activities
- Data on important resources can attract users' interests
- Collaboration between users and researchers enhances users' understanding of scientific data and information
- Improvement of livelihoods could foster conservation ideas and actions
- Evidence of resource improvement sustains community conservation activities

These aspects are very important to cultivate users' interests on nature, promote conservation activities, and for decision-making that could change daily actions. The aforementioned factors are closely related and when carried out could promote technology-led communities, community activities to improve data collection, and awareness-raising and users' interest enhancement on nature.

A good example on how scientific data contribute to decision-making process at local community towards the sustainable use of ecosystem services is shown in **Fig. 7**. The stock enhancement of *kuruma* prawn in Hamana Lake demonstrated how scientists can collaborate with local communities.

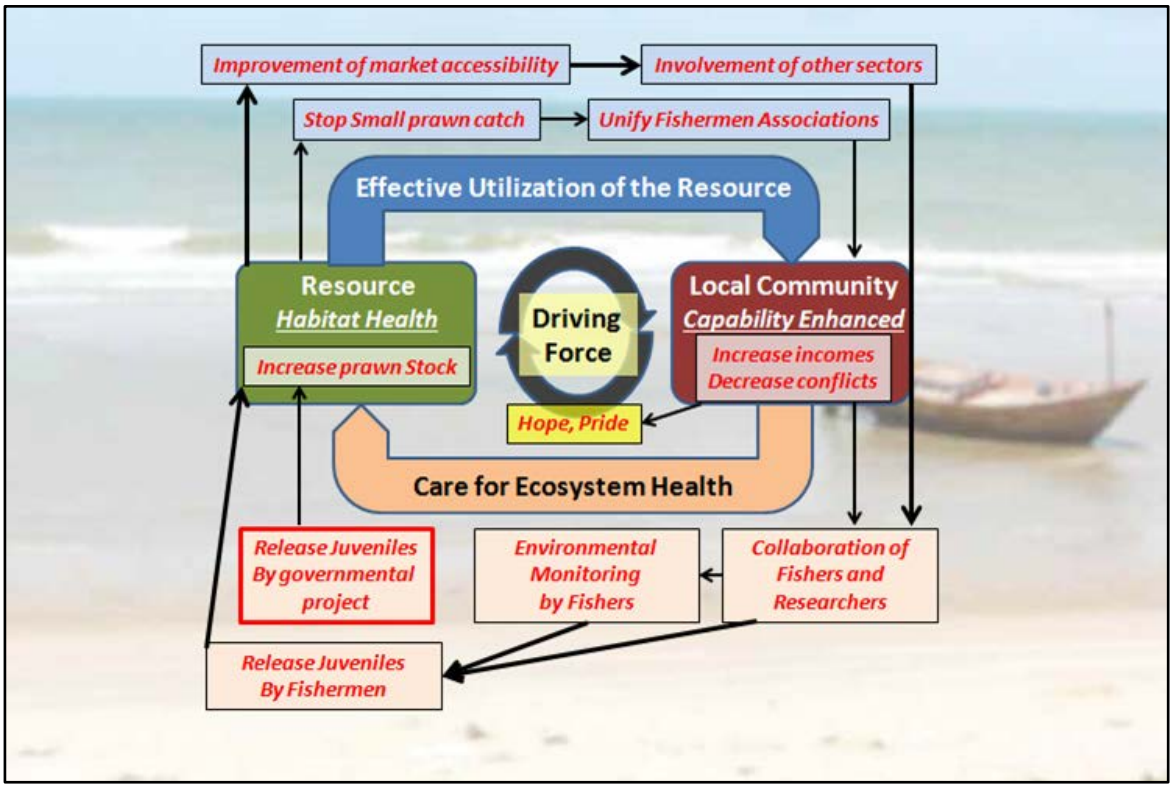

Fig. 7. Area-Capability cycle of stock-enhancement of Kuruma prawn in Hamana Lake, Japan

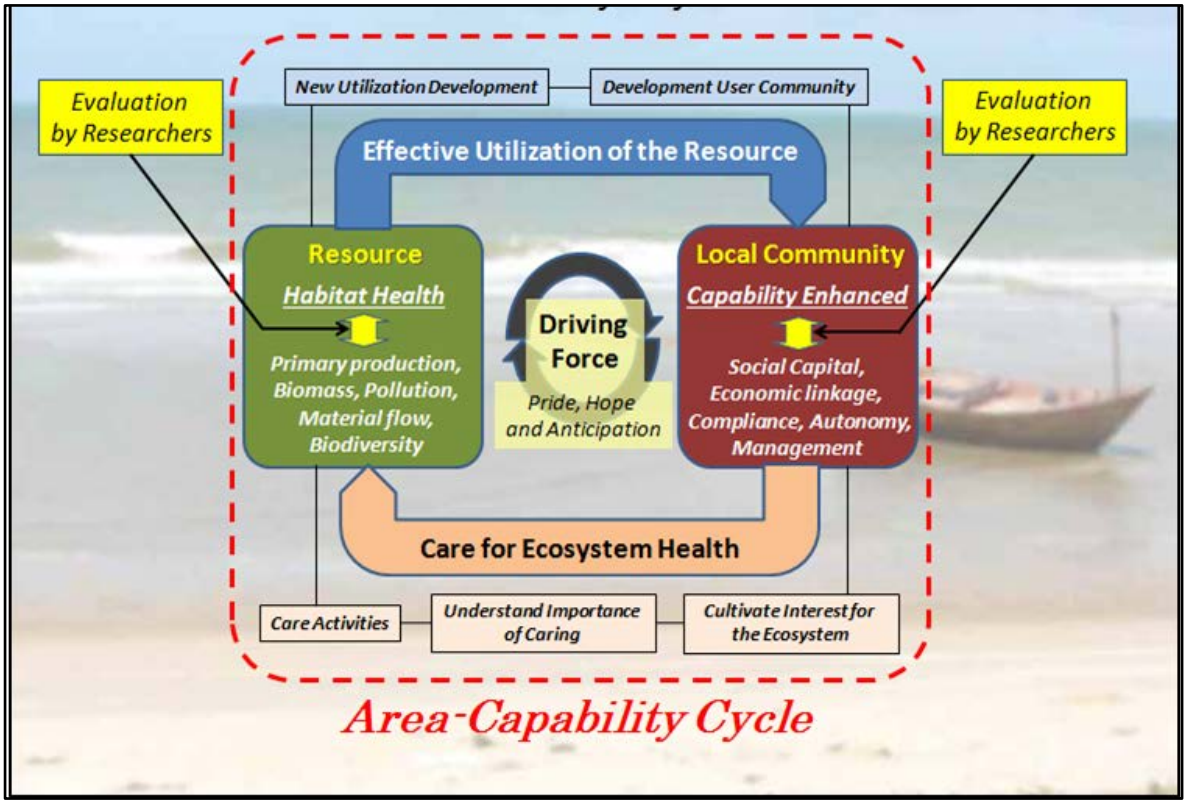

Fig. 8. Area-Capability cycle model for decision-making process at local community based on scientific information

Model for Decision-making Process at Local Communities Based on Scientific Information

Based on the findings from the aforementioned case study, a hypothetical model could be developed for *decision-making process at local coastal communities based on scientific information*. This model is known as Area-Capability Cycle. Using this cycle, eight (8) elements could be laid down as important aspects toward transformation of users' minds and attitudes. These elements are:

(1) existence of natural resources at sites is necessary to rediscover natural resources around

(2) technological or system improvement of utilization of the resources

(3) community development of users

(4) realization of improvement of livelihoods by natural resource utilization

(5) interest cultivation on nature supporting the resources

(6) understanding and realization of the importance of care on nature (in other words, ecosystem)

(7) activation of care of nature

(8) improvement of resource situation through such care

Scientists should contribute to the proof that leads towards the improvements of both livelihoods and resources. The concept of "Area-Capability Cycle" could provide the future prospect of "improvement of stocking efficiency" as shown in **Fig. 8**.

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Theme 1
Fishery Resources Enhancement through Habitat Improvement and Management

To pave the way for a thorough discussion of the various fishery resources enhancement programs and activities in SEAFDEC and the Member Countries including the strengths and weaknesses of such activities, **Theme 1** had been arranged into three (3) sessions, namely:

Session 1: Artificial Reefs for Fisheries Management; **Session 2**: Establishment and Management of Fisheries *Refugia*; and **Session 3**: Habitat Rehabilitation (Coral Reefs, Seagrass Beds, Mangrove Forests, Inland Habitats).

Introductory Paper

Information on the status and trend of fisheries in the Southeast Asian region and results of enhancement activities of fishery resources in the EEZs of SEAFDEC Member Countries were provided in the background paper to introduce **Theme 1.** Presented by the Policy and Program Coordinator of SEAFDEC, *Dr. Somboon Siriraksophon,* the paper discussed the **Overview of Current Status and Trends on Fisheries and Issues on Resources Enhancement in Southeast Asia.**

Projections of the world's fisheries production and fishing capacity towards 2030 that indicate escalating production trend from capture fisheries could lead to increasing levels of fisheries exploitation. While expressing such concern, Dr. Somboon mentioned that the data in 2003 had in fact, already exhibited certain levels of fish stock collapse by 32%, overfished by 39%, and at the limit of sustainability at 29% (**Table 1** and **Table 2**).

Dr. Somboon Siriraksophon presenting the Symposium Introductory Paper

Dr. Somboon added that although several Southeast Asian countries are among the leading producers of fish, contributing large amounts to the total inland and marine fishery production of the world, production of economically-important pelagic and demersal species from the countries in the region had been fluctuating over the past decades. Moreover, looking at the data on catch per unit effort (CPUE), fish size at maturity, species composition, habitat loss and degradation, it could be deduced that the fishery resources are also at certain levels of over-exploitation. Granting that production from aquaculture would continue to increase until 2030, over-exploitation of the fishery resources would still continue to occur since fish farming activities would remain heavily reliant on large amounts of fishmeal for aquafeeds.

Nonetheless, Dr. Somboon also elaborated that in their efforts to address the aforementioned concerns, most Southeast Asian countries had been embarking on various fishery resources enhancement programs but such efforts have often been confronted with issues and challenges, particularly on the insufficiency of baseline assessment data for carrying out successful resources enhancement activities, inadequate understanding on the concept of "fisheries *refugia*", and the need for regional collaboration in the management of transboundary fish stocks.

As such, Dr. Somboon emphasized that resource enhancement should not be carried out as a stand-alone measure, but should be integrated with other management measures to ensure the sustainability of the fishery resources.

Overview of Current Status and Trends of Fisheries and Issues on Resources Enhancement in Southeast Asia

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Abstract

This paper is prepared for the Symposium on Strategy for Fisheries Resources Enhancement with the objective of providing an overview of the current status and trends of fisheries in the Southeast Asian region as well as reviewing the activities on enhancement of fisheries resources within the EEZs of SEAFDEC Member Countries for discussion during the development of the Regional Strategies or Approaches on fisheries resources conservation and rehabilitation. Considering the need to address issues on fisheries resources enhancement as stipulated in the 2001 and 2011 ASEAN-SEAFDEC Resolutions and Plans of Action, several programs under the ASEAN-SEAFDEC Strategic Partnership (ASSP) have been implemented since 2003 at national and regional levels to enhance the countries' respective fishery resources. The constraints and challenges are discussed and summarized in this paper for consideration in the overall effort towards achieving sustainable fisheries in the region.

OVERVEW OF THE STATUS AND TRENDS OF FISHERIES

Global Production of Fish

Fish and fishery products are among the most important agricultural commodities providing significant contribution to the world's food security and economic development. Out of the total value of the global agricultural products reported at US$ 1,168.85 billion in 2009, fish and fishery products accounted for US$ 90.73 billion or about 8% of the total value (WTO, 2010). Aside from its contribution to the world's economies, fish and fishery products are also important source of protein for people worldwide and represent a significant part of the diets of peoples in many countries. From 2000 to 2012, the global fishery production had continuously increased from about 131.0 million metric tons (MT) to 158.0 million MT (**Table 1**) while the percentage of the production for human consumption also gradually rose from almost 74% to 86%. It should be noted however that the increasing trend in total fishery production is mainly due to the increasing contribution from the aquaculture sector, while production from capture fisheries has gradually been declining.

With the world's population increasing from 6.1 billion to 7.1 billion over the same period, the per capita fish consumption has also escalated. This trend is expected to continue to rise particularly in the developing countries where the population and demand for food are continuously growing because of increased income and purchasing power for high-value and quality food including food fish. In addition, the fishery sector with its ancillary activities which had expanded with increased numbers of people employed, significantly contributes to improved livelihoods and employment opportunities, as well as to the enhanced well-being of millions of peoples including those in the Southeast Asian region.

In terms of fishery statistics for both capture fisheries and aquaculture, fishery production of the countries in the Southeast Asian region is reported under FAO Fishing Area 57 (Indian Ocean, Eastern), 71 (Pacific, Western Central), 61 (Pacific, Northwest), and 04 (Asia, Inland Waters). Based on such arrangement, the total fishery production of the Southeast Asian region from 2000 to 2009 compiled by SEAFDEC from inputs of the countries and published in the Fishery Statistical Bulletin for the South China Sea Area 2000-2007 and the Fishery Statistical Bulletin of Southeast Asia 2008-2012 is summarized in **Table 2**.

From 2000 to 2012, the regional fishery production had continuously increased from about 17.0 million MT to 39.6 million MT. Among the Southeast Asian countries, Indonesia, Myanmar and Viet Nam showed gradually increasing trends in their total fisheries production.

Table 1. World's fishery production and utilization from 2000 to 2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production													
INLAND													
Capture	8.8	8.9	8.8	9.0	8.6	9.4	9.8	10.0	10.2	10.1	11.3	11.1	11.6
Aquaculture	21.2	22.5	23.9	25.4	25.2	26.8	28.7	30.7	32.9	35.0	77.8	82.6	79.7
Total Inland	**30.0**	**31.4**	**32.7**	**34.4**	**33.8**	**36.2**	**38.5**	**40.7**	**43.1**	**45.1**	**89.1**	**93.7**	**91.3**
MARINE													
Capture	86.8	84.2	84.5	81.5	83.8	82.7	80.0	79.9	79.5	79.9	36.8	38.7	41.9
Aquaculture	14.3	15.4	16.5	17.3	16.7	17.5	18.6	19.2	19.7	20.1	22.3	23.3	24.7
Total Marine	**101.1**	**99.6**	**101.0**	**98.8**	**100.5**	**100.2**	**98.6**	**99.1**	**99.2**	**100.0**	**59.1**	**62.0**	**66.6**
TOTAL CAPTURE	95.6	93.1	93.3	90.5	92.4	92.1	89.8	89.9	89.7	90.0	48.1	49.8	53.5
TOTAL AQUACULTURE	35.5	37.9	40.4	42.7	41.9	44.3	47.3	49.9	52.6	55.1	100.1	105.9	104.4
TOTAL WORLD FISHERIES	**131.1**	**131.0**	**133.7**	**133.2**	**134.3**	**136.4**	**137.1**	**139.8**	**142.3**	**145.1**	**148.2**	**155.7**	**157.9**
Utilization													
Human consumption	96.9	99.7	100.2	102.7	104.4	107.3	110.7	112.7	115.1	117.8	128.2	131.2	136.2
Non-food uses	34.2	31.3	33.5	30.5	29.8	29.1	26.3	27.1	27.2	27.3	19.9	24.5	21.7
Population(billions)	6.1	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.8	6.9	7.0	7.1
% of production for human consumption (%)	73.9	76.1	74.9	77.1	77.8	78.7	80.8	80.6	80.9	81.2	86.6	84.3	86.3
Per capita food fish supply (kg)	**15.9**	**16.2**	**16.2**	**16.3**	**16.2**	**16.5**	**16.8**	**16.9**	**17.1**	**17.2**	**18.5**	**18.7**	**19.2**

Source: FAO State of World Fisheries and Aquaculture 2004, 2010 and 2014

Table 2. Total fishery production of the Southeast Asian countries from 2000 to 2012 (MT)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Brunei Darussalam	2,577	1,575	2,215	2,160	3,133	3,103	3,100	3,227	2,747	2,418	2,772	2,447	5,079
Cambodia	298,798	411,200	424,432	390,657	343,492	546,000	661,542	525,100	536,320	515,000	550,000	631,695	728,000
Indonesia	5,120,490	5,409,504	5,515,648	5,915,989	6,005,622	6,646,965	7,183,586	7,510,767	9,054,873	10,064,140	11,662,311	13,626,141	18,763,893
Lao PDR	71,000	81,000	93,000	95,000	95,000	107,800	107,800	91,660	93,500	105,000	113,000	129,600	136,000
Malaysia	1,457,139	1,411,740	1,467,486	1,483,957	1,537,988	1,421,403	1,644,527	1,654,221	1,639,008	1,729,002	1,806,577	1,665,842	1,760,840
Myanmar	1,309,830	1,474,460	1,606,240	1,987,020	2,148,580	2,581,780	2,817,990	2,808,037	3,147,605	3,491,103	3,901,979	4,149,799	4,417,676
Philippines	2,993,332	3,166,528	3,369,524	3,619,282	3,926,173	4,161,870	4,408,472	4,711,252	4,964,703	5,084,674	5,155,647	4,973,588	4,865,678
Singapore	9,984	7,784	7,795	7,109	7,579	7,837	11,675	8,026	5,141	5,687	5,233	5,592	5,546
Thailand	3,713,248	3,648,429	3,797,014	3,914,025	4,137,066	4,132,826	4,051,824	3,675,382	3,204,200	3,137,672	3,113,316	2,870,085	3,068,345
Viet Nam	1,961,145	2,009,623	2,647,407	2,859,200	2,944,030	3,397,200	3,656,152	4,315,500	4,559,720	4,782,400	5,127,600	5,432,900	5,816,100
Total	16,937,543	17,621,843	18,930,761	20,274,399	21,148,663	23,006,784	24,546,668	25,303,172	27,207,817	28,917,096	31,438,435	33,487,689	39,567,157

Source: Fishery Statistical Bulletin for the South China Sea Area 2000-2007
Fishery Statistical Bulletin of Southeast Asia 2008-2012

Fisheries production of the Southeast Asian region comes from three sub-sectors, namely: marine capture fisheries, inland capture fisheries, and aquaculture. **Table 3** shows the total fishery production of the region by sub-sector in 2012 and indicates that the largest portion of the production is derived from aquaculture accounting for approximately 53.5% followed by marine capture fisheries of about 39.5%, and inland fisheries 7.0%.

While aquaculture contributes the largest volume of production, its production value which accounts for 48% of the total production value only comes next to marine capture fisheries which contributes approximately 45% and that of inland capture fisheries of about 7%. While the value per metric ton of marine capture fisheries production was about US$ 1,286/MT that of aquaculture production was only about US$ 1,025/MT.

Table 3 Fishery production (quantity and value) of Southeast Asia by sub-sector in 2012

Sub-sector	Quantity (MT)	Value (US$ 1000)	Value (US$/MT)
Marine Capture Fisheries	15,590,704	20,049,002	1,286
Inland Capture Fisheries	2,819,963	3,226,605	1,144
Aquaculture	21,160,458	21,683,275	1,025
Total	**39,571,125**	**44,958,882**	**1,136**

Capture Fisheries Production in the Southeast Asian Region

Fisheries of the Southeast Asian region are by nature tropical, multispecies and multi-gears, and involve large numbers of fishers and farmers mostly engaged in small-scale fishing operations and aquaculture practices. Indonesia consistently attains the highest capture fisheries production from 2003 to 2012 with an average annual production increase of almost 1.3 million MT **(Fig. 1**). Thailand's production was second after Indonesia in 2003-2006, its production maintained at 2.8 million MT during the ten-year period until 2005.

After 2007, the country landed into the fifth place in terms of total fisheries production. Production of Thailand from capture fisheries decreased from 2005 until 2008 at an average rate of about 200,000 MT per year. After 2008 until 2012, capture fisheries production of Thailand maintained at 1.8 million MT. In contrast, fishery production of Myanmar has been increasing from 2003 to 2012, from rank number five in 2003 the country ranked second in 2012 by about 3.6 million MT.

For the Philippines, capture fisheries production slightly increased from 2003 until 2010 after which the production decreased to about 2.4 million MT in 2012. Specifically, Indonesia's increasing production from 14 major groups of marine species that include marine fishes nei (Osteichthyes), scad nei (*Decapterus* spp.), skipjack tuna (*Katsuwonus pelamis*), short mackerel (*Rastelliger brachysoma*), stelophorus anchovies (*Stelophorus* spp.), kawakawa (*Euthynnus affinis*), goldstripe sardinella (*Sardinella gibbosa*), yellowstripe scad (*Selaroides Leptolepis*), Bali sardinella (*Sardinella lemuru*), and frigate tuna (*Auxis thazard*) among others, had contributed to the country's overall increasing production trend. On the other hand, although production from marine capture fisheries of Myanmar and Viet Nam had not been classified by species, both countries recorded escalating production trend of marine fishes nei (Osteichthyes). For the Philippines, production of six major groups of marine species that include sardinellas nei (*Sardinella* spp.), skipjack tuna (*Katsuwonus pelamis*), scad nei (*Decapterus* spp.), yellowfin tuna (*Thunnus albacares*), frigate tuna (*Auxis thazard*), and bigeye scad (*Selar crumenophthalmus*) among others had escalated, contributing to the country's increasing production from marine capture fisheries.

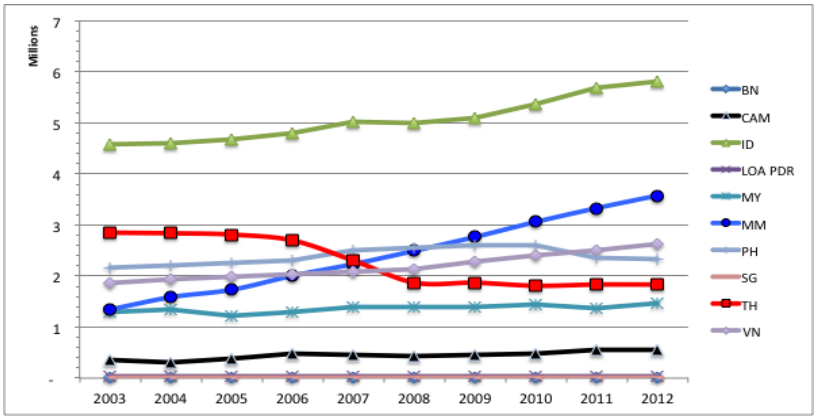

Fig. 1: Capture fishery production of the Southeast Asian region by country

STATUS AND TREND OF SOME ECONOMICALLY-IMPORTANT SPECIES

Based on preliminary analysis during 2000-2012 of the status and trend of some economically-important species, some findings are presented below:

Pelagic Fish Resources

The status and trend of production of five pelagic fish species in Southeast Asian countries during 1988-2012 are shown in **Fig. 2**. Skipjack tuna, scad nei, sardinellas nei, short mackerel and anchovies are the top five in the overall pelagic fish production. The same figure shows that during the past two decades, production trend of skipjack tuna and short mackerel gradually increased from 155,828 MT in 1988 to about 312,930 MT in 2012. Similar increasing trends were also found in skipjack and scad nei with production in 2012 at 711,403 and 666,558 MT, respectively.

For sardinellas nei, the production dramatically increased during 1988 to 1997, but fluctuated and decreased from about 500,000 MT in 1997 to about 367,887 MT in 2003 and after that it increased again to 567,880 MT in 2009. However, the production of sardinellas nei had decreased and maintained at about 400,000 MT in 2011.

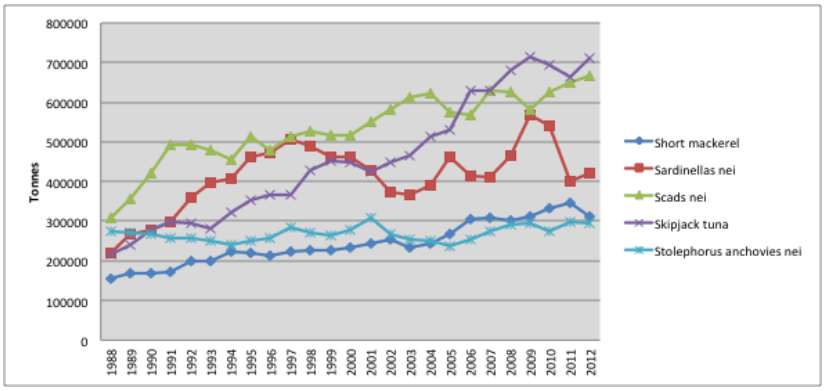

Fig. 2. Production from top five pelagic fishes in Southeast Asian countries

Demersal Fish Resources

Statistical data shows that the total production of demersal fish was one-third of the pelagic fish production during the last 20 years. Threadfin bream, ponyfishes, snappers, sea catfish, and bigeye nei were among the top five in the demersal fish production in this region. **Fig. 3** shows the trend of the top five demersal fish species in this region, indicating that only the snapper group tends to experience drastic increase in its production during the last decade from about 66,330 MT in 2002 to about 122,973 MT in the year 2012. The rest seems to have reached their maximum yield.

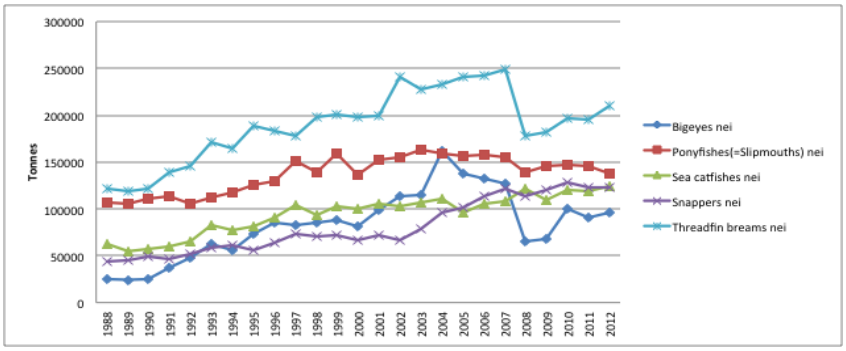

Fig. 3. Production from top five demersal fishes in Southeast Asian countries, 1988-2007

Resource Indicators

The status of the demersal resources focusing on economically-important species as surimi raw materials, was studied from bottom trawls in particular areas, *i.e.* Thailand, Cambodia, West Kalimantan of Indonesia, Brunei Darussalam waters and Malacca Strait (west coast of Peninsular Malaysia) from 2004 to 2007.

Results have indicated that the most abundant sea areas are the waters of Brunei Darussalam and West Kalimantan around the Natuna Islands where the CPUEs were 143.9 and 135 kg/hr, respectively. The water depths in both areas are more than 75 m and in some areas up to 110 m. For the Gulf of Thailand, the CPUEs ranged from 10 to 16 kg/hr only which were quite low compared with those of the other sea areas such as Malacca Strait (Yasook, 2008). Results of the joint study in different three areas (Stobutzki *et al*., 2006) showed serious declines in fishery resources in many areas that tend to continue if unsustainable fisheries and over-exploitation would still be practiced.

The study sites in Malaysia, Thailand and the Philippines showed declines in total biomass of demersal species. In Malaysia, the decline was greatest in shallow depths (<50 m) where the biomass declined to 4–20%.

In the Gulf of Thailand, the total biomass estimates had declined to less than 8%, and in the Philippines, changes in the biomass were examined and the recent estimates of the biomass were 12–64% of the original estimates. Severe declines in total biomass were thought to be due to over-fishing compounded by environmental degradation.

Exploitation ratios (fishing mortality: total mortality) calculated from length-frequency data, were on the average >0.5, suggesting that over-fishing occurs. Severe declines in fishery resources had also been observed in many areas and tend to continue if unsustainable fisheries and over-exploitation would still be practiced.

ENHANCEMENT OF FISHERIES RESOURCES IN THE SOUTHEAST ASIAN REGION

The declining fishery resources in both demersal and pelagic fishes in the coastal and offshore areas had created impacts to the fishing industries which had attained quick growth in the past two decades. This also pushed large numbers of fishing vessels to perform illegal fishing outside national jurisdictions or on the foreign exclusive economic zones and high seas. This led to big problems not only at the regional but also at global level.

Reduction of fishing capacity and improvement of fisheries management should therefore be implemented at national level. In addition, enhancing the fishery resources and fish stocks within the EEZs as a fishery management tool is needed to support the sustainable development of fisheries at the country level. Specifically, regional approach on this issue is necessary for trans-boundary pelagic species and shared stock species.

Southeast Asian Countries' Fisheries Resources Enhancement Programs

Many Southeast Asian countries have been concerned with declining resources, and thus had mainstreamed fishery resources enhancement programs in their respective national plans, policies and legislations, with the purpose of addressing the degradation of fishery resources.

Various tools have been used to alleviate the declining resources, while means of enhancing the habitats and controlling the utilization of resources have been undertaken, *e.g.* artificial reefs deployment, promotion of fishery *refugia* and marine protected areas (MPAs), use of fish aggregating devices (FADs), and installation of stationary fishing gears (SFGs).

❖ **Brunei Darussalam**

The Government through its Fisheries Department had developed and set up ARs since 1985 as means of promoting fishery resources enhancement using various types, *e.g.* used tires, steel pipes and prefabricated structures, and later on concrete prefabricated pyramidal structures. The ARs are used for protection and as barrier against illegal fishing gears. In 2003, two MPAs were developed in Selirong Island and Pelong Rocks, which had been integrated with the 8th National Development Plan (SEAFDEC, 2004 and 2005).

❖ **Cambodia**

In 1979, the Department of Fisheries established 13 protected areas called "fish sanctuaries" in freshwater zones especially in the Tonle Sap Great Lake. When the Fisheries Law was enforced in 1987, any fisheries activities were prohibited in the fish sanctuaries. In 1997, four national parks were established in coastal areas and part of the fifth park covering an area of 366,250 ha was considered as Protected Area.

Cambodia's Ministry of Environment and the Ministry of Agriculture, Forestry and Fisheries play significant roles in conducting the program in collaboration with many donors, *e.g.* the United Nations Environment Programme (UNEP), Danish International Development Agency (DANIDA), FAO, the Department for International Development (DFID) of UK. ARs program was initiated in 1991 using concrete modules and installed in the Tonle Sap Great Lake to provide habitats of aquatic species and improve fish stocks. In 2002, MPAs were established by the Fisheries Administration with funding support from ICRAND project under UNEP, in Koh Kong side of Sihanoukville where coral reefs are abundant (SEAFDEC, 2004 and 2005).

❖ **Indonesia**

In 1998, the Government launched a 15-year program (1998-2013) known as the Coral Reef Rehabilitation and Management Program (COREMAP) for the protection, rehabilitation and sustainable use of coral reefs and associated ecosystems through co-management. COREMAP covers 10 provinces including Maluku, Irian Jaya, South, Southeast, North Sulawesi, East and West Nusa Tenggara, Riau, and North and West Sumatra.

The major initiatives of Indonesia's COREMAP Phase 1 included public awareness campaigns, pilot community-based management, institutional development activities, and information and training network and development of a Monitoring, Control and Surveillance (MSC) system (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002).

❖ **Lao PDR**

Being landlocked, the country emphasizes only on inland fisheries. Several government development programs have been oriented towards clarification of boundaries and thereby enclosure of resources within fixed and legible territories. The country's Department of Livestock and Fisheries is responsible for the management of natural aquatic resources.

Between 1993 and 1999, the local government of Lao PDR endorsed the establishment of 68 Fish Conservation Zones as part of a community-based fisheries co-management initiative, all of which are situated in the mainstream Mekong River (Siphadone Wetlands) near the border of Cambodia. Besides government's support, communities also received support from international non-governmental organizations, especially for the Lao Community Fisheries and Dolphin Protection Project, and Environment Protection and Community Development (Baird, 2006).

❖ **Malaysia**

The country's primary policy relevant to the fisheries sector is its Third National Agricultural Policy (NAP3) governed by the Department of Fisheries Malaysia. In the 9th Malaysia Plan (1995-2010), the country's marine fish production was targeted at 1.32 million MT by maintaining the fish catch from coastal areas at the maximum quantity of 938,000 MT and increasing offshore catches to 382,000 MT.

In order to achieve the objectives, rehabilitation of resources through establishment of artificial reefs (ARs) and coral replanting programs are among the tools adopted in Malaysia. Meanwhile, fish aggregating devices (FADs) and ARs which have been found acceptable for fishery resources enhancement and management tools were also installed in the country's waters. As a result, a total of 99 ARs have been deployed since 1975 then later, more than 200 ARs have also been installed to mitigate the impacts and loss of habitats due to destruction and to increase the marine resources.

MPAs were first established in Malaysia in 1983 and promoted as no-take zones. At present, a total of 40 marine parks have been gazetted. FAD sites have been developed at the same time with MPAs, and a total of 222 FAD sites were established utilizing a budget of RM 24 million (SEAFDEC, 2004).

❖ **Myanmar**

The Ministry of Livestock and Fisheries is responsible for the fisheries development of the country. Marine parks and marine reserves as well as fisheries protected areas have been established under its Fisheries Law. Fishing in fisheries protected areas is prohibited unless specifically licensed to do so. ARs deployment and coral planting have not yet been established. Although the Department of Fisheries of Myanmar also recognizes the advantages of installing ARs, it is more concerned in increasing the number of marine parks and marine reserves or Marine Protected Areas at places where corals are abundant to restore and enhance the marine aquatic resources (SEAFDEC, 2004 and 2005).

❖ **Philippines**

The country's Fisheries Code of 1998 provides specific management measures to conserve and manage the fisheries resources of the country. ARs have been deployed by the Bureau of Fisheries and Aquatic Resources (BFAR) and technically supported the Local Government Units (LGUs). BFAR formed the SCUBA divers group to monitor, manage and safeguard the coral reefs. Initially, the group implemented the Coral Garden and Reef Rehabilitation Project in Tangalan, Aklan in central Philippines (SEAFDEC, 2004), and to date, there are over 500 MPAs around the Philippines. Established through local community initiatives in the entire Philippine coastline, these MPAs are locally managed marine areas entirely for artisanal (small-scale commercial) fishing activities (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002).

❖ **Singapore**

The Primary Production Department (now the Agri-Food and Veterinary Authority) launched a 10-year stocking program in 1986. Over 80,000 sea bass, 8,500 cherry snappers and 630,000 banana shrimps were released in the country's rivers basically promoting re-stocking and game fishing. ARs were installed in mid 1989s in the southern islands under the ASEAN-US Coastal Resources Management Project. In 2001, the National University of Singapore and Singapore Tourism Board conducted collaborative research on the use of ARs as a tourism sites. Nevertheless, Marine Protected Areas have no place elsewhere in the country so these are not included in the national policies on coral reefs of government agencies responsible for this resource. FADs were however installed to serve as obstacles in waterways but consequently, there was lack of interest in this aspect (SEAFDEC, 2004).

❖ **Thailand**

Since 1978, the Department of Fisheries (DOF) as the main agency responsible in governing fishery resources had been installing ARs for resource rehabilitation both in the Gulf of Thailand and Andaman Sea. From 1978 to 1986, DOF experimented on the substance, structure and techniques for deploying ARs.

The DOF of Thailand had established that the most suitable structure of ARs is the square concrete tube as these could also provide shelter for aquatic species, and obstruct trawlers and push netters from entering the AR areas. From 1986 until the present, 280 sites had been installed with small ARs, while 30 sites for large ARs were installed during 1988-2006 with funding of about one billion Baht. At present, local fishers can request installation of ARs from local authorities (Supongpan, 2006).

The Master Plan for Marine Fisheries Management of Thailand serves as guide for sustainable management of marine fisheries resources, and includes a 10-year plan starting in 2009 to "promote sustainable fisheries development based on the sufficiency economy that places the people at the center". The DOF has the main responsibility of encouraging related agencies and stakeholders to be involved in the plan. Included in Strategy 4 on ecosystem and fishing ground rehabilitation to safeguard biodiversity and marine environmental quality and to demonstrate the importance of resource enhancement, are several guidelines.

The guidelines under Strategy 4 of the Master Plan for Marine Fisheries Management of Thailand include: identification of natural habitats on which important fish stocks depend in certain parts of their lifecycle to ensure sizeable recruitment to fishable stocks; establishment of artificial reefs ARs and promotion of the use of living resources surrounding them under the management by community or fishermen organization; and promotion of sea ranching practices that do not jeopardize the marine ecosystem (DOF, 2008).

❖ **Viet Nam**

National activities on ARs are still being implemented and no ARs are yet in place (SEAFDEC, 2004). Development of the country's MPAs is governed by the Ministry of Science, Technology & Environment (MoSTE); Department of Fisheries Resources Protection, Ministry of Fisheries (MoFi); and Ministry of Forestry. Recently, the Government of Viet Nam authorized MoFi to develop a National Plan for Marine Protected Areas with marine components, particularly coral reefs and sea grass beds, and also includes marine protected areas in the Spratly's archipelago. However, the plan is still pending government's approval. MoFi will be responsible for the MPAs with the objective of conserving mainly the coral reefs, sea grass beds, island ecosystems and marine living resources (UP-MSI, ABC, ARCBC, DENR, ASEAN, 2002).

Country Synthesis on Overview of Resources Enhancement

The Workshop on Enhancing Coastal Resources: Artificial Reefs, Stationary Fishing Gear Design and Construction and Marine Protected Areas organized from 30 September to 3 October 2003 by SEAFDEC/TD in Samutprakan Thailand, concluded that all participating countries have in place their respective national legislations, policies and plans including resource enhancement activities to promote conservation and management of marine resources. However, this does not include Singapore because the country has no national policies or agencies managing coral reefs and reef resources.

With regards to resource enhancement activities, most of the participating countries have promoted ARs, stationary fishing gears (SFGs), and MPAs as approaches towards conservation and management of coastal resources.

✓ Cambodia, and Myanmar are currently promoting only MPAs but with the intention to expand to other potential measures

✓ Singapore is basically promoting only re-stocking to increase resident fish stocks and game fishing as well as ARs but not SFGs as these are considered obstacles in navigation pathways

✓ Vietnam is in the initial stage of deploying ARs

Nonetheless, resource enhancement activities in most countries generally focus on the following objectives:

✓ To mitigate impacts and loss of habitats due to natural and man-made destructions

✓ To enhance marine productivity and biodiversity of coastal resources

✓ To provide physical obstruction against invasion of trawlers into coastal areas

✓ To provide productive and alternative near shore fishing areas to small-scale fishermen

✓ To promote sustainable livelihoods such as eco-tourism and small-scale selective fishing in the use of coastal marine resources

KEY ISSUES/CHALLENGES ON ENHANCEMENT OF FISHERIES RESOURCES

❖ **Initial Assessment**

Appropriate measures and assessment for any enhancement program should be formulated together with the investments for these projects, *e.g.* ARs includes funds, time, labor, logistics support. So, the feasibility of each program should be assessed.

❖ **Perspective in Fisheries *Refugia* Management**

Development of the fisheries *refugi*a concept as a tool for integrating fish stock and habitat management had been undertaken by the UNEP/GEF Regional Working Group on Fisheries in the South China Sea (SCS) area in close collaboration with SEAFDEC, FAO, IUCN, and World Fish Center during the period 2003-2008.

The concept of *refugia* was later on elaborated and refined, and priority *refugia* sites were identified, based on the outputs of regional and national level experts and fishing community consultations; national reports on fisheries, mangroves, coral reefs, sea grass, and wetlands from the seven participating countries of the SCS Project.

Moreover, 135 habitat site characterizations had been prepared during the SCS Project; the SCS meta-database and GIS were developed; and compiled information had contributed directly by fisheries and habitat focal points. This has been supported by three regional training courses and 12 national training seminars on the scientific and management aspects of operating regional *refugia* system. Cost effectiveness was a key criterion for the development of the *refugia* initiative, which was aimed at improving the use of area-based approaches to fish stock and habitat management, while overcoming the problems associated with emphasis on no-take Marine Protected Areas in the region. The latter includes low fishing community acceptance, and high costs in terms of displacement of fishers and enforcement. The fisheries *refugia* initiative addresses the present problems by drawing on fisheries management concepts that are easily understood at the fishing community level and emphasizes on the sustainable use of fisheries resources and their habitats rather than prohibiting fishing activities. In the promotion of Fisheries *Refugia*, the ASEAN and SEAFDEC adopted the "UNEP/GEF Regional Guidelines on the Use of Fisheries *Refugia* for Sustainable Capture Fisheries Management in Southeast Asia" in April 2006. The Guidelines is part of the ASEAN-SEAFDEC Regional Guidelines for Responsible Fisheries in Southeast Asia that were developed to regionalize the FAO Code of Conduct for Responsible Fisheries for adoption in the Southeast Asian region.

❖ Regional Collaboration on Trans-Boundary Fish Stocks

In the regional waters, migratory fish pass through overlapping 'exclusive economic zones' (EEZs) is often claimed by more than one country. As fish may be dependent on habitats in the competitive areas or on either side of the EEZs, there is a need to develop viable fisheries management systems, which in the end could ensure the enhancement of aquatic resources and the sustainable use of the resources.

❖ Issues for Future Consideration

- ✓ Common understanding on the purpose of resource enhancement tools particularly fisheries *refugia*
- ✓ Types of resource enhancement measures and activities and their context/implications for conservation and management purposes (ARs vs. FADs, fisheries *refugia*, MPAs vs. marine parks and sanctuaries, etc.)
- ✓ Directions and needs for supporting research, legislations and tools on ARs for resource enhancement
  a. Durability and appropriate designs and installation of AR modules
  b. Studies on appropriateness and effectiveness of different AR modules
  c. SFGs as resource enhancement tool for conservation and management purposes for coastal resources
- ✓ Regional source of information including the system to facilitate information and experience sharing including guidelines for resource enhancement promotion
- ✓ Balancing objectives and benefits of environmental, economic and social aspects of the conservation and management policies and plans for coastal development
- ✓ Guidelines on criteria, conduct of indicators and impact assessment of resource enhancement activities
- ✓ Integrating resource enhancement into innovative management plans, strategies and approaches for sustainable utilization of coastal areas
  a. Management framework
  b. Resource use pattern in the resource enhancement areas
  c. Involvement of communities and fishers
- ✓ Resource enhancement is not the only solution – needs for other measures (*i.e.* stock enhancement, management measures, etc.) to supplement conservation and management of coastal resources

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Session Papers
Session 1: Artificial Reefs for Fisheries Management

With the Assistant to the Chief on Technical Matters of SEAFDEC Training Department *Mr. Bundit Chokesanguan* as the Facilitator, four papers were discussed, namely: (1) Artificial Reefs Management and Development in Malaysia by *Mr. Ahmad Zuwairi Zainudin*; (2) Royal Initiative Project: Coastal Fishery Resource Rehabilitation in Pattani and Narathiwat Provinces, Thailand by *Dr. Kamonpan Awaiwanont*; (3) Environmental Survey Studies on Artificial Reefs in Rayong Province, Thailand: Technical Assistance in a Pilot Site for Suitable Designs of Resource Enhancement Practices by *Dr. Yuttana Theparoonrat*; and (4) Artificial Reefs Contribute to Marine Resources Enhancement by *Dr. Sadamitsu Akeda*.

In his paper, ***Mr. Ahmad Zuwairi Zainudin*** summarized the progress of Malaysia in its R&D activities on artificial reefs, *e.g.* construction and designs, materials used, and site selection. He also presented some of Malaysia's success stories on artificial reefs installations as natural resources habitat and reviewed the case study on management of artificial reefs in Sabah implemented by the Department of Fisheries Malaysia in collaboration with local fishermen's community which was established for the purpose of developing and protecting the artificial reef sites. He emphasized that in the installation of artificial reefs, local communities should be involved especially the fishers to make sure that the construction plans and installation are beneficial to them, especially in terms of socio-economic returns.

Mr. Zainudin added that artificial reefs installation should also aim to minimize conflicts between traditional and commercial fishers by curbing possible encroachment of commercial fishers in traditional fishers' fishing areas. Meanwhile, he also mentioned that the Malaysian Fisheries Act 1985 clearly prohibits any fishing activities within the 0.5 nautical miles radius of artificial reef areas.

During the discussion, the Symposium considered the result of the impact assessment on the installation of artificial reefs in Malaysia with respect to the socio-economic benefits of fishers to be very impressive. Increases in terms of the fishers' average monthly income, *i.e.* from RM 1,500 to RM 2,100 could mean generating an increase of RM 12.45 to the monthly landing value from each fishing vessel for every unit of artificial reef. It is clear that such trend would facilitate the full cooperation of fishers in the management of the artificial reef areas. However, it was also suggested that other benefits that fishers could derive from artificial reefs should also be included in the analysis of the case study, such as for example in recreational fishing, encroachment control, and conservation of habitats.

Initial results of the Royal Initiative Project on the Installation of Artificial Reefs which was implemented from 2002 to 2015 in Pattani and Narathiwat Provinces, using five (5) types of materials, namely: concrete pipes, concrete blocks, abandoned train cars, used military tanks, and used cars, were presented by ***Dr. Kamonpan Awaiwanont***. Specifically, he provided a brief summary of the results of the study on monitoring the artificial reefs and fishing gear operation, and income of fishers from fishing around the artificial reefs.

Dr. Kamonpan added that the findings to date indicated that most artificial reefs are still in good condition although some are observed to be sinking, while results of diving surveys showed a total of 188 fish species inhabiting the artificial reef areas. The survey on fishing gears indicated that hook and line, threadfin bream fish trap, fish trap, and short-bodied mackerel gill net have been used by small-scale fishers in their fishing operations around the artificial reefs. Moreover, results of the income survey also suggested that the total income of fishers ranged from 14,275.38 to 110,064.71 Baht/month and catch rate of about 31.045 kg/boat while the average income was 47,371.20 Baht/month. He also mentioned that the project has therefore succeeded in raising the standards of living of fishers and in restoring the natural wealth of the fishery resources.

In responding to the queries from the participants, Dr. Kamonpan shared the methods which the Department of Fisheries of Thailand s adopted in monitoring and evaluating the artificial reefs well as the country's success in monitoring the area which was attained through consultations with fishers from nearby villages. On the effect of substances from military trucks on the environment in the artificial reef areas, Dr. Kamonpan mentioned that a study on this aspect is being carried out by a graduate student of the Prince of Songkhla University in Thailand.

In the paper on Environment Survey Studies on Artificial Reefs in Rayong Province, Thailand, ***Dr. Yuttana Theparoonrat*** focused on the results of the pilot project that aimed to evaluate the impacts of enhancement practices including artificial reefs (ARs) on the fishery resources and the environment. With an ultimate objective of sharing the findings to the Member Countries through capacity building on rehabilitation of fishery resources and habitats/fishing grounds, the pilot project was conducted by SEAFDEC/TD in Rayong Province of Thailand in 2009-2014 in collaboration with the Eastern Marine Fisheries Research and Development Center (EMDEC) in Rayong Province, Thailand.

The activities carried out included identification of fishing gear used, as well as species composition and abundance. Underwater observation was also conducted to assess the condition of the artificial reefs.

The results showed that the fishery resources around artificial reefs appeared to be less enhanced which could be due to certain environmental problems. Dr. Yuttana cited that the accidental crude oil leak from the PTT Global Chemical pipelines off the coast of Rayong Bay could have created a massive impact to the environmental condition, especially that of the artificial reef area in the adjoining Ban Phe Bay that led to massive reduction of the fishery resources around the Bay. More specifically, a study on the water circulation in the Bay also suggested that there was less water exchange in the AR areas due to a blockage of the shore tidal current flow.

During the discussion, it was suggested that the aforementioned survey studies should also consider the impacts of artificial reefs installation on the environmental conditions such as primary productivity, suspended solids, water turbulence, characteristics of bottom sediments, and marine benthos.

Considering that monitoring activity is important in setting up a work plan for the follow-up activities, it was therefore suggested that monitoring of the AR areas should be carried out four (4) times in a year, *i.e.* before and after monsoon seasons, to compare the results obtained considering the different sea conditions of the AR areas.

Two main aspects of the Japanese artificial reef activities, namely: artificial reef fishing ground for marine resources enhancement, and measurement method on the effects of fish-gathering and fish propagation around artificial reefs were introduced by ***Dr. Sadamitsu Akeda.*** In reviewing the historical background of artificial reefs construction in Japan, he recalled that in the early times artificial reefs were constructed as auxiliary fishing gear to gather fish. Now, artificial reefs are constructed to serve as fishing grounds to gather, propagate and protect fish from their larval/juvenile stages to adult stage, considering that in many cases, juvenile fish resources have been extremely diminished.

Construction and installation of artificial reefs should therefore aim to expand natural reefs and create new fishing grounds with the same conditions as those of natural reefs. He added that to date, a new type of ARs known as “upwelling reef” is being promoted in Japan following the concept that when rich nutrient salts near the bottom layer rise to the euphotic zone, primary productivity would be enhanced in the surrounding sea areas leading to increase in fishery production.

In the ensuing discussion, Dr. Akeda explained that “upwelling reef” is constructed using concrete blocks and stones at sea bottom with depths of more than 80 meters. Based on his experience in Japan, upwelling reef has been beneficial in terms of enhancing the primary productivity and fisheries production capacity of the surrounding sea areas.

Artificial Reefs Management and Development in Malaysia

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Abstract

Development of artificial reefs in Malaysia started since 1975 in Kedah. The 1st artificial reefs were made of used tyres. Advancements in technology allowed the development of artificial reefs using other materials such as PVC, ceramic, culvert, and concrete. From 2006 until 2014, development of artificial reefs in Malaysia focused on specially built concrete-based materials since concrete provides better and stronger foundation to sustain the artificial reefs' functions. Various designs have been made to match the seabed conditions in order to obtain optimum effects in enhancing the fishery resources and habitat rehabilitation. Results of socio-economic studies among fishers in Terengganu indicated that 89% of fishers agree that artificial reefs development enhance their monthly income from fishing activities. In addition, artificial reefs installation also increased fishers' monthly income by RM12.45. Artificial reefs installation usually involves local communities especially fishers to make sure that planning to build and installation will be beneficial to fishers. Artificial reefs installation also helps to minimize conflicts between traditional fishers and commercial fishers by curbing encroachment of commercial fishers in traditional fishers' areas. Underwater observation conducted in several artificial reefs showed that more than 100 fish species are living or foraging in artificial reefs areas. The Malaysian Fisheries Act 1985 clearly stipulates that fishing activities within 0.5 nautical miles radius from artificial reefs areas are prohibited and considered as an offence.

Keywords: artificial reef, concrete reef, Malaysian Fisheries Act, fishery resources, fish stock enhancement

Introduction/Background Information

In 1970s, the Australian Royal Air Force based in Butterworth, Kedah, Malaysia introduced artificial reefs (ARs) made from used tires for recreational purposes. Research and development on ARs were then initiated by the Research Division of the Department of Fisheries Malaysia (DOFM) with used tires as building materials. The first ARs made from used tires were installed in Pulau Telur, Kedah in 1975. Over the years, other materials have been used such as PVC pipes, decommissioned vessels, ceramics, and concrete. From 2006 until 2015, Malaysian ARs focused on concrete-based materials since these proved to be more durable as well as provide better and stronger foundation to sustain the functions of ARs. A number of AR designs had been produced since then to suit certain areas and target species. The main objective of ARs installation in Malaysian waters is to enhance and conserve marine biology and fishery resources productivity in coastal waters by establishing an ecosystem which could function as sanctuary, breeding and nursery areas for fishes; and conserve and protect damaged/destroyed habitats due to natural disasters or human activities. ARs also act as tidal breaker to minimize and control beach erosions, provide new substrate for coral propagation, enhance fish stocks and increase fish landings, and help curb encroachment of commercial fishers in traditional fishers' areas (<5 nautical miles). Development of ARs has been based on a guideline published by the United Nation Environmental Program (UNEP) *'Guideline for the Placement of Artificial Reefs'* which indicates that building materials for ARs should not be made from hazardous materials or items meant for disposal but of materials/items which help to enhance the fishery resources productivity. The Guideline also specifies that tidal breakers, buoys, cables, pipes and platforms should not be considered as artificial reefs even though they provide similar effects/functions as ARs.

Activities Conducted

Construction and Installation of ARs

Site Selection

Site studies have been conducted to determine the location and suitability of ARs installation by monitoring the water parameters such as seabed conditions, water depth, turbidity, and current. Conducted by researchers, the site studies consider that public engagement is important to get feedback/suggestions from local communities and to obtain their consent to avoid any conflict.

Design

The AR designs are chosen or re-designed based on results of site studies and purpose of ARs installation. Engineers are commissioned to come up with the appropriate designs after several discussions with managers and researchers.

Construction

Construction site should be closed to deep water jetty, near to deployment site, and accessible to hired cranes, trucks and pontoon. The site should have access to unload ARs, sufficient supply of water and electricity, road for heavy vehicles.

All specifications and technical drawings provided by DOFM must be met. For constructing concrete-based ARs, the use of vibrator and ready-mix concrete equipment from batching plant is mandatory. Cube test is conducted to determine concrete strength and curing period of at least 28 days after construction.

Installation

Before ARs are installed, detailed briefing of concerned workers is mandatory. Officers from DOFM should be directly involved during ARs installation to ensure that all procedures and specifications are complied. Certified and experienced divers are tasked to monitor the ARs installation. Two installation methods are used: (i) cables released by divers (not practical for water depth more than 5 meters); and (ii) mechanical release from the surface (recommended).

Monitoring

Monitoring is done by researchers few months after ARs have been deployed.

Results

Monitoring of AR sites in Malaysian waters have been conducted from 2006 until 2010, results of which indicated that through the years, AR sites have developed into breeding and nursery grounds, substrate for coral growth, fish aggregating device and natural habitats for marine life. Nevertheless, AR developments after installation differ from one site to another due to several factors such as distribution of corals and conditions of seabed sedimentation. A socioeconomic study on traditional fishers in Terengganu, Malaysia was completed in 2012 by DOFM in collaboration with Universiti Putra Malaysia (UPM).

Results of the study indicated that the ARs development gave an average monthly income of more than RM 2,100. For every one unit of ARs, it is estimated that monthly landings value for each fishing vessel could increase to RM 12.45, and the annual benefits value is estimated at RM 342,375. This study however did not include other benefits of ARs to fishers such as recreational fishing, encroachment control, conservation of habitats, and other factors which could definitely give added value to fishers' livelihoods.

Lessons Learnt

Management of ARs Site in Sabah

Since 2008, a smart-partnership between DOFM and local fishers' community has been established for the development and protection of ARs sites aligned with the Ecosystem Approach to Fisheries management (EAFM). Locally, the system known as *Tagal System* provides the local community some kind of ownership to the ARs site. Local fishers are allowed to fish in ARs Site in a sustainable manner, and are responsible for monitoring and protecting the area from encroachment and fishing activities (*e.g.* use of dynamites and poison, and fishing with electric current) in close cooperation with DOFM, Marine Police, and the Agensi Penguatkuasaan Maritim Malaysia (APMM) or Malaysian Maritime Enforcement Agency, in the enforcement of regulations. Importantly, Sabah has a slightly different legislation which allows this type of management and collaboration to take place.

Tagal System (ARs Zoning)

Tagal System divides the ARs site into two zones, namely: Green Zone and Red Zone. While fishing activities is allowed in the Green Zone, it is prohibited in the Red Zone. The Red Zone acts and functions as fish sanctuary for conservation purposes. Rules are in place to control and monitor the fishing activities in the ARs site. These include:

i. Only local fishers are allowed to fish in the ARs site
ii. Fishers from other villages are allowed to fish in the ARs only after getting approval from the ARs Task Force
iii. Only hand lines are permitted to be used, while other gears are not allowed
iv. Fish less than 300 g must be released back to the waters
v. Anyone found encroaching in the ARs site must be advised to leave the site by the ARs Task Force, otherwise, they will be reported to DOFM, Marine Police and APMM for further actions.

Malaysian Fisheries Act 1985

In the Malaysian Fisheries Act 1985, under the licensing policies and procedures, it is clearly stated that fishing activities within 0.5 nautical miles radius from gazetted ARs site are prohibited and considered an offence. However, there is no gazetted ARs site for the time being because discussions and public engagement are still in progress in order to obtain public consent.

Recommendations and Way Forward

ARs installation is a famous method used to enhance and conserve fishery resources. However, what is important is the management of ARs sites after installation. Without proper management, ARs would not meet their objectives as conservation tools. The most preferable management tool is the EAFM concept which involves the collaboration among related agencies, the community and other stakeholders. Each party involved should discuss and play their respective roles in managing the fishery resources in ARs site.

Community's role is also essential and important especially in monitoring the ARs sites and reporting of any wrong doing or offence that occurs in the area. Scientific data and analysis is important to determine the most appropriate AR designs, sites for the installation, as well as the effectiveness of ARs, biomass calculation and other related data. A standard procedure or methodology must be in place in order to come up with good and conclusive results. This would also help researchers to develop a guide for ARs related studies and research.

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Royal Initiative Project: Coastal Fishery Resource Rehabilitation in Pattani and Narathiwat Provinces, Thailand

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Abstract

The Royal Initiative Project on Coastal Fishery Resource Rehabilitation in Pattani and Narathiwat Provinces of Thailand has been implemented during 2002 .2015-Five (5) types of materials are used for ARs, *i.e.* 707 concrete pipes, 5318 concrete blocks, 881 used train cars, 590 used cars, and 25 used military tanks. These ARs were installed in 101 fish habitats in Pattani and Narathiwat Provinces (2 fish habitats used concrete pipes, 50fish habitats concrete blocks, 30 fish habitats train cars, 18 fish habitats cars, and 1 fish habitat used military tank). In 2015, results of the monitoring and evaluation carried out through diving survey, fishing gear survey and income survey, showed that most artificial reefs are still in good condition but some are sinking. For artificial reefs using train cars, the walls and roofs had collapsed. A total of 188fish species were found in the artificial reefs areas. Small-scale fishers from Pattani and Narathiwat Provinces fish around the artificial reefs using hook and line, threadfin bream fish trap, fish trap, and short-bodied mackerel gill net, earning total incomes that ranged from 14, 275.38to 110, 064.71Baht/month. The catch rate was 31.045kg/boat while the average income was 47,371.20 Baht/month.

Introduction/Background Information

The Royal Initiative Project on Coastal Fishery Resource Rehabilitation in Pattani and Narathiwat Provinces in Thailand was launched in October 2001 (Siripech *et al*, 2002; DoF, 2005), after which studies were conducted, and all related activities regularly monitored. Involved in the project were public agencies, universities, and the private sector. Such undertaking made it possible to learn more about this important project that had already succeeded in raising the standards of living of fishers in the two provinces, and in restoring the natural wealth of the fishery resources. The achievements of the project have fully met the objectives that were graciously established by Her Majesty the Queen of Thailand in bringing to the Thai citizens effective solutions to their problems.

Activities/Results

This Royal Initiative Project had been implemented in Pattani and Narathiwat Provinces of Thailand from 2002 to 2014.

The materials used as artificial reefs (ARs) are shown in **Fig. 1**, while **Table 1** shows the number of materials that have been used as ARs in these provinces.

Fig. 1. Materials used as ARs in Pattani and Narathiwat Provinces, Thailand under the Royal Initiative Project during 2002-2014: (*clockwise from upper left*) concrete pipes, concrete blocks, train cars, military tanks, and garbage trucks

Table 1 Artificial reefs installed in Pattani and Narathiwat Provinces, Thailand through the Royal Initiative Project during 2002-2014

Year	Area	Concrete pipes		Concrete blocks		Train cars		Garbage trucks		Military tanks	
		Hab.	No.	Hab.	No.	Hab.	No.	Hab.	No.	Hab.	No.
2002	P	1	221	3	2,100	5	208				
	N	1	486	1	700						
2003	P			1	875	3	25				
	N			3	7,170	4	75				
2004	P			7	4,570	7	160				
	N			7	4,580	4	140				
2005	P			1	630						
	N			1	645						
2006	P			1	605			2	93		
	N			1	610			2	96		
2007	P			1	544			1	40		
	N			1	587			4	160		
2008	P			1	501						
	N			1	485						
2009	P			3	1,560						
	N			3	1,505						
2010	P			2	1,277	3	75	6	135		
	N			1	660	4	198	3	66	1	25
2011	P			1	549						
	N			2	1,103						
2012	P			2	1,016						
	N			1	522						
2013	P			2	987						
	N			1	515						
2014	P			1	502						
	N			1	520						
Total	**P**	**1**	**221**	**26**	**15,716**	**18**	**468**	**9**	**268**		
	N	**1**	**486**	**24**	**19,602**	**12**	**413**	**9**	**322**	**1**	**25**
Grand Total		**2**	**707**	**50**	**35,318**	**30**	**881**	**18**	**590**	**1**	**25**

Note: **P** - Pattani Province **N** - Narathiwat Province **Hab.**- Habitat **No**. – Number of materials

Objectives and Study Areas

1. Monitor the artificial reefs of the Royal Initiative Project in Pattani and Narathiwat Provinces in 2015
2. Survey the fishing gears used around artificial reefs in 2015
3. Survey the income of fishers operating around artificial reefs in 2015

The fishing areas covered two (2) villages in Pattani and Narathiwat, namely:

(1) Bangkao M.1, Bangkao Sub-district, Saiburi District, Pattani Province

(2) Bouengcharam M.10, Paiwan Sub-district, Takbai District, Narathiwat Province

Results

In early 2015, monitoring and evaluation were carried out in the study areas through diving survey, fishing gear survey, and income survey. The results are as follows:

Diving survey

Most artificial reefs were still in good condition although some were sinking. However, for ARs built from train cars, the walls and roofs had collapsed. A total of 188 fish species were found around the ARs (**Fig. 2** and **Table 2**).

Fig. 2. Results of diving survey to monitor the aggregation of fish in ARs installed through the Royal Initiative Project during 2002-2014 (*clockwise from upper left)*: fishes near the concrete pipes, concrete blocks, train cars, military tanks, and garbage trucks

Table 2. Number of fish species and fish family in different ARs in 2014

	Total	Concrete pipes	Concrete blocks	Train cars	Garbage trucks	Military tanks
No. of fish species	188	50	132	122	119	98
No. of fish family	55	23	46	39	40	36

Fishing gears survey

Small-scale fishers from Pattani and Narathiwat Provinces fish around the ARs using hook and line, threadfin bream fish trap, fish trap, short-bodied mackerel gill net. The results are shown in **Table 3**.

Table 3. Catch rate (kg/boat) and income (Baht/boat) based on monitoring of ARs of different materials in 2014

Materials	Fishing gear	Catch rate (kg/boat)	Income (Baht/boat)	Income (Baht/month)
Concrete blocks	Hook and Line	19.32	1,838.21	36,764.28
	Threadfin bream fish trap	74.40	948.51	18,970.20
	Fish Trap	19.94	1,136.67	22,733.33
	Short-bodied mackerel gill net	59.22	5,329.62	106,592.31
Train cars	Hook and Line	19.41	2,109.88	42,197.58
Garbage trucks	Hook and Line	11.91	1,368.38	27,367.59
Military tanks	Hook and Line	18.55	1,127.50	37,233.40
	Fish Trap	17.40	1,416.00	28,320.00

Income survey

The results indicated that the total income ranged from 14,275.38 to 110,064.71 Baht/month. The catch rate was 31.045 kg/boat while the average income was 47,371.20 Baht/month.

Lessons Learnt

The Royal Initiative Project on Coastal Fishery Resource Rehabilitation involved various stakeholders including the public agencies, universities, and the private sector. Through such undertaking, it was possible to learn more about this important project that has already succeeded in raising the standards of living of fishers in the two provinces, and in restoring the natural wealth of the fishery resources. The achievements of the project have fully met the objectives that graciously established by Her Majesty the Queen of Thailand in order to bring to the Thai citizens, the effective solutions to their problems.

Recommendations and Way Forward

The Royal Initiative Project on Coastal Fishery Resource Rehabilitation in Pattani and Narathiwat Provinces succeeded in restoring fishery resources in the waters of these provinces. The Department of Fisheries has a duty to monitor and install more ARs every year with the intention of attaining sustainability of the resources and improving the fishing communities' livelihoods.

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Environmental Survey Studies on Artificial Reefs in Rayong Province, Thailand: Technical Assistance in a Pilot Site for Suitable Designs of Resource Enhancement Practices

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Abstract

The series of environmental survey studies on artificial reefs carried out in Rayong Province, Thailand by SEAFDEC Training Department was part of the pilot project and capacity building on rehabilitation of fisheries resources and habitats and fishing grounds implemented during 2010 to 2014. Selected onsite study and evaluation of enhancement practices including impacts of artificial reefs to fisheries resources and environment were conducted in order to provide technical assistance to the Member Countries in their efforts to identify pilot project sites and capacity building activities on rehabilitation of fishery resources and habitats/fishing grounds. The survey studies were carried out based on fishing gear used in order to determine the species composition and abundance, while underwater observation was carried out to inspect the conditions of the artificial reefs "Rayong No. 2" installed at the eastern part of Samed Island, Rayong Province in December 2009 by the Department of Fisheries (DOF) of Thailand. The G-18 position of the artificial reefs (Lat. N 12° 31.085, Long. E 101° 30.830), was selected and referred to as a major site for the study as it comprised large amount of concrete block ARs (35 pieces of ARs 1.5 m^3) and probably has the most abundant species diversity in the ARs area. The fishing gears and equipment used for the species composition survey were fish trap, bottom gill-net, hand line, juvenile fish trap, Smith-McIntyre grab, and underwater observation. Results of the survey from fish trap operation before the ARs installation (February – March 2009) indicated the abundance of 18 fish species, and total catch was 52,658 g inside the ARs area. The major species caught were *Lutjanus vitta*, *Diagramma pictum*, *Scolopsis monogramma* and *Monacanthus chinensis* at 1863.3, 1520.8, 348.3, and 162.5 g/trap/time, respectively. Meanwhile, one year after ARs installation (March 2011), the fish trap operation indicated 12 fish species were found inside ARs area, and total catch was 22,520 g. The major species caught were *Siganus javas*, *Lutjanus lyjanus*, *Lutjanus russelli*, *Siganus canaliculatus* and *Diagramma pictum* at 202.5, 1360.0, 500.0, and 500.0 g/trap/time, respectively. Results from fish trap operations showed that the number of species and amount of catch decreased one year after ARs installation.

Results from benthos survey in August 2011 showed that there were 26 species of macro benthos found around the G-18 ARs position. There were 531 individuals found at the distance of 50 m to the west (W-50) yet in the most concentrated position there were 8 species. The major species found belong to Family Capitellidae, Family Pectinariidae and Family Maldanidae. Results of benthos survey in October 2012 found that there were 31 species around the G-18 ARs position, where 968 individuals were found at the distance 50 m to the south (S-50) yet the most concentrated position there were 10 species. The major species found belong to Family Capetellidae, Family Nereididae, Family Onuphidae, and Family Maldanida.

Results from interview with local fishers around Ban Phe Bay indicated that the major fishing gear used were fish trap, squid trap, bottom gill-net, hand line, and towing-line. Most of the fishers occasionally operated their fishing gear around ARs because the abundance of fish was not rich. The accident where about 50,000 liters of crude oil leaked from the PTT Global Chemical pipeline around 20 km off the coast of Rayong on 27 July 2013 had caused massive impact to the environmental condition and ARs around Ban Phe Bay. This accident led to severe reduction of the fishery resources around Rayong Bay for a year. However, the results from a study on water circulation around Rayong Bay and Samed Island during September 2013 showed that water circulation around ARs area was less due to a blockage along the shore where tidal current flow eastward Samed Island. Less current which flowed through the ARs structures could be the cause of less biological growth in the ARs areas.

Keywords: artificial reefs, resources enhancement, Rayong

Introduction

A series of environmental survey studies on artificial reefs has been being carried out in Rayong Province, Thailand since 2010 by the Coastal and Small-scale Fisheries Management Division of SEAFDEC Training Department. This is part of the five-year pilot project on Rehabilitation of Fisheries Resources and Habitats/Fishing Grounds implemented during 2010 to 2014 and aimed at seeking suitable designs of resources enhancement practices for the SEAFDEC Member Countries in the future. Under this project, selected onsite study and evaluation of enhancement practices including impacts of artificial reefs to fisheries resources and environment were carried out in Rayong Province, Thailand (**Fig. 1**) to be able to provide technical assistance to Member Countries wishing to establish pilot project sites and capacity building on rehabilitation of fisheries resources and habitats/fishing grounds. Large-scale artificial reefs (ARs) known as "Rayong 2 ARs", was selected for the study which was conducted from December 2009 to February 2010. Covering an area of 1.86 x 4.16 km^2, the Rayong 2 ARs were installed at Suanson Beach Ko Kudee in Klang District, Rayong Province (**Fig. 2**). The survey analyzed the catch from fishing gears for species composition and abundance, and conducted underwater observation to inspect the conditions of the ARs previously installed in December 2009 by the Department of Fisheries (DoF) of Thailand. The study intended to determine the resources rehabilitation processes by ARs and to establish appropriate methodology for ARs evaluation.

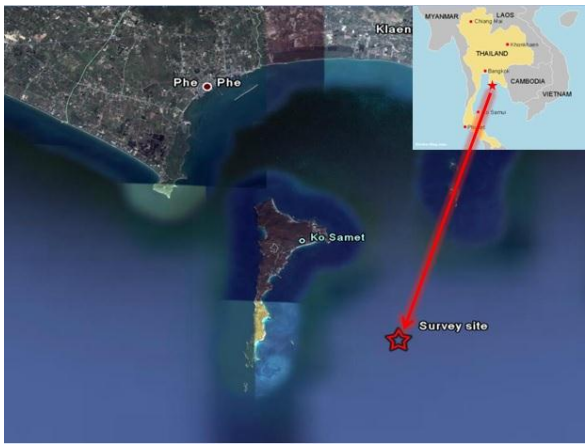

Fig. 1. Survey site in Rayong Province, eastern coast of the Gulf of Thailand

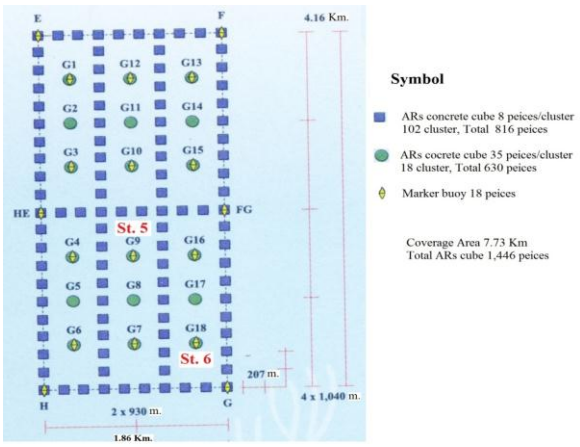

Fig. 2. Layout of ARs installation in survey site

Results

During the survey, fishing gears and devices were used to investigate the species composition and abundance of the fisheries resources near the selected ARs at G-18 position (Lat. N 12° 31.085, Long. E 101° 30.830) and referred as major site for the study as it comprised large concrete blocks (each measuring 1.5 m^3) and probably with the most abundant species diversity in the area off Rayong Province. Fish length and weight were recorded and species were identified and classified by types of fishing gear used. Juvenile fishes were identified, preserved and recorded. Benthic fauna specimens were identified and their distribution and abundance in the sampling area were estimated.

Fish Trap Operation

Data on fish species composition were collected from fishing operations using fish trap made of rectangular wooden frame 1.0 x 2.0 x 0.5 m covered with 2 cm mesh size wire and the narrowest entrance of opening funnel is 5 cm. Without bait, the fish trap was set for 10 days per operation, and positioned in station No. 5, 6, 9 and 10 inside and outside the installed ARs. Three fish trap fishing operations were conducted during February-March 2009 (before ARs installation), February-April 2010 (2 months after ARs installation), and March 2011 (1 year after ARs installation). The fish caught by the fish trap operations are shown in **Table 1** while the average catch per operation is shown in **Fig. 3**.

Table 1. Number of species caught by fish trap operations inside and outside Rayong 2 ARs

Area	Number	Feb.-Mar. 2009 (before ARs Installation)	Feb. – Apr. 2010 (2 month after ARs installation)	Mar. 2011 (1 year after ARs installation)
Inside ARs	species(sp), (quantity)	18 sp, (17,552.7 g)	16 sp, (47,440.0 g)	12 sp, (22,520.0 g)
Outside ARs	species(sp), (quantity)	20 sp, (26,177.7 g)	18 sp, (53,950.0 g)	14 sp, (13,060.0 g)
TOTAL	species(sp), (quantity)	26 sp, (43,730.4 g)	26 sp, (101,390.0 g)	14 sp, (35,580.0 g)

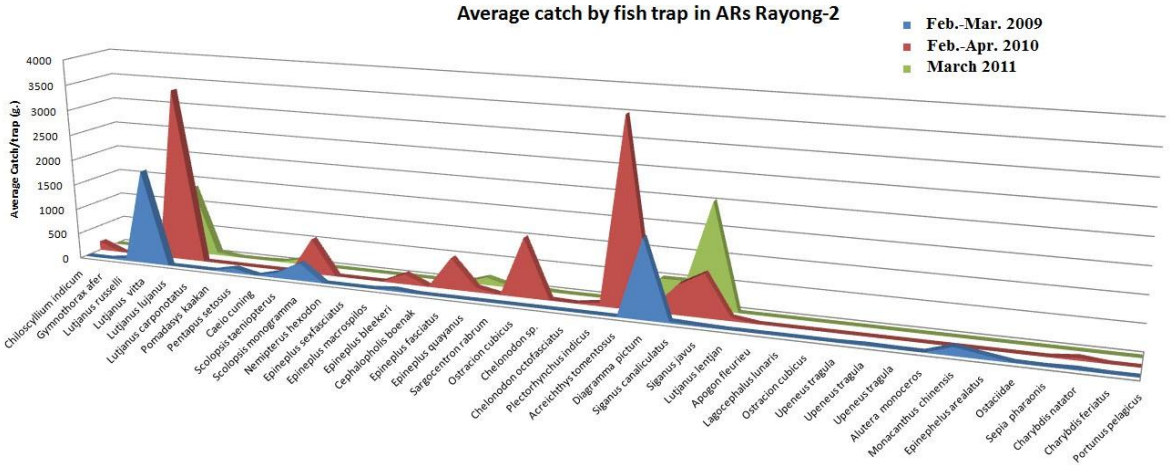

Fig. 3. Average catch by fish trap in Rayong 2 ARs during Feb.-Mar. 2009, Feb.-Apr. 2010 and Mar. 2011

As shown in **Fig. 3**, 18 species were caught before ARs installation (February-March 2009) and total catch was 17,552.7 g inside ARs area. The major species caught comprised *Lutjanus vitta*, *Diagramma pictum*, *Scolopsis monogramma* and *Monacanthus chinensis* at 621.1, 506.9, 116.1, and 54.2 g/trap/time, respectively. One year after the ARs installation (March 2011), 12 fish species were caught with total catch of 22,520 g inside ARs area dominated by *Siganus javas*, *Lutjanus lyjanus*, *Lutjanus russelli*, *Siganus canaliculatus* and *Diagramma pictum* at 2025.0, 1360.0, 500.0, and 500.0 g/trap/time, respectively. Results indicated that number of species in ARs area from fish trap operations slightly differed and decreased, while the amount of catch increased a little one year after ARs installation.

Bottom Gill Net Fishing Operation

A custom-made vertical extension pieces of trammel net (2.3 m high × 30 m long, 15.0 cm outer mesh size, 4.0 cm inner mesh size, nylon multi-filament, 110d/2) was used in the investigation. Five pieces of nets were sewn together horizontally to attain a length of 150 m and installed near Position G-18 to sample the catch of both demersal and pelagic fishes. The net was immersed underwater near the ARs for over 12 hours and retrieved the next morning. Three gill net fishing operations were conducted on December 2010, October 2011 and June 2012. During the survey, the bottom gill net caught 37 fish species while the other 25 were non-fish species (crabs, shrimps and cuttlefish), and were classified by groups, *i.e.* fish, crab, squid, and shrimp. The major fish species caught were therapon, yellow-striped scad, pony fish, threadfin bream, and rabbitfish with long-armed crab dominating the catch for non-fish species in all operations. Results indicated that the number of catch of therapon and pony fish increased from 2010 to 2012 from 5 to 61 individuals and 18 to 30 individuals, respectively. Catch of threadfin bream was stable at 9 to 11 individuals from 2010 to 2012, while catch of yellow-striped scad and long-armed crab decreased from 2010 to 2012, from 11 individuals to 0 and 35 individuals to 0, respectively (**Fig. 4**). From 2010 to 2012, fish species (by percentage weight) contributed 64%, 64% and 76% to the total, respectively, while crabs contributed 33% in 2010 and 12% in 2012 **(Fig. 5)**, suggesting that the species composition around Rayong 2 ARs must have changed with the age of ARs deployed.

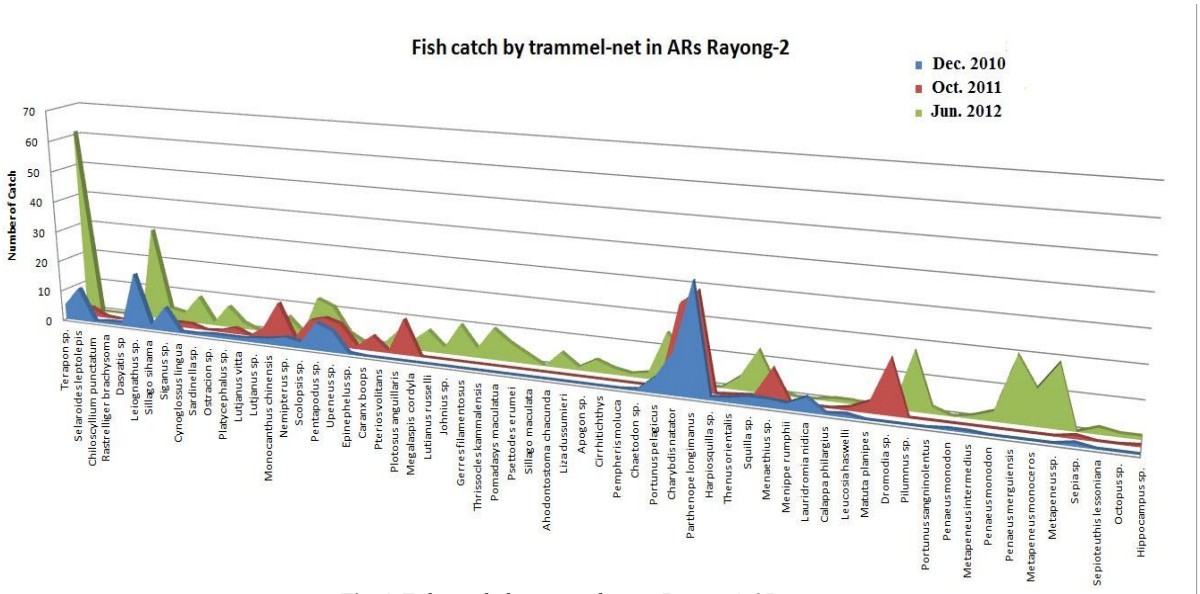

Fig. 4. Fish caught by trammel net in Rayong 2 ARs

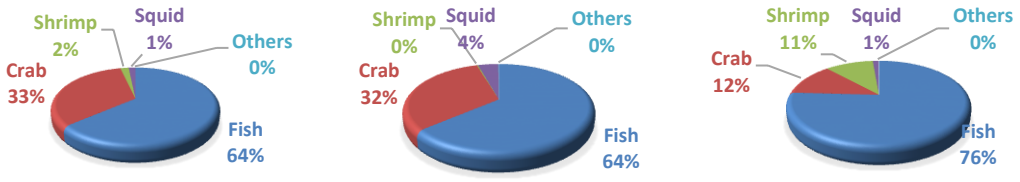

Fig. 5. Catch composition classified by percentage (weight) from trammel net in 2010 (*left*), 2011 (*center*) and 2012 (*right*)

Juvenile Fish Traps Operation

Two cylindrical-shaped juvenile fish traps made of steel frame (100.0 cm high and 90.0 cm in diameter) covered with fine-mesh net with an under entrance (diameter 26.0 cm) and two sided-entrances (inner diameter 15.0 cm, 22.5 cm long funnel from the outer entrance) attached with 2 luring lights (**Fig. 6**), were deployed near Position G-18 to collect data on juvenile fishes in the ARs area. The traps were suspended vertically at 1.0 m interval and 1.0-2.0 m above the sea bottom. Immersion time of the traps was over 12 hrs at night, and hauling operation was done the following day.

Results indicated that approximately 7 fish species and 2 non-fish species were caught by the juvenile fish traps. Among these species was one demersal species, *Upeneus* sp. (goat fish) while the others were pelagic (Engraulidae) or mid-water species, and the other 2 non-fish species (loliginid squid and polychaete) were classified as bottom dwellers.

The juvenile fish species comprised *Upeneus* sp., *Alepes* sp., *Gnathanodon* sp., *Encrasichoiina heteroloba*, *Encrasicholina* sp., *Archamia* sp., *Secutor ruconius*, Loliginid squid, and Nereididae. These results confirmed that 7 species of early stage juvenile fishes are using ARs as nursery ground or probably spawning ground.

Fig. 6. Cylindrical-shaped juvenile fish traps

Benthos Survey

Benthic fauna survey was carried out using a Smith McIntyre's grab at sampling stations near the G-18 position in the N-S and E-W directions at an interval of 25 m from the center (**Fig. 7**). Samples from 17 stations for benthic fauna sampling were collected and preserved and then identified by specialists. Results of the benthos survey in August 2011 indicated that there were 26 species of macrobenthos found in the sampling sites around the G-18 ARs position, and 531 individuals were found at a distance of 50 m to the west (W-50) yet at the most concentrated position only 8 species found. The major species found belong to Family Capitellidae, Family Pectinariidae and Family Maldanidae (**Fig. 8**). Results of the benthos survey in October 2012 indicated that there were 31 species around the G-18 ARs position, 968 individuals were found at a distance of 50 m to the south (S-50) yet the most concentrated position had only 10 species. The major species found belong to Family Capetellidae, Family Nereididae, Family Onuphidae and Family Maldanidae (**Fig. 9**).

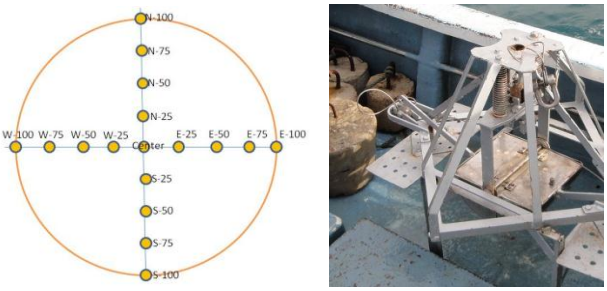

Fig. 7. Benthos survey sampling stations neat G-18 position in the N-S and E-W direction at interval of 25 m from the center (*left*) and Smith McIntyre's grab used for the sampling (*right*)

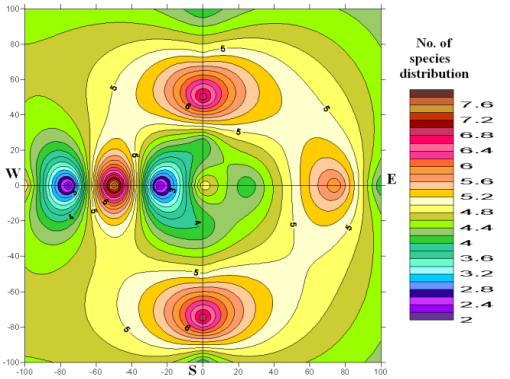

Fig. 8. Species distribution of benthic fauna at an interval of 25 m away from the G-18 position in North, East, South and West directions (100 m range) in August 2011

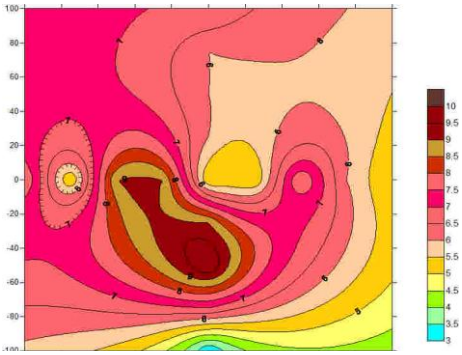

Fig. 9. Species distribution of benthic fauna at an interval of 25 m away from the G-18 position in North, East, South and West directions (100 m range) in October 2012

Conclusion

The socio-economic status of fishers fishing around ARs was determined through a questionnaire survey. Results of interview with local fishers around Ban Phe Bay indicated that their major fishing gears used were fish trap, squid trap, bottom gill-net, hand line, and towing-line. Most of the fishers occasionally operate their fishing gear around ARs because fish around ARs was no longer abubdant. This might have been due to the massive impact to the environmental conditions and ARs around Ban Phe Bay brought about by an incident where about 50,000 liters of crude oil leaked from PTT Global Chemical pipeline about 20 km off the coast of Rayong on 27 July 2013. This led to reduction of the fisheries resources around Rayong Bay for a year. Moreover, results of the study on water circulation around Rayong Bay and Samet Island in September 2013 conducted by the Marine Meteorological Center indicated that water circulation around the ARs area was less due to a blockage along the shore where tidal current flows eastward of the waters of Samet Island. Minimal water current flowing through the ARs structures had caused low biological growth in the ARs area.

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Artificial Reefs Contribute to Marine Resources Enhancement

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Abstract

When there are things such as sunken vessels in sea bottoms, Japanese ancient people knew by experience that various fishes gather near these sunken vessels. The function of sunken vessels is the same as natural reef. Therefore, artificial reefs had been constructed from ancient times as auxiliary fishing gear that aim to gather fishes. At present, artificial reef fishing ground had been constructed to gather, propagate and protect fishes from larval/juvenile stage to adult stage, because fishery resources are observed to be in extreme decrease in their juvenile stages. Depending on the scale of artificial reef fishing ground, in Japan there are the fishing grounds of around 400 cubic meters called "Namigata-sho", fishing grounds of several thousand cubic meters called "Oogata-sho", and fishing grounds of more than 30,000 cubic meters called "Jinkou-sho". The aim of installing artificial reefs is to expand the natural reefs and create new fishing grounds equal to natural reefs. In addition, there is a new-type of artificial reef which is called "upwelling mound". If this new artificial reef can raise rich nutrient salts near the bottom layer into the euphotic zone, artificial reefs will enhance primary productivity of the surrounding sea area, which in turn will raise fishery production capacity as a result. For discussion in this Symposium, two Japanese artificial reef activities will be introduced. The first is artificial reef fishing ground for marine resources enhancement, and the second is measurement method on fish-gathering effect and fish-propagation effect around artificial reefs.

Keywords: artificial reef, fish-gathering effect, fish-propagation effect

Introduction

Among the many things that linger at the bottom of the sea are sunken vessels. Ancient people in Japan learned through experiential observations that various fishes gather near these sunken vessels and that these sunken vessels function as natural fish reefs. Based on such observations therefore, artificial reefs (ARs) had been constructed from ancient times in the waters of Japan as auxiliary fishing gear for the purpose of gathering fishes.

Moving from the ancient times to the present, fishing grounds with ARs have recently been created to gather, propagate and protect fishes from their larval/juvenile to adult stages, considering that the fishery resources are observed to be extremely decreasing, especially the juvenile stage of many species.

The creation of fishing grounds with ARs is aimed at expanding the natural fish reefs, and establishing suitable habitats similar to that of natural fish reefs. Thus, several types of fishing grounds with ARs had been constructed in Japan, such as the "namigata-sho", "oogata-sho", "jinkou-sho", and others depending on the scale of fishing ground creation.

In order to increase the fishery production from constructed AR fishing grounds, sea farming is practiced to enhance the marine resources, *i.e.* from seed production, releasing and transplantation, in addition to enforcement of fishery restrictions.

Recently, a new type of AR fishing ground known as the "upwelling reef" has been promoted in Japan. This type of AR is capable of raising rich nutrient salts near the sea bottom layer to the euphotic zone, enhancing the primary productivity of the surrounding sea areas, and as a result increasing fishery production.

Therefore, integrating fishing ground creation, sea farming and marine resources management would lead to marine resources enhancement. Recent movements in Japan with respect to development of ARs include determining the amount of fish or other marine resources that gather or aggregate around ARs, and creating AR fishing grounds for marine resources enhancement.

Determining the quantity of fish that aggregate around ARs

The main objective of determining the fish or marine resources that aggregate around ARs is to know the answers for 5W1H on the impacts of ARs, *i.e.* when, where, who, what, why, and how. In Japan, observations of fish schools around ARs are carried out through visual inspections by divers using optical and acoustic devices, among others. Sampling surveys are also being carried out using such fishing gear as pole-and-line, longline, gillnet, and others. In addition, biotelemetry and tagging of fish for releasing experiments have been undertaken. Results of fish gathering surveys, fish market surveys, questionnaire surveys, and interviews have been used to analyze the extent of enhancement or cost-effectiveness of the AR fishing grounds. The characteristics of several measurement methods to determine the fish and marine resources aggregating around ARs are shown in **Table 1**. For example, the characteristics of diver's visual inspection could include: observation area which should be narrow and short; observation inside of ARs should be possible; duration time of observation should be very short, *i.e.* within about 1 hour; observation of the composition and body lengths of fishes near the ARs could be done. If the water depth near the created AR fishing grounds is shallow, observation cost could be cheaper than in deeper waters.

Table 1. Characteristics of several measurement methods to be used around created AR fishing grounds

Method	Observation of Fish School			Observation Area			Duration Time	Cost
	Composition	Mass	Body Size	Distance	Width	Inside		
Visual Inspection by Diver	◎	△	○	Short	Narrow	Available	Hour	Average
Optical Device ROV	○	△	△	Short	Narrow	Unavailable	Day	Average
Acoustic Echo-sounder	×	△	×	Long	Extensive	Unavailable	Day	Expensive
Fish Finder	×	○	△	Long	Extensive	Unavailable	Day	Average
Pole and Line Fishing	△	△	○	Short	Narrow	Unavailable	Day	Cheap
Long Line Fishing	△	△	○	Middle	Middle	Unavailable	Day	Cheap
Gill Net Fishing	○	△	○	Middle	Middle	Unavailable	Day	Cheap

Note: ◎Exact result ○Present conditions recognition is possible △ Conjunction with other investigations ×Unavailable

How the created AR fishing grounds can contribute to marine resources enhancement

The creation of AR fishing grounds could contribute to marine resources enhancement through the promotion of three major attributes, namely: integrating or linking resources enhancement with sea farming and resources management; creation of protected areas; and adoption of new method of AR fishing ground creation such as the establishment of "upwelling reef."

Integrating resources enhancement with sea farming and resources management

Marine resources enhancement has been carried out in Japan through the integration of fishing ground creation, sea farming, marine resources management, and fishery restrictions. The aim of fishing ground creation is to improve or create habitats for marine organisms while that of sea farming is for artificial enhancement of the marine resources. As shown in red broken line in **Fig. 1**, the aim of marine resources management is to control illogical fishing in order that through marine resources enhancement which aims for artificial creation of habitats, the blue broken line could be reached starting from the black solid line which is the natural condition of the resources (**Fig. 1)**.

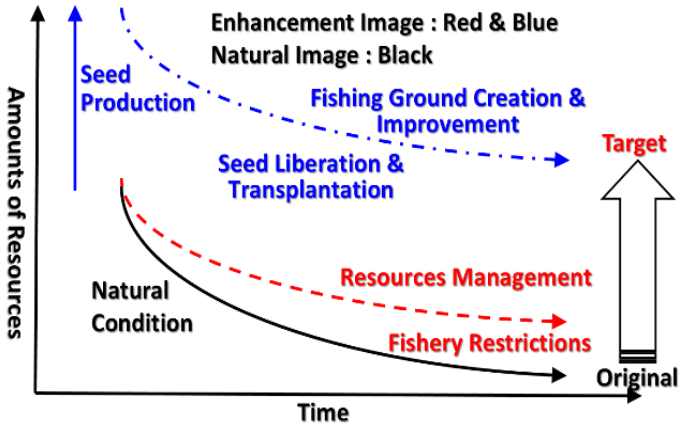

Fig. 1. Concept of marine resources enhancement adopted in Japan

When marine organisms are observed to have extremely decreased until juvenile stage, artificial enhancement of the marine resources is undertaken such as seed production, intermediate breeding, seed releasing, and transplantation (**Fig. 2**). Based on the life stages of target species, the habitats of marine organisms could therefore be improved or created artificially. In addition, fishing restrictions on fishing methods, gear, season, ground, catch-size, among others could be enforced. If necessary, protected areas or fishing prohibitions should also be established.

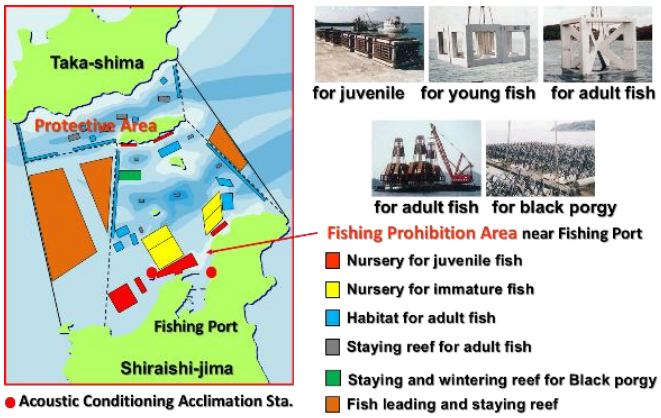

Fig. 2. Methods of marine resources enhancement adopted in Japan

A marine ranching project around Shiraishi Island in the Inland Sea of Japan shown in **Fig. 3**, was carried out from 1993 to 2001, targeting such species as the red sea bream, black sea bream, gopher, scorpion fish, Japanese sea bass, red-spotted grouper, and others. Sea farming that involves seed production, seed releasing and intermediate breeding with acoustic acclimation was carried out, while protected area and fishing prohibition had been established. Taking into consideration the life stages of the target fishes, existing fishing grounds had been improved into suitable habitats, especially when new juvenile nurseries with ARs were constructed.

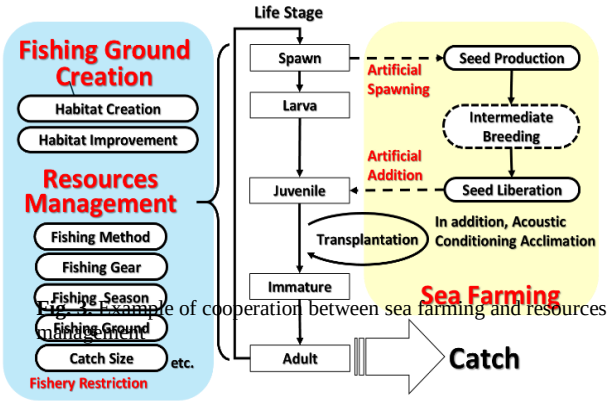

Fig. 3. Example of cooperation between sea farming and resources management

Furthermore, as shown at the left side of **Fig. 4**, fish catch from set net fishery had increased immediately based on the progress of this project.

At the right side of **Fig. 4**, fish catch of gill net fishery had also gradually increased after the effects of the cooperation that had taken place. However, there was a time-lag in the emergence of such effect.

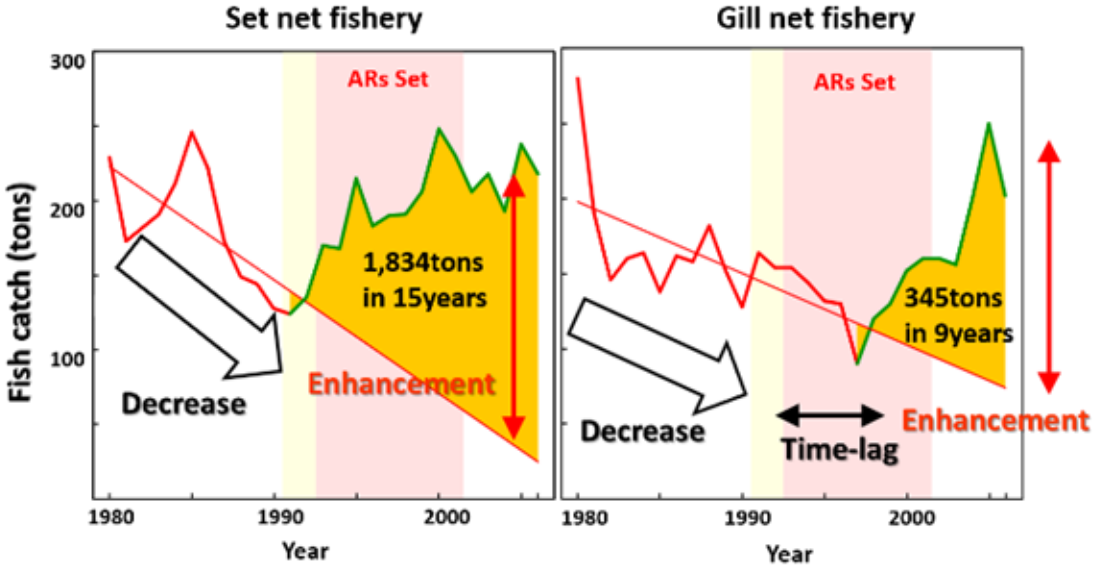

Fig. 4. Effects of cooperation with sea farming and resources management

Creation of protected areas

In the case of female snow crabs which should be protected during their spawning season from trawl fishery or basket net fishery, a fishing ground was created by local governments in the western part of the Sea of Japan since the 1980s (**Fig. 5**). In addition, fishing ground creation was undertaken by the national government starting in 2007. The red circles in **Fig. 5** are the sites of fishing grounds created by the national government, which also specified certain conditions for constructing AR fishing grounds under their direct control, *i.e.* (1) inside the EEZ, (2) target species for TAC or TAE, and (3) development of marine resources recovery plan.

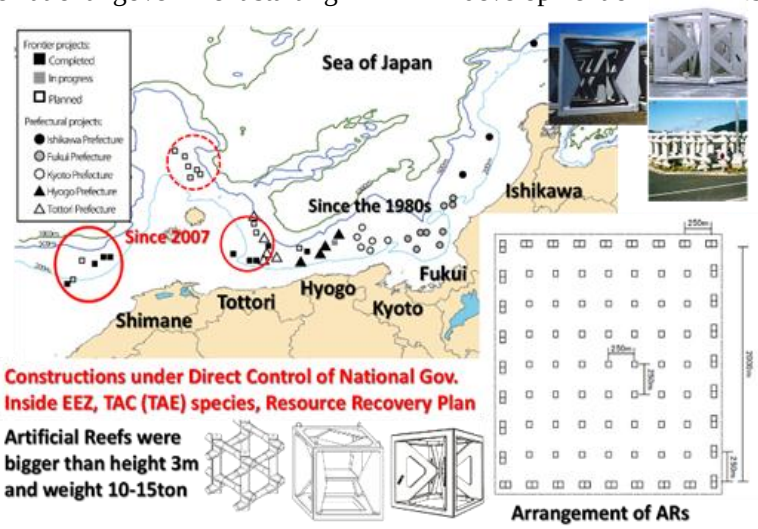

Fig. 5. Creation of protected area for snow crabs

The water depth of the spawning grounds of snow crabs was about 200 m to 300 m in the western part of the Sea of Japan. Several AR fishing grounds within the 2.0 km^2 area had been constructed with sizes bigger than 3 m high and weighing 10 tons. The progress after construction indicated gradual increase of attached organisms and benthic organisms in and around the ARs. Gravid female snow crabs which were about to spawn and various fishes had aggregated in the AR fishing ground. At the left side of **Fig. 6**, the catch of snow crab from the western part of the Sea of Japan was about 15,000 tons/year in the 1960s. Later, the catch of snow crab suddenly decreased to only about 2,000 tons/year in the 1980s. Thus, fishing prohibition area had been established and declared within 2 km of the created fishing ground. In the right side of **Fig. 6**, gravid female snow crabs or spawners had been protected in the created fishing ground. As a result, the catch of snow crab had gradually recovered since the 1990s.

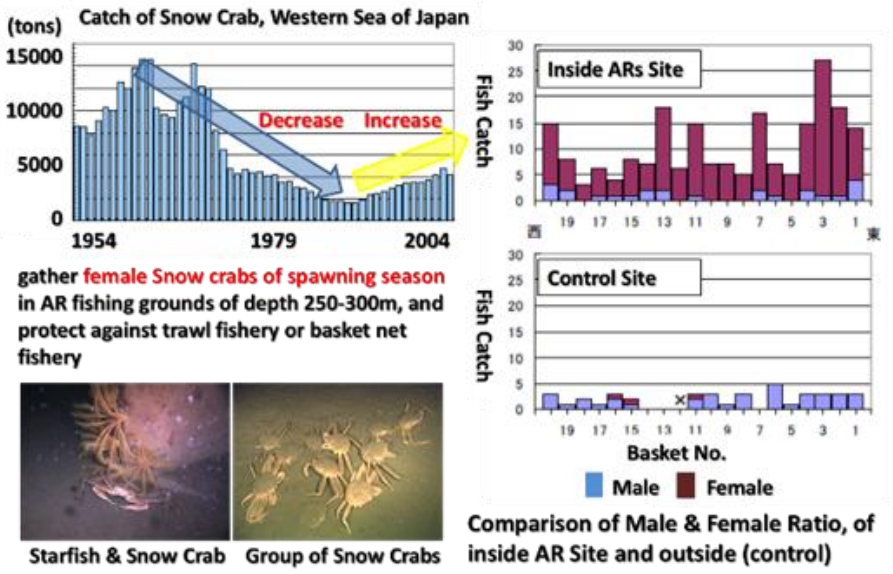

Fig. 6. Effects of creation of protected area for snow crabs

Adoption of a new method to establish upwelling reef

If upwelling reef can raise rich nutrient salts from the bottom layer into the euphotic zone, then upwelling reef would enhance the primary productivity of the surrounding sea areas, and eventually, the fishery production would be increased (**Fig. 7**). An upwelling reef 5 km off the Ikitsuki Island in Nagasaki Prefecture was constructed for the first time in Japan from 1997 to 2000. This upwelling reef 16 m high, 120 m long and 60 m wide, was constructed using concrete blocks set at sea bottom with depth of about 82 m. Since the construction at Ikitsuki, more upwelling reefs had been constructed at 7 sites in Nagasaki, 1 site in Kagoshima, 2 sites in Miyazaki, and 1 site in Shizuoka.

An analysis of the chlorophyll distribution in the sea surface was carried out to confirm that the primary productivity near the upwelling reef had been enhanced. Results of the progress after the construction indicated that chlorophyll distributions around the upwelling reef had increased as shown in blue line in **Fig. 8**. In the control sea area, which was away from the upwelling reef, chlorophyll distributions were not increased as shown in the red line of **Fig. 8**. Fish catch around the upwelling reef was also increased from 250 tons/year before construction to 1,500 tons/year after the construction. Specifically, the catch of anchovy, a plankton-eating fish had increased.

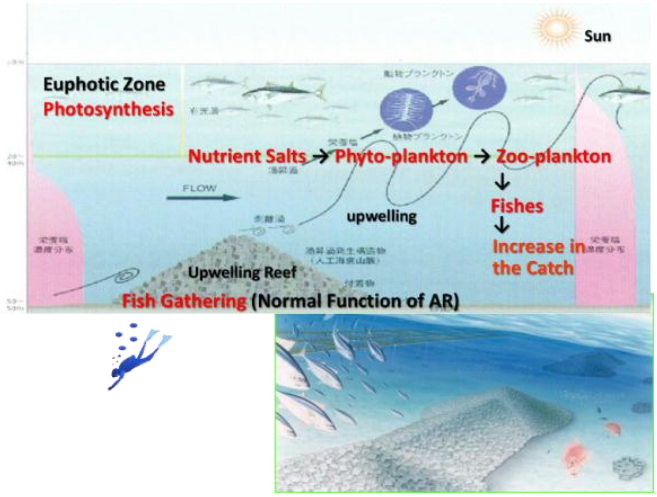

Fig. 7. Concept of establishing an upwelling reef

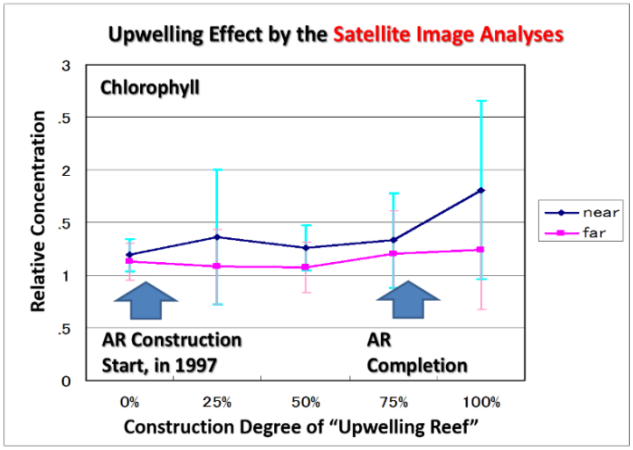

Fig. 8. Effects of creating an upwelling reef

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Session Papers
Session 2: Establishment and Management of Fisheries *Refugia*

This Session which had the SEAFDEC Policy and Program Coordinator *Dr. Somboon Siriraksophon* as the Facilitator discussed six papers on fisheries *refugia*. These are: (1) Effectiveness of Blood Cockle *Refugia*: a Case in Community Fisheries Prey Nub 2, Sihanoukville, Cambodia by *Mr. Yos Chanthana*; (2) Establishment of Marine *Refugia* in Malaysia: Conservation and Protection of Wild Penaeid Shrimp Stocks in Baram, Sarawak and Wild Lobster Population in Tanjung Leman, Johor by *Mr. Mohd Ghazali bin A. Manap*; (3) Identification and Establishment of Fisheries *Refugia*: Experience in the Philippines by *Mr. Noel C. Barut*; (4) Development of Fisheries *Refugia* through Closed Seasons and Areas in the Gulf of Thailand by *Mr. Pirochana Saikliang*; (5) Fisheries Stock Enhancement: an Important Measure Towards Sustainable Development of the Fisheries Sector of Viet Nam by *Ms. Nguyen Thi Phuong Dzung*; and (6) Fisheries *Refugia*: a Regional Initiative to Improve the Integration of Fisheries and Habitat Management by *Dr. Somboon Siriraksophon*.

In presenting his paper, ***Mr. Yos Chanthana*** shared his experience on the establishment of Blood Cockle *Refugia* in Sihanoukville, Cambodia. He explained the significant impacts that the Blood Cockle *Refugia* had created not only on the blood cockle resources but also on the habitats that this species rely on such as mangroves and sea grass that had also been protected and enhanced. Nevertheless, since the Blood Cockle *Refugia* has been placed under the guidance of provincial fisheries administration, the management approach had been modified to take into consideration the issues raised by fishers such regulation as blood cockle size which seems not applicable and reasonable.

In addition, Mr. Chanthana explained that the site of the *refugia* is relatively big making it difficult for the Community Fisheries to manage. As a result, it has been recommended that the restriction on the size of blood cockle to be harvested should be modified; the coverage area to be appropriately reduced; the current blood cockle team from the Community Fisheries should be restructured; and a scientific research on blood cockle biology should be carried out.

In responding to the queries from the Symposium participants, Mr. Chanthana explained that the site of the Blood Cockle *Refugia* is a natural blood cockle sea bed. The Community Fisheries had established self-regulatory measures such as fishing rights and entry, fishing seasons and fishing hours, and harvestable size of blood cockle that were set up based on consultations with the stakeholders, *e.g.* local fishers, local officers, government staff, researchers, and relevant organizations and agencies. He added that in spite of such regulations, illegal fishing operations still prevail in the area, especially by those who collect blood cockle using draggers with engine. This rampant practice could easily deplete the blood cockle resources in the area.

In his paper, ***Mr. Mohd Ghazali bin A. Manap*** described the experiences gained from the introduction of special *refugia* for two economically important commodities such as shrimp and lobster in Sarawak and Johor, respectively, following the concept of *refugia* similar to what has been successfully adopted in Sarawak, Malaysia which is known as "tagal system". The system is intended for the seasonal conservation of a freshwater fish, the Malaysian red mahseer (*Tor tombroides*).

Moreover, considering that Malaysia's production of penaeid shrimps and lobsters had been declining, the Department of Fisheries Malaysia initiated the activities that were mainly aimed at safeguarding spawning aggregations, nursery grounds, and migration routes; protecting and reviving fish populations from being overfished; and increasing and sustaining the catch and incomes of fishers and other stakeholders. Mr. Manap therefore briefly announced that a new concept of *refugia* would be introduced in Malaysia. However, this is still at the initial stage of preparation, especially on its work plan as well as the written guidelines and references to be disseminated to all stakeholders.

In the discussion, Mr. Manap explained that in the development of the aforementioned new concept of *refugia*, science-based information has been taken into consideration while agro-tourism aspects were explored. All these are meant to ensure that local communities could generate new and/or additional incomes.

However, Mr. Manap also explained that the aforementioned three established *refugia* systems had been constrained by various factors. The most significant of which include: inadequate support from local communities resulting in less active participation during consultations; pollution from terrestrial activities especially the sludge coming from crude palm oil milling factory that flows into the *refugia* area in Tanjung Leman; local communities not empowered to stop encroachment by illegal fishers in *refugia* areas. Moreover, the characteristics of target commodities being migratory make it difficult to manage the fisheries. More particularly, the target fish species in "tagal system" have become dependent on artificial diet provided by tourists instead of finding food by themselves from the natural environment.

In his presentation, ***Mr. Noel C. Barut*** outlined the process of identifying and establishing fisheries *refugia* in the Philippines based on two case studies conducted in Busuanga, Palawan; and Zamboanga Peninnsula. Specifically, Mr. Barut cited that in the case of the Philippines, success of fisheries *refugia* depends on the actions at the local level with the level of community support dependent on the involvement of local stakeholders in any relevant actions undertaken.

Mr. Barut added that that while science-based management measures are most acceptable, it is also necessary to harness local knowledge as this is critical for site selection and establishment of management measures. Information and communication also helped in enhancing communities' acceptance of the fisheries *refugia* approaches.

During the discussion, Mr. Barut explained that the case study in Busuanga, Palawan facilitated the development of a model of fish egg dispersal and larval settling in Philippine waters. The source and sink of fish eggs and larvae had been used to identify the spawning and nursery *refugia*. For the case study in Zamboanga Peninsula which was meant to address the decreasing catch of sardines, a management measure was established through the enforcement of closed fishing season in the Peninsula's fishing ground. The result led to increased catch of sardines but the price also decreased due to oversupply.

In his paper, ***Mr. Pirochana Saikliang*** introduced the development and management, and the challenges in the establishment of fisheries *refugia* in the Gulf of Thailand.

Mr. Pirochana recalled that the increasing demand for protein sources together with rapid development and improvement of fishing gear and fishing techniques resulted in the major stock reduction of the Indo-Pacific mackerel (*Rastrelliger brachysoma*) and other economically important species in the Gulf of Thailand.

Mr. Pirochana declared that this concern led to the establishment of fisheries *refugia* by the Department of Fisheries (DOF) of Thailand through the enforcement of closed seasons and areas in some parts of the Gulf of Thailand. He cited that this measure involves prohibiting the operation of some fishing gears and practices as well as monitoring of the changes in the status of the target species, and evaluating the fishing methods to determine the appropriate measures that could be promoted from time to time for the sustainable utilization of this pelagic species.

The measures developed for conserving the Indo-Pacific mackerel had been used as basis for the formulation and development of conservation measures for other commodities. Mr. Pirochana added that cancellations and revisions of the measures have been effected from time to time based on the changes in the status of the fishery resources and effective management of the aquatic resources.

During the discussion, Mr. Pirochana explained the importance of enhanced involvement of stakeholders through their participation in consultations for the establishment of fisheries *refugia*. He also mentioned that in the fisheries *refugia* area as a critical area of the life cycle of economically-important fish species, monitoring, control and surveillance of the area should always be enhanced. Nevertheless, Mr. Pirochana also stated that many challenges are hindering the effective implementation of closed seasons or areas. For example, the issue on tranboundary fisheries *refugia* should be considered in the management and conservation of shared stocks while concerns on certain overlaps in the management of fisheries *refugia* and transboundary areas should be addressed.

In order to discuss the experience of Viet Nam in fisheries stock enhancement, ***Dr. Nguyen Thi Phuong Dzung*** briefly summarized the issues related to the marine protected areas (MPAs) system and fisheries *refugia* (closed seasons and areas) promoted in Viet Nam. Addressing such issues had been considered useful for promoting stock enhancement, especially for endemic, rare and important economic aquatic species.

Such species include the tiger shrimp *(Penaeus monodon),* featherback *(Notopterus notopteru),* ray-finned carp *(Semilabeo notabilis),* spiny barb *(Spinibarbichthys denticulatus),* redtail catfish *(Hamibagrus elongatus),* common carp *(Cyprinus carpio),* barbel chub *(Squaliobarbus curriculus).* Dr. Dzung explained that the MPAs system in Viet Nam has been playing an important role in stock enhancement, which is considered as potential successful approach to addressing barriers in fish stock and habitat management. Results of stock enhancement activities could therefore serve as important measure for enhancing the resources to enable them to continue providing animal protein, employment and household income for the rural populace. However, a comprehensive evaluation of stock enhancement in large water bodies and rivers should also be undertaken.

In the discussion, Dr. Dzung mentioned that monitoring of the MPAs system in Viet Nam is done once a year, the results of which are used as basis for formulating policies and regulations on the protection and development of the aquatic resources of Viet Nam, and are meant for adoption throughout the country. It is also crucial that the engagement of stakeholders during the process of establishing conservation zones should be ensured considering the knowledge and experience of local stakeholders, *e.g.* officers, fishers, scientists, and government authorities. Furthermore, consultations with stakeholders should be regularly conducted to make them understand the system and the benefits that could be gained from the MPAs system.

To complete the session, ***Dr. Somboon Siriraksophon*** summarized the process of establishing fisheries *refugia* based on the outcomes of a regional initiative under the UNEP/GEF South China Sea Project carried out from 2002 to 2009. He explained that fisheries *refugia*, which is a "spatially and geographically defined, marine or coastal area in which specific management measures are applied to sustain important species [fisheries resources] during the critical stages of their life cycle," is a management tool that aims to enhance the fisheries resources through the integration of fisheries and habitat management.

Dr. Somboon cited that the ASEAN-SEAFDEC Ministers responsible for fisheries had demonstrated their support in the promotion of the fisheries *refugia* approach in the Southeast Asian region by endorsing the ASEAN-SEAFDEC Regional Guidelines on the Use of Fisheries *Refugia* for Capture Fisheries Management in Southeast Asia in 2006, and adopting the 2011 ASEAN-SEAFDEC Plan of Action on Sustainable Fisheries for Food Security Towards 2020 which serves as guide in formulating and implementing programs and activities that promote the adoption and use of the *refugia* concept in line with the aforesaid ASEAN-SEAFDEC Regional Guidelines.

Effectiveness of Blood Cockle *Refugia* in Community Fisheries Prey Nub 2, Sihanoukville, Cambodia

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Abstract

Blood cockle is one of the major marine products in the community but the resource is encountering the risk of stocks degradation mainly due to destruction of the fisheries habitats from rampant illegal fishing by dredgers and over-exploitation. Considering this as a very critical issue, the Fisheries Administration of Cambodia and Community Fisheries Prey Nub 2 in collaboration with SEAFDEC agreed and established the Blood Cockle Refugia. Since the project supported by SEAFDEC ended in 2009, a research was conducted in 2014 to evaluate the effectiveness of the blood cockle *refugia*. The specific objectives of the study were to evaluate the current status of the *refugia* management and improve the blood cockle resources in the Community Fisheries. The study used quantitative approach to collect data including key informant interviews with key stakeholders such as fishers, fisheries officers and commune councils, focus group discussion and field observation. Documents from the Integrated Coastal Resources Management Project: Sihanoukville, were reviewed. The report findings indicated that blood cockle refugia is still working under the guidance of the Provincial Fisheries Administration which modified the management approach. The regulation established on blood cockle size to be harvested was no longer enforced because local fishers complained about its negative impact on their daily catch. Other concerns of the Provincial Fisheries Administration included the relatively big proposed site for *refugia* which was difficult to manage; members of the Community Fisheries seemed not to be actively participating in the management scheme although the concerned local fisheries officers were working hard to implement the said scheme. Nevertheless, the daily catch of blood cockle was significantly stable indicating the effectiveness of the *refugia*. In general, the blood cockle *refugia* in Community Fisheries Prey Nub 2 brought a significant impact not only on blood cockle harvest but also on the habitats that this species rely on such as mangroves and sea grass beds that had been well protected. Anyhow, the management approaches of the *refugia* should be revised to reflect the socio-economic and environmental conditions of the local people in the area. Few suggested recommendations should be taken into account, such as (1) the restriction on size of blood cockle to be harvested should be modified, (2) the coverage area should be reduced, (3) the current Blood Cockle Team of the Community Fisheries should be restructured, and (4) a scientific research on blood cockle biology should be conducted using the baseline data from ICRM-SHV supported by SEAFDEC.

Keywords: blood cockle *refugia*, *refugia* management, effectiveness, community fisheries

Introduction

Blood cockle is one of the major marine products in Community Fisheries Prey Nub 2 in Shihanoukville, Cambodia but the resource has been observed to be at risk of degradation mainly due to destruction of the fisheries habitats from rampant illegal fishing by dredgers and over-exploitation. Considering this as a very critical issue, and in order to improve the situation, SEAFDEC together with the Fisheries Administration of Cambodia and the Community Fisheries Prey Nub 2, agreed and established the Blood Cockle *Refugia.*

After the project supported by SEAFDEC was completed in 2009, a review was conducted in 2014 to evaluate the effectiveness of the blood cockle *refugia*. The specific objectives of the study were to evaluate the current status of the *refugia* management and promote the improvement of blood cockle resources in the Community Fisheries. Data for the review were collected through key informant interviews with key stakeholders such as fishers, fisheries officers and commune councils, focus group discussions, and field observations.

(*left to right*): collecting blood cockle by hand; sorting harvested blood cockle; illegal engine-operated dragger used to harvest blood cockle

Results of Review

Findings from the review indicated that the blood cockle *refugia* is still working under the guidance of the Provincial Fisheries Administration with modifications of the management approach. Specifically, the specific regulation on size of blood cockle to be harvested which was adopted by the Blood Cockle Team during the Integrated Coastal Resource Management–Shihanoukville (ICRM-SHV) supported by SEAFDEC, was no longer enforced as the local fishers complained about the negative impact of such regulation on their daily catch. Moreover, the proposed site for the *refugia* was found to be relatively big and difficult to manage with some members of the Community Fisheries not actively participating in the management of the *refugia*. For such reasons, management of the *refugia* was placed under the Provincial Fisheries Administration with local fisheries officers taking up the responsibility of implementing the activity. Since then, the daily catch of blood cockle has been significantly stable indicating the effectiveness of the *refugia*.

In addition, the fisheries officers at commune level have also been assigned to work closely with the Community Fisheries Prey Nub 2, especially in patrolling the *refugia* area, although those officers do not stay permanently in the area. As a result, illegal collection of blood cockle still persists. In general, the blood cockle refugia in Community Fisheries Prey Nub 2 brought a significant impact not only on the blood cockle harvest but also on the habitats that this species rely on such as mangroves and sea grass beds that had been well protected.

It should be noted that the Blood Cockle Team under the ICRM-SHV Project had developed two types of sieves for sorting and filtering the harvested blood cockles: one for filtering 10 g blood cockle and the other for 20 g. There is a need to review use of such sieves from the socio-economic point of view, and if necessary, the regulation on the size of blood cockle to be harvested should be revised accordingly.

Conclusion and Recommendations

In general, the management approaches of the blood cockle *refugia* should also be revised to reflect the socio-economic status of the local people and the environmental conditions in the *refugia* area. Few recommendations should be taken into account for the sustainability of the *refugia*. These could include modification of the regulation on the size of blood cockle to be harvested, reduction of the coverage area to facilitate effective management, restructuring of the current blood cockle team of the Community Fisheries, and conduct of a scientific research on blood cockle biology using the baseline data compiled from the ICRM-SHV Project. Furthermore, it should be considered that fish *refugia* could be effectively managed if illegal fishing activities especially by outsiders are eliminated. Activation of patrol work is important to help reduce illegal fishing in the *refugia* area. Community Fisheries should maintain close collaboration with the Fisheries Administration in combating illegal fishing activities, especially in enforcing the relevant laws and regulations.

Establishment of Marine *Refugia* in Malaysia: Conservation and Protection of Wild Penaeid Shrimp Stock in Baram, Sarawak and Wild Lobster Population in Tanjung Leman, Johor

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Abstract

The Department of Fisheries Malaysia (DOFM) has taken initial steps in ensuring that natural resources are not threatened with extinction by introducing the concept of special *refugia* for two commodities, such as the penaeid shrimp and lobster. Tanjung Leman in Johor (Southeast of Peninsula Malaysia) has been identified as special *refugia* for lobster, and Kuala Baram (Northeast of Sarawak State) as special *refugia* for the penaeid shrimp. Since 2006, annual landings of lobster (*Panulirus* spp.) in Johor had been dramatically decreasing below 500 metric tons (MT) from previously recorded which was 2059 MT in 2002. Landings of lobster had dropped particularly in the West Coast of Peninsula Malaysia while landings in the East Coast, such as in Sabah and Sarawak also showed decreasing trend to below 200 MT. For penaeid shrimp (*Penaeus monodon*), capture data mainly from Sabah and Sarawak also showed decreasing pattern from 1948 MT in 2003 to 1226 MT in 2013. The month of March is the highest peak for annual landings of lobster and penaeid shrimp in Malaysia, mostly delivered by trawlers. Harvest of lobster and penaeid shrimp had contributed around 89% and 74%, respectively, to the overall catch landings of the country. Currently, several committees and action groups involving various stakeholders in the two areas were established and plans of action for 2014-2018 serve as written guidelines and references for all stakeholders. The successful implementation of the concept of *refugia* for seasonal conservation of a freshwater fish in Sabah under the program called Tagal System, had been an inspiration of the concerned stakeholders, believing that such success could be replicated in other areas of the country and for other economically-important aquatic species.

Introduction

The concept of *refugia* which is different from protected area, had been legally introduced in Malaysia since 1996 when the DOFM gazetted Fisheries Regulation 1996 (Closed Seasoned to Catch Kerapu Fry) from November to December every year in the State of Kelantan and Terengganu (north-east side of Peninsular Malaysia) for 370 km long stretching beaches. Also in the same year, DOFM gazetted Fisheries Regulations 1996 (Prohibition of Method of Fishing Grouper Fry) allowing only fish traps to catch grouper fry along Malaysian coasts. Catching grouper fry without special permit during the closed season is considered an offence under this regulation. However, enforcing these regulations faced a lot of constraints to the Government in terms of financial resources especially in engaging government personnel to do the patrolling, providing fuel for patrol boats, allocating allowances for concerned staff, among others. In 2000, the Department of Fisheries Sabah introduced one concept that had been rejuvenated from traditional practices called the Tagal System. A traditional concept of co-management, this system involves the local communities in various disciplines to manage certain area for the conservation of native species of fish in wild environment. The aim of Tagal System is to strengthen the smart partnership between government agencies and local communities in protecting, reviving depleted river fish population, and then harvesting such resource in a sustainable manner for the benefit of the local communities.

Tagal System

The concept of symbiosis between local community and authority has been successfully adopted for freshwater fish conservation. The first Tagal System in Malaysia was introduced in the State of Sabah in 2001 to protect 30 natural river fish pools for the river mahsheer (*Tor tombroides*) (Wong, 2012; Said, 2015). Local communities acting as "local policemen" have played important role in controlling the access for fishing in a designated pool declared as a Tagal area. Penalties are imposed by the local leader to those committing any offence in the Tagal area.

Tourists to the Tagal area are allowed to visit and experience swimming with the fish, and conduct feeding activities but at the Green and Yellow Zones only. While the Green Zone is open for other activities including fishing (catch and release method) and fish feeding with permission from the local community, the Yellow Zone is only open for fish feeding but fishing is absolutely prohibited. The Red Zone, usually located at the upstream of a river, is permanently closed and considered as resource conservation pool.

Tagal System in Sabah which started with 30 areas in 2001 had expanded to 487 areas in 2014 and benefited 170,000 local communities in various economic activities. Seventeen districts in the Western State of Sabah comprising 192 rivers have already been involved in Tagal Programs. Success of the Tagal Program is highly dependent on the close collaboration and cooperation between local communities and government authority as demonstrated in **Fig. 1**.

Fig. 1. Partnership between local communities and Department of Fisheries for successful management of Tagal System in the State of Sabah

The roles of local communities in the Tagal System are:

a) to identify suitable sites to be developed as tagal areas;
b) to form a committee for tagal to be headed by a local leader;
c) to monitor and protect the tagal site from illegal poachers, overfishing and pollution;
d) to ensure that only sustainable manner of harvesting is allowed in tagal areas; and
e) to provide updated information on the progress and development of the tagal area to the Department of Fisheries.

The Government Authority (Department of Fisheries) is responsible for:

a) providing technical advice on tagal system to the concerned local community;
b) monitoring the progress of existing tagal system;
c) pursuing direct involvement in relevant R&D activities;
d) conducting study tour for tagal communities;
e) assisting local communities in launching new tagal sites; and
f) promoting agro-tourism.

Rationale for Implementation of Marine *Refugia*

From 2000 to 2014, landings of lobster nationwide sharply decreased from 1140 MT to 217 MT (as reported in the Annual Statistics of DOFM) which could be due to reclassification of data in the Annual Statistics between *Panulirus* spp. and *Thennus orientalis* in 2005. However, the real landings of *Panulirus* spp. are still low in spite of some areas which have already been identified as natural nursery ground for this species. Meanwhile, for the tiger shrimp (*Penaeus monodon*), intensive exploitation of broodstock from wild habitat for mass production in shrimp fry hatcheries also contributed to the decline in landings of this species. From 2000 to 2013, landing patterns for this penaeid shrimp declined from around 1900 MT to 1200 MT. The main gears used by fishers to catch these two species are trawl net and gill net, while March and November are identified as high season for landing of lobster and June to August for the tiger shrimp. Within Peninsular Malaysia, the State of Johore has been identified with the highest landing area for the spiny lobster. Meanwhile, the State of Sarawak are identified with the highest landing for tiger shrimp. Due to the high economic value of these two species which as well as high demand, and based on the principle of conserving while still abundant, these two species were selected as trial for the new Malaysian *refugia* area in Tanjung Leman, Johor and Kuala Baram for spiny lobster and tiger shrimp, respectively (**Fig. 2**). Both areas also experience rapid development and strong competition with other indsutries such as tourism, oil and gas explorations and rubber plantations.

Fig. 2. Locations of Kuala Baram and Tanjung Leman, in Malaysia

Implementation Malaysian Marine *Refugia*

The methodologies adopted for the implementation of *refugia* in Malaysia are based on four main components (Said, 2015), namely:

a) Identification and management of fisheries and critical habitat linkages at two (2) priority fisheries *refugia*
b) Improvement of the management of critical habitats for fish stocks of trans-boundary significance via national actions to strengthen the enabling environment and knowledge-base for *refugia* management
c) Information management and dissemination in support of national-level implementation of the fisheries *refugia* concept
d) National coordination for integrated fish stocks and critical habitat management

Coordination for the implementation of *refugia* in Malaysia involved two structures of management and two levels of national coordination committee (**Fig. 3**). The first is National Structure comprising two levels of coordination committees: first level committee is Policy and Decision Making; and second is Scientific and Technical Committee. Meanwhile, at the refugia sites, second level committee is established involving local stakeholders (communities and authorities) concerned with these two particular sites.

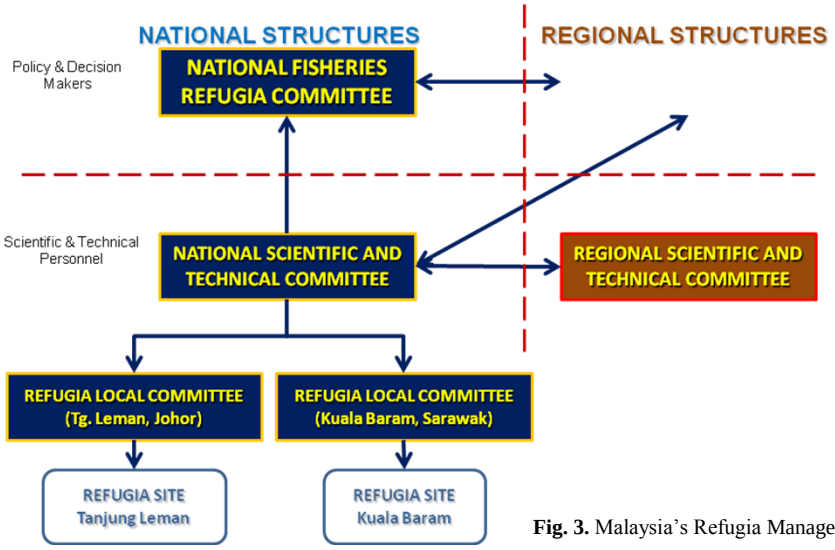

Fig. 3. Malaysia's Refugia Management Structure

The stakeholders involved for each committee are listed below while the detailed memberships in each committee are listed in **Appendix 1**:

a) First Level Committee
   i. Policy and Decision Maker Committee
   ii. Scientific and Technical Committee
b) Second Level Committee
   i. Tanjung Leman Refugia Committee
   ii. Kuala Baram Refugia Committee

Issues and Constraints

Active participation and support from local communities

Local communities hardly give their full cooperation and support to the *refugia* concept, limiting their efforts to catch fish all year round. This concept is already portrayed as a closed area where fishing is permanently prohibited. Furthermore, local fishers who are directly impacted from this partly conservation concept rely on lobster and tiger shrimp for their daily family incomes, seeking substitute incomes through other activities has become necessary to support the daily lives of fishers and their family needs during closed season.

Source of pollution from terrestrial activities

The two refugia sites are exposed and threatened with pollution from terrestrial activities. Tanjung Leman is surrounded with palm oil plantations and two crude palm oil refinery stations. While for Kuala Baram is located in famous oil-rich fields. Palm oil refinery, oil and gas industry and other terrestrial activities are major contributors and agents of pollution in the *refugia* areas. Therefore, the involvement of local authorities responsible for environmental quality is important in order that immediate actions could be taken to control pollution in the *refugia* areas.

Clear boundary

Conflict between fishers within refugia areas and fishers from other areas persist since clear boundaries of the *refugia* areas are not properly marked. Encroachment of fishers from other areas especially during the closed seasons has sparked tension and anguish among local fishers while watching other fishers fishing in *refugia* areas during closed seasons. Local communities are not empowered to arrest any encroachment by illegal fishers in *refugia* areas.

Migratory species

As noted, these two species are short-range migratory species. Lobsters from Tanjung Leman in Johor, Malaysia are known to migrate to adjacent Indonesian islands, while tiger shrimp in Kuala Baram *refugia* freely moved from Malaysia into Brunei Darussalam waters. These behaviors make all efforts in conserving the species and their habitats useless and difficult to measure it successfulness.

Experience from Tagal System

The fish in tagal has lost the ability to find food in natural environment. Most fishes in Tagal areas rely on artificial diets provided by visitors to Tagal areas.

Conclusion and Recommendations

Latest approaches of refugia with full participation of stakeholders, especially local communities are considered new concept in Malaysia. It is still in its initial stages and requires more intensive consultations and discussions on this newly introduced concept to get mutual agreement on management of the *refugia*. Awareness programs on the direct and indirect benefits of having *refugia* in their areas and their crucial roles in local community development would ensure successful adoption of this concept and sustain the continuity of this program. In addition, active participation of local communities in this new concept of *refugia* should be community-centered rather than top-bottom approach, in order to ease burden to the government and authorities concerned in enforcement as well as in controlling, safeguarding, reporting, monitoring and other government related activities.

Mutual agreement between authority and local communities will directly benefit the conservation of resources. The species that would be conserved through the *refugia* concept should be identified with the objective of protecting the scarce marine resources, such as the case of the spiny lobster and tiger shrimp, and raising the status of such species from being threatened to extinction. The bottom point in this concept is conserve will resources are still in abundance.

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Appendix 1

National Fisheries Refugia Committee (Policy and Decision Maker)

National Structure	Agency Involved
National Fisheries Refugia Committee ***Resource Management Division, DOFM Putrajaya (Secretariat)***	Department of Fisheries Malaysia (Chairmanship – Director-General of Fisheries Malaysia) Ministry of Agriculture and Agro-based Industry Ministry of Natural Resources and Environment (Biodiversity Division) Ministry of Modernization of Agriculture (MOMA) Sarawak. Economic Planning Unit Sarawak Economic Planning Unit Johor Malaysia Maritime Enforcement Agency (APMM) Royal Police of Malaysia Malaysia Fisheries Development Agency (LKIM) Ministry of Science, Technology and Innovation (MOSTI) Economic Planning Unit, Prime Minister Department Resource Management Division, DOFM. Fisheries Research Institute, DOFM. Resource Proctection Division, DOFM. Extension and Technology Transfer Division, DOFM. Planning and Development Division, DOFM. Legal Advisor Office, DOFM.

National Scientific and Technical Refugia Committee

Technical & Scientific Structure	Agency Involved
National Scientific & Technical Committee ***Fisheries Research Division (Secretariat)***	Fisheries Research Institute (Chairman – Director of Fisheries Research) FRI Batu Maung, Penang FRI Kampong Acheh FRI Bintawa FRI Rantau Abang Dept. Of Marine Park Malaysia Pahang State Fishereis Office Johore State Fisheries Office Sarawak State Marine Fisheries Office Universiti Malaysia Terengganu Universiti Malaysia Sarawak Universiti Malaysia Sabah National University of Malaysia Sarawak State Forestry Department World Wide-fund of Nature for Flora and Fauna (WWF) Malaysia Nature Society
	Johor State National Parks Department Pengerusi Refugia Perikanan Tg. Leman Pengerusi Refugia Perikanan K. Baram

Refugia Local Committee

a. Tanjung Leman Local Refugia Committee

Local Structure	Stakeholder Involved
Tg. Leman Local Refugia Committee, Johor	Mersing District Fisheries Office Rompin District Fisheries Office Mersing Fisherman Association Rompin Fisherman Association Fisheries Development Authority District of Mersing Mersing Land and District Office Local Enforcement Agency Trawler Vessel Owner Associaton Fisheries Ecosystem Community of Tg. Leman Johor State National Park Director

b. Kuala Baram Local Refugia Committee

Local Structure	Stakeholder Involved
Kuala Baram Local Refugia Committee, Sarawak	Sarawak Region 3 Fisheries Office, Miri. Sarawak Fishing Vessel Owner Association, Miri Chapter. District Fisherman Association. Fisheries Development Authority District of Miri. Miri Land and District Office Malaysia Maritime Enforcement Agency (MMEA) Petroleum Nasional (PETRONAS) Fisheries Ecosystem Community of Kuala Baram

Identification and Establishment of Fisheries *Refugia*: Experience in the Philippines

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Abstract

The process of identifying and establishing fisheries *refugia* is discussed in this paper, where "fisheries *refugia*" is an approach that integrates fisheries and habitat management to improve fisheries management in terms of space and time for sustainable use of fish stocks and protection of habitats. Also presented in this paper are site specific studies that showed the source and sink of fish eggs and larvae used in identifying the spawning and nursery *refugia*. Success of fisheries *refugia* depends on the actions at the local level where the level of community support depends on the involvement of local stakeholders in actions. Harnessing local knowledge is critical for good site selection and establishment of management measures. Science based management measure is most acceptable while education, information and communication is very helpful in terms of community acceptance of the fisheries *refugia* approaches. Other resource enhancement and management described in the paper are the closed fishing season for sardines in Zamboanga Peninsula, and closed fishing season for small pelagic fishes in the Visayan Sea and Davao Gulf. The effects of these management measures are seen in increased number of fish species as well as fish production.

Introduction

The concept of "fisheries *refugia*" was discussed and defined by the technical fisheries working group of the fisheries component on "*Over Exploitation of Fisheries in the Gulf of Thailand*" under the project on "*Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand*" funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP). The fisheries component project focused on the connection between integrating habitat and fisheries management. While the project was designed to have an agreement to establish a regional system of fisheries *refugia* in order to sustain trans-boundary fish stocks in the region, in-country or national activities were also carried out focusing on the establishment of country's fisheries *refugia.* The participating countries of the fisheries component were Cambodia, Indonesia, Philippines, Thailand, and Viet Nam.

Fisheries refugia as defined by the fisheries component are ***"****spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical phases of their life-cycle, for their sustainable use."* The features of *fisheries refugia* are: (a) specific areas of significance to the life-cycle of fish species; (b) should be defined in space and time; (c) should NOT be no-take zones; and (d) should serve to safeguard spawning aggregations, nursery grounds and migration routes.

National activities of the fisheries component were implemented by responsible government fisheries agencies in Cambodia, Indonesia, Philippines, Thailand, and Viet Nam. Their Governments nominated their respective focal points for fisheries, and later comprise the members of the Regional Working Group on Fisheries focusing on *Fisheries Refugia* supported by experts from UNDP, UNEP, FAO, and SEAFDEC, among others. **Fig. 1** shows the priority types of fisheries *refugia.* As defined, fisheries *refugia* are sites of importance to the critical stages of the life cycle of fish species which are also reflected in **Fig. 1**.

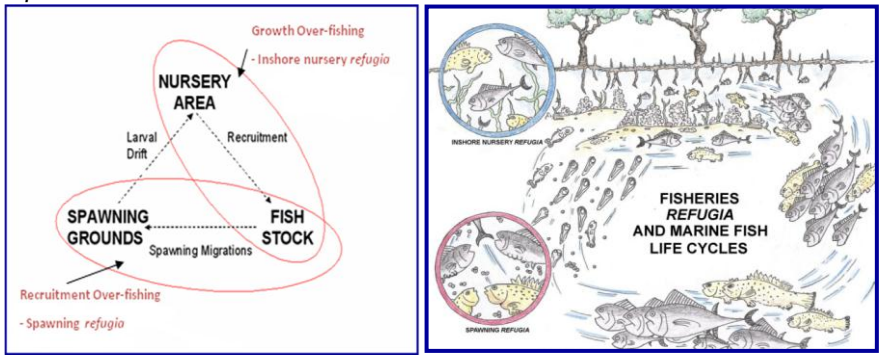


Fig. 1. The fisheries *refugia* concept and priority types
Left: spawning refugia (sources, function)
Right: nursery refugia (sink, function)

Activities and Results

Initial Review of Data and Information Requirements to Identify Refugia

Information from available studies, literatures, and other possible sources were compiled for the project. Prospective members of the Technical Working Group (TWG) were requested to provide their confirmation on the data compiled. After their confirmation, the National Focal Point convened the meeting of the TWG and discussed with the members the project. The information from available studies, literatures and other sources of data gathered were also presented at the TWG meeting. The TWG then convened a workshop participated in by stakeholders coming from the academe, research institutions, government agencies, fisherfolks, and Local Government Units (LGUs) that would host the proposed *fisheries refugia*, as well as representatives from Non-Government Organizations (NGOs), to validate the data and information compiled. Traditional knowledge on the seasonality, monthly sizes of fish observed by the fishers was very useful in identifying the fisheries *refugia*. The same activities were conducted in the different project sites.

Establishment of Fisheries Refugia

The following activities were considered in the process of establishing the fisheries *refugia* in all the project sites:

a. Study of the life-cycle of the species for which the fisheries *refugia* are being established;
b. Identification of the type of fisheries *refugia*;
c. Identification of the location of natural refugia and suitable sites of the fisheries *refugia* to be established;
d. Establishment of goals, objectives, and guiding principles for the fisheries *refugia* at the local level;
e. Development of priority fisheries *refugia* types, definition of the problems and concerns that will resolve the anticipated challenges in the establishment of fisheries *refugia;*
f. Study of the national and local level competencies in the implementation of fisheries management measures and spatial approaches to fisheries management and planning in establishing and managing *refugia;*
g. Identification of the actions needed at the national and local level to establish fisheries *refugia* like legislative, policy and administrative requirements and support.

Once all the above processes have been done, the steps in the formal establishment of the fisheries *refugia* could be carried out. Some examples of the studies conducted to support the establishment and implementation of fisheries *refugia* are shown below.

Lessons Learned from Two Case Studies: Busuanga in Palawan and Zamboanga Peninsula

- Success of fisheries *refugia* depends on actions at the local level. Sustained support of local communities is very important in sustaining the established fisheries *refugia*.
- Level of community support depends on involvement of stakeholders in the actions. A well informed community about fisheries *refugia* concept encourages their full cooperation and support.
- Harnessing local knowledge is critical for good site selection and establishment of management measures. Local knowledge of the fisherfolk reduces time, effort and money in conducting the survey where fisheries *refugia* would be established. Fisherfolks know where the small fish species are found during certain months of the year, the fish species, and the abundance of fish among others.
- Science based management measure is most acceptable and are easily understood when data are presented to the community;
- Education, Information, Communication (IEC) is very helpful. IEC campaign can deliver the messages easily to the community like, some aspect on the biology of the fish, the spawning time, and growth among others, in relation to fisheries management.
- Follow-up technical assistance/monitoring/ communication with Local Government Units is also very helpful in the implementation of the management measures at the local level. Once the fisheries *refugia* is established a regular visit to the site by the national government agencies can boost the sustainability in the operation of the management of fisheries *refugia*

<u>Case Study 1</u> - Busuanga, Palawan: Modeling fish egg dispersal and larval settling in the Philippines

Case Study 1 (Busuanga, Palawan)

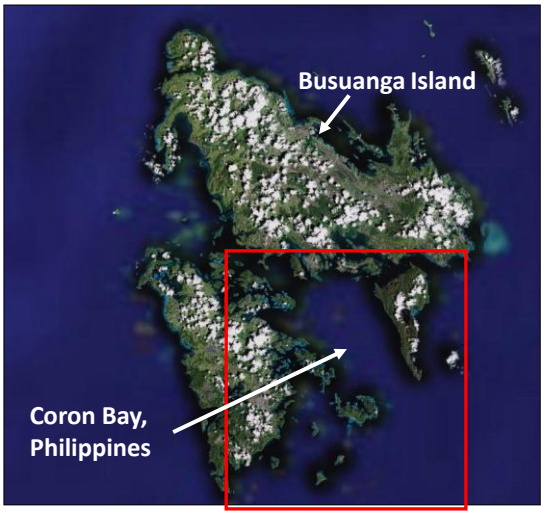
Modelling fish egg dispersal and larval settling in the Philippines

- **Oceanographic information and fish egg and larvae data used to identify spawning *refugia* (sources) and nursery *refugia* (sinks)**

Following slides illustrate:

- **Circulation pattern**
- **Simulated dispersal**
- **Density Distribution of fish eggs and larvae**

in Coron Bay, Philippines

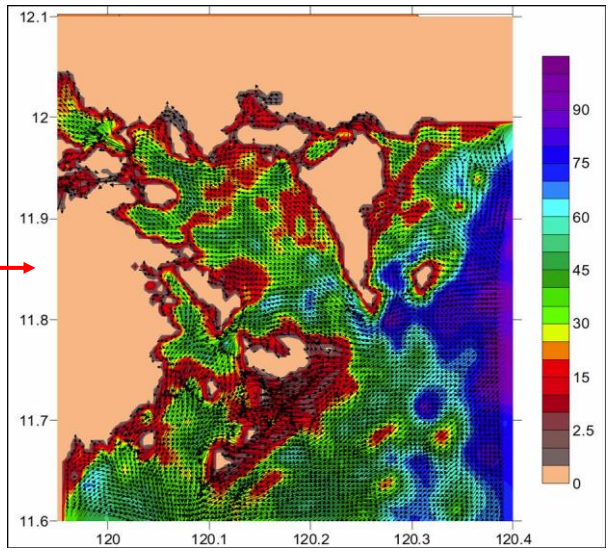


Source: USAID FISH Project

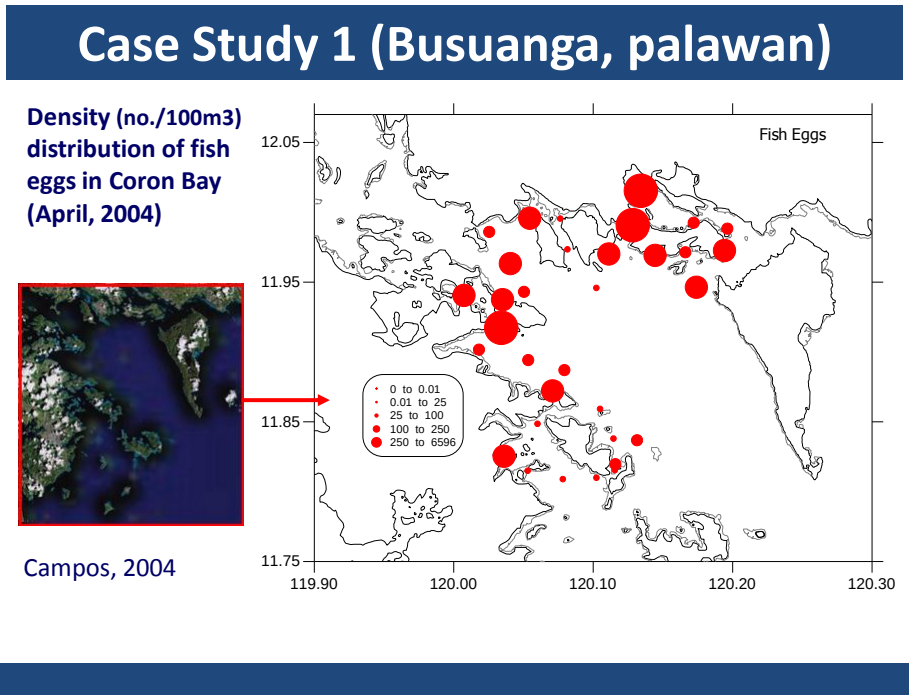
Case Study 1 (Busuanga, Palawan)

Circulation pattern in Coron Bay

Villanoy, 2006



Source: USAID FISH Project



Source: USAID FISH Project

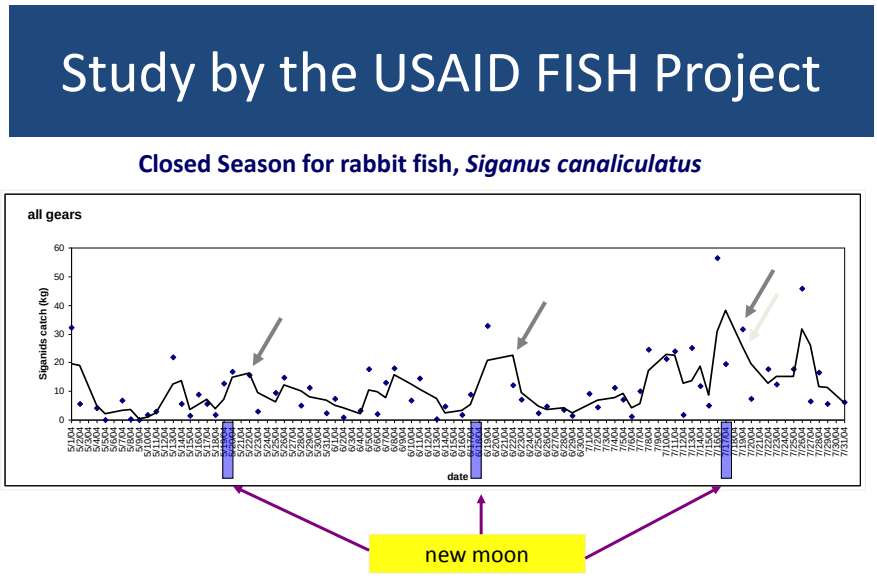
<u>Case Study 2</u> – Establishing close season for sardines in Zamboanga Peninsula, and other small pelagic fishes in Visayan Seas, Davao Gulf, and Bohol Sea, in the Philippines

Another activity in the Philippines that support resource enhancement is the close fishing season for some days or months as the case maybe. This close fishing season is anchored on fish biology particularly on reproductive biology of particular fish species of concern. In Zamboanga Peninsula, close fishing season for sardines is implemented from December 1 to March 1 every year. Studies on the reproductive biology of *Sardinella lemuru* showed that the peak spawning months for sardines is during December and from January to February majority of the sardines are still small in sizes.

Close fishing season is also observed in the Visayan seas from November 15 to February 15 every year. The species covered for this close fishing season are the small pelagic fishes such as mackerels, sardines and herrings. The ban is to protect the spawning populations of the fish stocks, the larvae, fry and the young fish.

In Davao Gulf, the close fishing season for small pelagic fish is from June 1 to August 31 every year. The target fish species are the big-eye scad, skipjack tuna, scad mackerel, and moonfish. The ban also aims to protect the spawning populations and the young individual fish.

In Bohol Sea, close fishing season is only for 3 days or nights per month for the whole year or certain months only. This is based on results of detailed studies conducted by the USAID Project on *Fisheries Improved for Sustainable Harvest* (FISH) where the peak specific spawning time per month of the target species rabbit fish (*Siganus canaliculatus*) had been determined. The fishing banned for rabbit fish is on the 4th, 5th and 6th day after the new moon monthly. Other management measures implemented is banning the use of fine meshed gears for catching rabbit fish and banning the sale of rabbit fish during the close season.



Catch monitoring data from various gears catching rabbit fish in Danajon Bank, Bohol from May to July 2004

Source: USAID FISH Project

Recommendations and Way Forward

Fisheries *refugia* is only one of the tools in fisheries management to enhance fishery resources production. To better improve the establishment and management of fisheries *refugia*, a more detailed study should be conducted to really determine the exact spawning time following the FISH project experiences.

However, more financial resources would be needed to conduct such study. Identification and establishment of more sites for fisheries *refugia* is a good activity for resource enhancement and fisheries and habitat management. The activity should be continued in other areas in the country.

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Development of Fisheries *Refugia* through Closed Seasons and Areas in the Gulf of Thailand

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Abstract

Marine capture fisheries of Thailand had been in the top ten fisheries production countries in the world. Indo-Pacific mackerel (*Rastrelliger brachysoma*) is one of the country's most important pelagic species, particularly those caught from the Gulf of Thailand. However, increasing demand of the Thai people together with the rapid development and improvement of fishing gear and fishing techniques resulted in the stock reduction of the Indo-Pacific mackerel and some other commercially important pelagic species in the Gulf of Thailand. Therefore, the Department of Fisheries of Thailand established fisheries *refugia* or closed seasons and areas in some parts of the Gulf of Thailand in order to prohibit some fishing gear and fishing techniques as well as monitor the changes in the status of aquatic species and also the fishing methods in order to determine appropriate measures from time to time for sustainable use of these pelagic species. During the past 60 years (1953~2015), the Department of Fisheries issued a total of 13 fisheries management measures in five periods relating to the development of fishing gears and fishing techniques corresponding to the "Gulf Closing" in the southern areas (Prachaup Khiri Khan, Chumphon, and Surat Thani) with the aim of conserving the spawning areas and nursery stage of aquatic resources in the Gulf. The measures for conserving the Indo-Pacific mackerel were used as basis for the formulation and development of other conservation measures. Cancellation and revision of these measures were also made from time to time in accordance with the change of status of the fishery resources and the effective management of the aquatic resources for sustainable exploitation.

Keywords: Fisheries *refugia*, closed seasons and areas, Gulf of Thailand

Introduction

Thailand's marine capture fisheries are highly significant both nationally and internationally, the country being among the top ten fish producing countries world-wide. The country's capture fisheries are dominated by "trawl fisheries" which mainly harvest demersal species. Pelagic fisheries are also significant with total production in 2011 that accounted for 38.0% of the total fisheries production, of which 66.0% was harvested from the Gulf of Thailand (GOT). Indo-Pacific mackerel (*Rastrelliger brachysoma*) is one of the most important pelagic species for the Thai people being considered "good meat and delicious". However, increasing demand of Thai people for protein sources together with rapid development and improvement of fishing techniques resulted in stock reduction of the Indo-Pacific mackerel and some other commercially-important pelagic species in GOT during the 1980s.

The GOT is one of the most highly productive shallow water areas due to high sediments and organic inputs including nutrients from river runoff that provide suitable conditions for high natural productivity. The Gulf of Thailand also supports high biological diversity and reports of a study indicated that there were more than 4,300 aquatic species found in the GOT (Sukhavisidh, 1996).

Inter-annual variations in climate, including extreme events are neither extreme nor frequent as in the Andaman Sea and together with the wide continental shelf, these conditions support important fishing grounds and permit the use of a variety of fishing gears including trawlers, surrounding nets, gill nets and various smaller gear types. Traditionally, capture fisheries in Thailand used to be operated in near-shore waters using stationary fishing gears such as bamboo stake traps. In 1925, this had changed by using "surrounding net" or "purse seines" based on the technology introduced from China in 1925. Subsequently, fishing operations evolved from the initial use of two small boats pulling the net from the mother boat, to the use of only a single main boat.

At the same time as the fishing technology changed, the size of fishing boats increased and as well as the means of propulsion from the original rowed boats, to sailing boats, and finally motorized vessels. Japanese trawlers with engines were also introduced in the 1930s, but these were not readily adopted by Thai fishers at that time. In the early development, Thai marine fisheries focused mainly on harvesting pelagic fishes and the development of fishing gear and methods to increase fishing efficiency.

Following the use of two purse seine boats and changing to a single large size fishing boat, the so-called "Thai purse seine" or "auan-chaloum" has become the dominant technology used by Thai fishers for catching the Indo-Pacific mackerel (Phasuk, 1979). Since the 1930s, aquatic resources had been increasingly harvested to meet the market demand resulting in declining fish stocks. Since the 1950s the Department of Fisheries of Thailand (DOF) has been monitoring the changes in status of aquatic species and also the fishing methods used, with the aim of determining appropriate measures for the sustainable utilization of these pelagic species.

Various management measures have been promulgated including mesh size regulation, fishing zone delimitation, and establishment of fishing and closed seasons. One of the important measures was the "Gulf Closing" that has been implemented in the GOT to prohibit some fishing activities operating during the spawning and nursing periods.

Concurrently, such measures have also been implemented in the Andaman Sea. This report presents the development of marine fisheries management in the GOT over the past 62 years. During the course of implementation of the fisheries management measures, focused has been placed in conserving the Indo-Pacific mackerel. Later, other commercially important species have also been included under these measures. The management measures implemented in the GOT from the past to present are reviewed in the following section.

Implementation of Management Measures

Prior to 1953, no measures had been established for the conservation and management of any marine resources including the Indo-Pacific mackerel (Hongskul, 1975). In 1953, DOF recognized that the Indo-Pacific mackerel in the GOT had been exploited in substantial quantities, thus, a Notification of the Ministry of Agriculture and Cooperatives (MOAC) dated 25th August 1953 was issued in order to conserve the Indo-Pacific mackerel stock by prohibiting the use of some fishing gear and methods during their spawning period. The prohibition focused on the use of specific types of fishing gear (such as large-scale Chinese purse seine, Thai purse seine, etc.) operating in southern Chumphon Province to the southern Gulf of Thailand from first day of the fourth waning moon to full moon day of the sixth (**Fig. 1** (left)). In practice however, fishing vessels still continued to operate in the prohibited area during the closed season.

During Period Two (1954-1967), the rapid improvements and development of new fishing gear and methods for catching pelagic fish in the Gulf of Thailand, resulted in increased pelagic fish catch, particularly the Indo-Pacific mackerel. In 1957, the catch of Indo-Pacific mackerel started to decline. The DOF established a Technical Committee for Indo-Pacific Mackerel Investigation Program to study the causes of the declining stocks in response to requests and complaints from fishers. In 1960, some of the fishers changed their fishing gear to otter-board trawl, which had been introduced from Germany. Even though the overall production from pelagic capture fisheries was still at high level during that time, it was found that the quantities of Indo-Pacific mackerel displayed a decreasing trend.

Therefore, Notification of MOA dated 18th March 1959 was issued to prohibit the use of some fishing gears and practices including the purse seine and encircling gill nets in the areas identified as spawning grounds of the Indo-Pacific mackerel. However, exceptions were provided for those who received individual fishing licenses (Phasuk, 1982).

In addition, this notification also aimed to obtain statistical information on catch data of the Indo-Pacific mackerel, through the use of logbooks provided by the DOF for recording catch data by fishers and submission of data to DOF. In practice, all fishers applied for licenses and none were refused.

Consequently, fishing effort remained much the same as before. In 1962, Notification of the MOAC dated 8th March 1962 was issued with the aim of defining the spawning duration of Indo-Pacific mackerel and limiting the use of mesh size in some fishing gear for catching small size Indo-Pacific mackerel. This was due to the heavy exploitation of the small size Indo-Pacific mackerel during the closed season. Then, the closed season was extended for one month and divided into two periods: the first from 15th January to 31st March defined as the spawning period of Indo-Pacific mackerel.

During this season, the use of all types of fishing gear equipped with purse line and also encircling gill nets were prohibited. The second from 15th April to 14th June defined as juvenile period. During this season, the use of purse seine and mackerel encircling gillnets of mesh size smaller than 4.7 cm were prohibited.

At the same time, the DOF also issued a regulation that any fishers who intend to engage in any fishing activity must receive individual permission in advance with the condition that the catch data should be recorded in the logbook (Phasuk, 1979). However, illegal and un-reporting activities during the closed season continued to occur due to weak enforcement of the regulations. The first closed areas and life cycle of the Indo-Pacific mackerel in the Gulf of Thailand are shown in **Fig. 1**.

In Period Three (1968 to 1982), over capacity of the fishing fleet that had been rapidly developed resulted in serious problem over this period due to increasing number of fishing boats, as well as development and improvement of bottom trawlers in the GOT (Bunyubon and Hongskul, 1978). Modified trawlers for catching Indo-Pacific mackerel were developed resulting in increased quantity of fish being caught by these vessels for many years (Boonprakob, 1974).

In 1972, MOAC Notification dated 13th October 1972 was issued to prohibit the use of trawlers in the southern areas (Prachuap Khiri Khan, Chumphon, Surat Thani, and Nakhon Si Thammarat Provinces), during the period from 1st February to 31st March. This regulation aimed to prevent trawlers from catching Indo-Pacific mackerel during the spawning period. This was based on the fact that between 17 and 22% of the catch taken from bottom trawlers and pair-trawlers were composed of spawners and juvenile stages.

The oil crisis in 1973 resulted in changes and modifications of pelagic fishing practices to reduce harvest expenses. These included the use of fish aggregating devices (usually using a bunch of coconut leaves) and light to attract fish (Phasuk, 1979). MOAC Notification dated 7th November 1975 was issued to specify the spawning season and prohibit the use of some fishing gear; and also to regulate mesh size. By revising the Notification dated 8th March 1962, gear prohibition was extended to include luring purse seine using coconut shelter with/without lights. The previously defined closed season was extended by an additional month starting from 15th April to 14th July annually (Phasuk, 1979).

During this period, a peak occurred for the first time in the GOT. The catch of Indian mackerel (*Rastrelliger kanagurta*) exceeded that of the Indo-Pacific mackerel. This could be probably a result of the increased number of luring purse seine fishing vessels from 100 in 1973 to 383 vessels in 1977 (Phasuk, 1979).

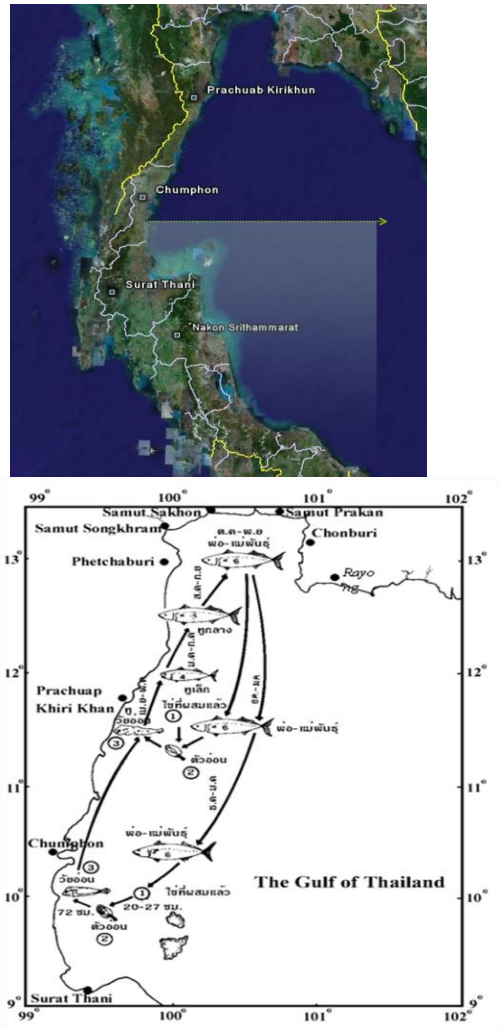

Fig. 1. Closed areas(*above*) and life cycle of the Indo-Pacific mackerel (*below*) in the Gulf of Thailand (Boonprakob, 1974)

Due to shortage of fuel gas in the domestic market, fishers started to lure fish by using lights generated by Dynamo-motor with capacities from 5 to 50 kW. The luring purse seine has become the common fishing practice since 1978 until the present (Sreungcheep, 1997).

Over the period from 1979 to 1981, fishers began to use electronic equipment such as echo sounders and sonar for locating fish schools. Since then, net hauler or power block had been used to minimize the number of crew during fishing operations.

Thus, from 1953 to 1977, a total of 5 Notifications relating to the management and conservation of Indo-Pacific mackerel were issued, aimed at protecting both the mature and juvenile stages of the Indo-Pacific mackerel. The contents of these notifications led to changes in the regulations regarding the length of closed seasons, gear prohibition and other regulations, and reflected the changes in the status of the fishery.

Effective control and enforcement of the regulations were major constraints reflecting both the insufficient number of officials and surveillance vessels. As fishers continue to defy the regulations (Phasuk, 1979), their gear and equipment had been modified in order to make their fishing gear different from those defined in the Notifications (Phusuk *et al*., 1988).

The areas of Prachuap Khiri Khan, Chumphon, and Surat Thani are also important spawning and nursing grounds not only for the Indo-Pacific mackerel, but also for other aquatic species (Phasuk, 1982). It was obvious that the Notifications issued in 1975 – 1983 were used for effective management and protection not only for the Indo-Pacific mackerel but also other aquatic species (Phusuk *et al*., 1988). Based on available data and information, the Pelagic Fisheries Investigation Unit of the Marine Fisheries Division of DOF had proposed to control the fisheries during the spawning and nursing period of Indo-Pacific mackerel by moving from closure of the whole area of GOT to closure of the specific spawning and nursing grounds during the two months period from 1st February to 31st March.

Under this Notification dated 13 October 1974, all types of fishing gears and methods were not allowed to operate, except the bamboo stake trap (Phasuk, 1982). The increasing number of trawl nets in the GOT resulted in the demersal resources reaching critical levels, since juveniles of both pelagic and demersal resources were over-exploited. From 1983 to 1984, it was also found that a lot of juvenile Indo-Pacific mackerel were caught, usually comprising 27-30% of the total catch of mackerel (Srireungcheep, 1997).

Therefore, DOF issued MOA Notification dated 3rd March 1983, by revising the Notifications dated 19th October 1972 and 7th November 1986. All trawl nets and purse seines with purse lines were not allowed to operate during the period from 1st February to 31st March (spawning period), and during 1st June to 31st July (nursery and juvenile period) for a total period of 4 months. This Notification which was effective from 1st June 1983 was meant to reduce the pressure of trawling and purse seining on all demersal and pelagic resources especially the Indo-Pacific mackerel. However, this Notification was temporally suspended due to the fishers' complaints, and then MOAC issued a Notification dated 6th May 1983 to support the temporary cancellation.

After 1984, the management measures for bamboo stake trap and encircling gill net with mesh size larger than 4.7 cm were accepted and these were considered appropriate gears (Phasuk *et al*., 1988). Subsequently, MOA issued Notification dated 28 November 1984 revising the Notification dated 29th August 1983 by extending the closed season from 2 months to 3 months and again dividing it into two periods: the first phase, spawning period from 15th February to 31st March, and the second phase, nursery and juvenile period from 1st April to 15th May of each year. Under this Notification, trawl nets and otter board beam trawls were not permitted to operate during daytime and purse seines were prohibited during the 45 days from 15th February to 31st March. From 1980 onwards, the anchovy purse seine fishing fleets had developed and expanded rapidly due to market driven demand, and the fishing fleet from the Andaman Sea had moved to the Gulf of Thailand in the waters of Surat Thani and Chumphon Provinces.

Anchovy fishers who were affected by the existing measures requested DOF to allow them to fish during the spawning period and quoted that their fishing practices targeted mainly anchovies and had little by-catch or no effect on other economically important species (letter of complaint dated 2nd February 1984). Later, the Surat Thani Governor requested DOF to consider the proposal on anchovy fisheries and DOF agreed to delay the implementation and issued instead a new Notification dated 11st January 1988. Based on this new Notification, anchovy purse seine was allowed to operate only in the daytime during closed season from 15th February 31st March annually.

The above Notifications reflected the recurring conflict among resource users, especially in Chumphon and Surat Thani Provinces. At the same time, the anchovy purse seine fleet from the eastern port that had moved into the western part of the GOT with the use of light luring and small mesh size, resulted in substantial catches of juvenile fish and other aquatic animals. As a consequence, fishers from Chumphon and Surat Thani Provinces requested the government to control the anchovy purse seine fishery. At the same time, the Thai Fishermen Association submitted a complaint document dated 14th April 1989 to DOF not to allow only anchovy purse seine to operate in the closed area and requested i DOF to reconsider and repeal the measure for anchovy purse seine.

Together with the results from the Seminar on "Fishermen and Aquatic Animals Conservation" organized in Surat Thani Province in December 1989, and the details of the joint meeting among governmental and private representatives on 8th March 1990, all parties agreed to delay the implementation of the Notification dated 11st January 1988.

DOF issued Order No. 7/2533 dated 3rd January 1990 with regard to the appointment of the members of a committee to study and resolve the problems and complaints concerning anchovy fishing. Results of the study showed that the distribution of anchovy eggs and larvae was extensive covering the area from 1 - 40 nautical miles from shore during January to March.

On the basis of such findings, Thai DOF issued Notification dated 12nd February 1994 which aimed to conserve anchovy resources, and prohibiting the use of some fishing gear that operate during spawning and nursery periods in specific areas. This Notification, which eventually caused the cancellation of the Notification dated 11st January 1988, also included the prohibition of daytime anchovy fishing during the period from 15th February to 15th May annually. This Notification has resulted in the stabilization of the Indo-Pacific mackerel production in the Gulf of Thailand of about 90,000 metric tons (MT) annually for the next six years.

Results of the monitoring and evaluation of this measure indicated that the catch decreased to around 80,000 MT from 1990-1991 and 1993 (Srireungcheep, 1997). In addition to the problems on anchovy fishing, fishers tried to develop and change their fishing gears and methods to increase fishing efficiency, and to enable them to operate during the closed season. Indo-pacific mackerel fishers also modified their encircling gill nets of mesh size over 4.7 cm targeting mature Indo-Pacific mackerel and Indian mackerel by increasing the net length, which was not prohibited by the Notifications. The number of this type of gear increased rapidly (DOF, 1996). From the monitoring and evaluation of this measure in 1996, it was found that the catch using mackerel encircling gill net of fishing boat size lower than 10 meters was approximately 90 kg/boat/trip. The catch by fishing boats size 10 -14 and more than 14 meters was 1,212 - 1,218, and 1,270 - 1,740 kg/boat/trip, respectively.

From a study in 1998, it was found that the average weight of catch from the mackerel encircling gill net was 941-1,367 kg/trip during the prohibited period (in Prachaup Khiri Khan, Chumphon, and Surat Thani areas). More than 80% of the catch was Indo-Pacific mackerel mixed with Indian mackerel, carangids, other hardtail scads, flying fishes, croakers, and pony fishes. This study found that the total length of individual Indo-Pacific mackerel ranged from 15.19 – 16.20 cm representing completely mature individuals (DOF, 1998). The encircling gill net fishing from February to June 1999 yielded a total fish catch of 6,316 metric tons, calculated as 86,365 mature individuals of Indo-Pacific mackerel. It was calculated that such numbers of Indo-Pacific mackerel individuals could themselves produced 130,027 million mature individuals (Nakrobru and Saikliang, 2003). At the same time, other developments occurred in terms of fishing technology. Fishers had improved push net fishing gear by increasing the net size, using longer push sticks operated with bigger boats and more powerful engines. Such gear is considered destructive fishing gear to various types of aquatic resources and benthic habitats. In addition, fishers had modified the push net and anchovy purse seine fishing boats into casting net, falling net, and lift net equipped with light for catching anchovy.

A study on this type of fishing operation found that the catch included large numbers of juveniles of commercially important species. Based on the results of the study on the status of marine fisheries development mentioned above, amendment was made by MOAC of the 1984 Notification by issuing Notification dated 24th September 1999 encompassing the waters of Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces. The focus of this Notification covered the spawning and nursery period from 15th February to 15th May annually, and specified the prohibition of certain types of fishing gear as follows:

1. Pair trawl and bottom trawl that had been changed to all types of motorized trawls except trawl net and used together with single motorized boat of length less than 16 meters operating at night between sunset and sunrise
2. Entangling net of mesh size lower than 4.7 cm that had been changed to entangling gill net operated with motorized fishing boat for surrounding and entangling Indo-Pacific mackerel or similar method
3. Surrounding net, the same as before, no revision
4. Additional prohibited fishing gears included: cast net, falling net and lift net using generated electricity for catching anchovy; and push net using motorized boats of length over 14 meters

Following the announcement of these measures, various groups of fishers especially the Fishermen's Association of Lang-soun District, Chumphon Province did not want to accept these measures as they used mackerel encircling gill net to catch Indo-Pacific mackerel during the closed season. The Thai DOF sent an official team to explain the background and rationale of this measure which was issued based on a scientific study. It was agreed to postpone the implementation of the measures for a year (Notification dated 24th September 1999). During the intervening period, the Notification issued in 1984 was temporarily used. In order to solve the problems that may occur in the area, multi-stakeholders committees were established in each province, consisting of representatives from each group of fishing gear users, and relevant governmental officials to address the new challenging issue of reducing the area to be closed. **Fig. 2** shows the present closed areas.

Since then, the Thai DOF proposed to MOAC to issue a Notification dated 10th February 2000 prohibiting the use of some types of fishing gear in the area of Prachaup Khiri Khan, Chumphon, and Surat Thani during the closed season (2nd Edition). The main reason was to temporarily delay the implementation of the Notification dated 24th September 1999, that will be effective from 15th February to 15th May 2000. Consequently, fishers of Lang-soun District demonstrated as they disagreed with this Notification. As a result of consultations with fishers on 22nd February 2001, permission was given for the joint scientific study on the use of certain fishing gear:

1. During the first 45 days (15th February to 31st March 2001), permission was given only for beam trawl or bottom otter board (small trawl) using only one single motorized boat and operate at night time; push net; anchovy purse seine to operate during day time; lift net; anchovy cast net equipped with electric generator
2. During the last 45 days (1st April to 15th May 2001), permission was given only for encircling gill net that use motorized boat and similar fishing method with Indo-Pacific mackerel purse seine.

The Notification specified that a study would be carried out in collaboration with Thai DOF, fishers and scientists, through a working committee. Subsequently however, 23 fishers from Paknam Lang-soun submitted a plea to the Central Administrative Court for the revision of the Notification dated 24th September 1999, with the Minister of Agriculture and Cooperatives as the primary defendant and Thai DOF as co-defendant.

As Undecided Case number 1284/2544 under consideration of Administrative Court (Undecided Case number A. 12/2546) which later became Decided Case number A.51/2547 of the Highest Administrative Court dated 26th July 2004. Finally, the Courts settled the case and acquitted the defendants.

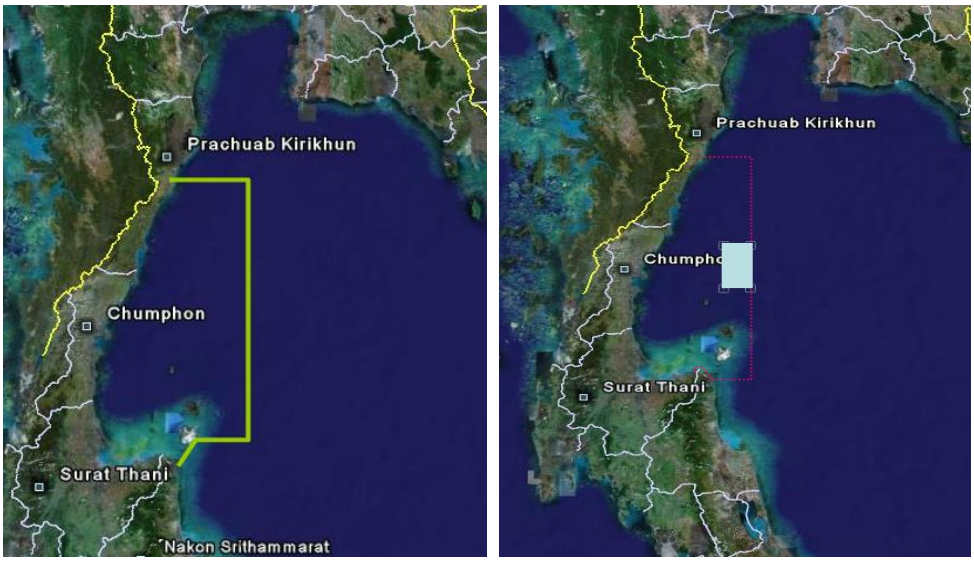

Fig. 2. Closed areas: the current (*left*) and challenged (*right*)

Recommendations and Way Forward

Following the prohibition of the use of mackerel encircling gill net resulting from the Notification dated 24th September 1999, there was a dramatic increase in the numbers of Indo-Pacific mackerel caught by drift gill netters during 2002 and 2005. The catch composition was mainly medium- and large-sized Indo-Pacific mackerel, approximately 10-15 and 8-10 individuals/kg, respectively. In addition, various demersal fishes were also caught, *e.g.* red snappers, big eyes, lizard fishes, and wolf herring. At the same time, some of fisher groups improved their techniques of drift gillnet fishing (targeting Indo-Pacific mackerel) by increasing the net depth from 50 - 80 to 200 - 300 meters. Fishing methods were also changed from straight set up nets to nets set in circles, zigzag, or something similar. This type of gear was called "auon-short" (gill net).

In 2005, results from the follow-up study indicated that the catch rate of this gill net, operated by using long-tail boat and inboard engine boat of length less than 10 m, was approximately 60-100 kg/day/boat of which 85.00% was Indo-Pacific mackerel. The catch rate for short nets operated by boats over 10 m in length averaged 800 kg/day/boat of which 77.49% was Indo-Pacific mackerel. It was also found that 75-98% of both males and females were fully mature. Since these fishing gears are newly developed with high efficiency and target mainly large size of Indo-Pacific mackerel, the Thai DOF has considered establishing an appropriate measure to conserve the Indo-Pacific mackerel.

Conclusion

In conclusion, during the past 62 years (1953 - 2015), the Thai DOF issued a total of 13 Notifications (specific management measures) relating to closures of fishing area in the Gulf of Thailand with the objective of conserving the spawning and nursery stages of aquatic resources. It was clearly observed that the measures for conserving Indo-Pacific mackerel were used as basis for the formulation and development of other fishery resources in the same areas. Cancellation and revision of these measures were made from time to time in accordance with the changes in status of the fishery resources and the development of fishing practices with an attempt to effectively manage the aquatic resources for sustainable fisheries.

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Fisheries Stock Enhancement: An Important Measure Towards Sustainable Development of the Fisheries Sector of Viet Nam

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Abstract

The contribution of coastal fisheries and inland fisheries to the livelihoods of the Vietnamese people has long been acknowledged, especially inland fisheries in the rural and mountainous areas. In recent years, inland and coastal fishery resources declined due to overfishing, environmental degradation and population putting increased pressure on the natural resources. The Government of Viet Nam has enacted many policies to support the sustainable development of the fisheries sector such as: the Fisheries Development Strategy 2020, National Master Plan for Fisheries Development 2020 oriented to 2030, Plan on the System of Viet Nam's Marine Protected Areas 2020, Program on Protection and Development of Aquatic Resources 2020. Stock enhancement is considered as an important measure towards sustainable development of Viet Nam's fisheries sector and is an integral component of many inland and coastal fisheries plans in many provinces of Viet Nam. With robust developments in artificial propagation techniques for fast-growing and desirable fish species and consequent increased availability of seed stocks, Viet Nam promotes stock enhancement is a management tool to recover depleted species populations. The main stocks released are *Penaeus monodon, Notopterus notopterus, Seminabeo notabilis, Spinibarbichthys denticulatus, Hamibagrus elongatus, Cyprinus carpio, Squaliobarbus curiculus*. A comprehensive evaluation of stock enhancement in large water bodies and rivers has not been done in Viet Nam. However, initial results of these activities are considered important measures for enhancing the resources to be able to continue providing animal protein, employment and household incomes for rural populations.

Keywords: stock enhancement, inland fisheries, coastal fisheries, sustainable development

Introduction/Background Information

Inland, coastal and marine ecosystems are high in productivity and biodiversity and have been providing enormous potentials for the development of the fisheries sector. The fisheries and aquaculture sectors of Viet Nam have expanded rapidly over the past decade, with aquaculture production rising from 1,202,500 metric tons (MT) to 3,620,000 MT from 2004 to 2014, of which 1.0 million MT was contributed by *Pangasius* and 660,000 MT by brackishwater shrimps. Fisheries production in 2014 was about 3,620 thousand MT, of which marine capture fisheries contributed 2,684 thousand MT.

The fisheries sector is significantly contributing to the economy of Viet Nam with the export value of its production in 2014 at about US$ 7.83 billion. Moreover, the sector employs more than 4 million people and an estimated 10% of the total population derives their main income directly or indirectly from fisheries. The fishery processing sub-sector in particular provides important employment opportunities for female labor.

The contribution fisheries sector to the livelihood of the Vietnamese people has long been acknowledged, especially in the coastal areas. However, the fisheries sector of Viet Nam nowadays also faces many challenges such as: reducing fishery resources, coastal habitat loss, and water pollution both in inland and marine waters. The fishery resources, particularly inshore and inland fisheries, are considered to be over-exploited with many high value fish resources having declined to low levels. Many natural habitats which play important role for the fishery resources are degraded.

Coastal ecosystems, especially mangrove forests and coral reefs that have important roles in protecting coastal areas and habitats for marine species and providing ecological services to maintain livelihoods of local people, have been degraded significantly. Mangrove areas was 408,000 ha in 1943 but reduced to 209,000 ha in 2007. These issues put more pressure on livelihoods of fishing communities.

Stock enhancement is considered as an important measure towards the sustainable development of Viet Nam's fisheries sector and being an integral component of many inland and coastal fisheries in many provinces of Viet Nam. Thus, fish stock enhancement was determined as a priority project in Decision 188/QD-TTg dated 13 February 2012, approving the Program on Protection and Development of Aquatic Resources 2020.

Viet Nam has attained robust developments in artificial propagation techniques for fast-growing and desirable fish species, and consequently increased availability of seed stocks. The main stocks released are species of *Penaeus monodon, Notopterus notopterus, Seminabeo notabilis, Spinibarbichthys denticulatus, Hamibagrus elongatus, Cyprinus carpio, Squaliobarbus curiculus.*

Activities/Results

Legal framework

The policies, laws and regulations for fishery sector management in Viet Nam have been largely developed and implemented to facilitate multi-sector integration. Various policies and regulations issued have assisted this process by building a policy framework for the fishery sector that includes fishing, aquaculture, processing and conservation, and fisheries resources development. The framework has also been revised and updated through the more recent orientation to sustainable development. To protect its fishery resources, the Government of Viet Nam has recently enacted many policies to support the objective of sustainable development, such as: (i) Vietnam Fisheries Development Strategy 2020 which was approved on September 16, 2010 by Decision 1690/QD-TTg of Prime Minister; (ii) Decision 1445/QD-TTg of Prime Minister dated August 2013 – the National Master Plan for Fisheries Development 2020 oriented to 2030; (iii) Decision No.742/QD-TTg of the Prime Minister dated May 26th, 2010, approving the Plan on the System of Vietnam's Marine Protected Areas 2020; (iv) Decision No.1479/QD-TTg of the Prime Minister dated October 10th, 2008, approving the Plan on the System of Vietnam's Freshwater Protected Areas 2020; (vi) Decision 188/QD-TTg dated on February 13th 2012, approving the Program on Protection and Development of Aquatic Resources 2020.

Fish stock enhancement in Viet Nam

The country's fish stock enhancement program is aimed towards multiple purposes, primarily aiming to improve (directly or indirectly) the stock size/yield above what is obtained in an existing fishery resource; conserve a species or a stock; supplement impoverished stocks; and override bottlenecks in recruitment.

Fish stocks released to water bodies: With robust developments in artificial propagation techniques for fast-growing and desirable fish species and consequent increased availability of seed stocks, stock releasing is conducted in inland water bodies (in reservoirs, rivers, lakes), estuaries and marine waters. The main freshwater species stocked are: *Notopterus notopterus; Seminabeo notabilis; Spinibarbichthys denticulatus; Hamibagrus elongatus, Cyprinus carpio, Squaliobarbus curiculus.* The main species released in marine waters are *Penaeus monodon; Epinephelus* spp. and *Chlamys nobilis.* Fish stock releasing is undertaken in both central and local levels. The releasing program is designed under the Program on Protection and Development of Aquatic Resources 2020 (Decision 188/QD-TTg dated 13 February 2012). All information such as fish species for releasing, fish species composition, releasing time, releasing location are determined. However, the program also faces many challenges such as lack of basic information of water bodies (fish composition, fish biological characteristics, ecological parameters, social-economic conditions); lack of effective monitoring and evaluation system for releasing program from central to local level; and limited budget and involvement of stakeholders in governing the releasing program.

Introduction of closed areas: 16 closed areas in Viet Nam have been established in 2011 in order to protect spawning areas, nursing periods of some important species. The establishment of 16 closed areas (**Table 1**) was based on (i) traditional knowledge of fishermen; (ii) consultations with local authorities; and (iii) available scientific information.

Establishment of protected areas: In May 2010, Viet Nam's Prime Minister issued Decision 742, creating 16 marine protected areas (**Table 2**) as part of a broad strategy to move the coastal economy to a more sustainable footing. The development of a marine protected area network has become an important national issue with the objective of establishing a system of marine protected areas to protect ecosystems and marine species, which have high economic and scientific values that contribute to marine economic development and livelihoods of fishing communities in coastal areas.

Table 1: Detailed information on closed areas, closed seasons of 16 closed areas in Viet Nam

Closed areas	Provinces	Closed seasons	Protected species
Hon My - Hon Mieu	Quang Ninh	April 15 – July 31	Metapenaeus
Co To	Quang Ninh	February 15 – June 15	*Haliotis diversicolor*, Poalloporidae, Acroporidae, Poritidae
Cat Ba - Ba Lạt	Hai Phong - Thai Binh	April 15 – July 31	*Lutraria rhynchaena, Perna viridis*, breed shrimps of *Penaeus merguiensis, Penaeus japonicus.*
Hon Ne – Lach Ghep	Thanh Hoa	April 15 – July 31	*Penaeus merguiensis, Penaeus japonicus*
Dien Chau Bay	Nghe An	March 01 – April 30	*Decapterus maruadsi, Upeneus moluccensis, Upeneus sulphureus.*
Gam River	Cao Bang, Tuyen Quang	May 01 – July 31	*Bagarius rutilus, Sinilabeo lemassoni, Semilabeo obscures*
Lo River	Tuyen Quang, Phu Tho	May 01 – July 31	*Semilabeo obscurus, Sinilabeo lemassoni*
Red River	Phu Tho, Vinh Phuc, Ha Noi	May 01 – July 31	*Knonsirus punctatus, Clupanodon thrissa, Hemibagrus guttatus, Cranoglamis sinensis*
Downriver of Lam River	Nghe An, Ha Tinh	July 01 – August 30	*Elopichthys bambusa, Sinilabeo tonkinensis, Tor (Folifer) brevifilis.*
Ya Ly Lake	Kon Tum, Gia Lai	April 1 – May 31	*Chitala sp., Cosmochilus harmandi Tor tambroides*
SerePok River	Dak Lak, Dak Nong	June 01 – August 30	*Probarbus jullieni, Chitala blanci, Cirrhinus microleppis*
Dong Nai River	Dong Nai, Ho Chi Minh City	June 01 – August 30	*Ompok miostoma, Gyrinocheilus aymonieri, Chitala ornat),*
Dinh An and Tran De Estuaries	Tra Vinh, Soc Trang	April 1 – June 30	*Tenualosa thibaudeaui, Tenualosa toil, Cirrhinus microlepis, Morulius chrysophekadion, Pangasianodon gigas*
Coastal area of Bac Lieu	Bac Lieu	April 1 – June 30	Metapenaeus
Coastal area of Ca Mau	Ca Mau	April 1 – June 30	Penaeidae, Metapenaeus
Coastal area of Kien Giang	Kien Giang	April 1 – June 30	Penaeidae, Metapenaeus and Penaeidae Mullidae, *Selaroides leptolepis,*

Source: Circular 89/2011/TT-BNNPTNTg

Table 2: List of 16 marine protected areas

No	Name/Provinces	Total area (ha)	Marine area (ha)
1	Dao Tran / Quang Ninh	4,200	3,900
2	Co To / Quang Ninh	7,850	4,000
3	Bach Long Vy / Hai Phong	20,700	10,900
4	Cat Ba / Hai Phong	20,700	10,900
5	Hon Me / Thanh Hoa	6,700	6,200
6	Con Co / Quang Tri	2,490	2,140
7	Hai Van - Son Tra / Thua Thien Hue – Da Nang	17,039	7,626
8	Cu Lao Cham / Quang Nam	8,265	6,716
9	Ly Son / Quang Ngai	7,925	7,113
10	Nam Yet / Khanh Hoa	35,000	20,000
11	Nha Trang / Khanh Hoa	15,000	12,000
12	Nui Chua / Ninh Thuan	29,865	7,352
13	Phu Quy / Binh Thuan	18,980	16,680
14	Hon Cau / Binh Thuan	12,500	12,390
15	Con Dao / Ba Ria – Vung Tau	29,400	23,000
16	Phu Quoc / Kien Giang	33,657	18,700

Source: Prime Minister's Decision No 742/QD-TTg

In 2001, Hon Mun Marine Protected Area (now known as Nha Trang Bay Marine Protected Area) in Khanh Hoa Province was the first marine protected area established in Viet Nam through a cooperation established between the former Ministry of Fisheries and Khanh Hoa Province. In 2005, Cu Lao Cham Marine Protected Area in Quang Nam Province was next established with support from DANIDA. Two latest marine protected areas (Phu Quoc in Kien Giang Province in 2007 and Con Co in Quang Tri Province in 2008) were established under the effort of the provincial governments with only technical support from DANIDA. Until now, 14 16 marine protected areas have been established. It is clear that marine protected areas play an important role in stock enhancement, and releasing high economic species and threatened species have been conducted yearly. Many pilot projects have been implemented with community participation on the sustainable exploitation and management of the fishery resources. The objectives of the Plan on the System of Vietnam's Freshwater Protected Areas 2020 were to set up 45 freshwater protected areas. In comparison with the marine protected areas, freshwater protected areas establishment has been slow, and so far, relatively few areas have been planned and established. However, the fish stock releasing program in central and local levels focusing on lakes and reservoirs aimed towards multiple purposes of fish stock enhancement. Every year, millions of juvenile fishes are released in freshwater bodies.

Lessons Learnt

With regards to legal framework, appropriate legislations exist, the problem is enforcement. Limited available resources are barriers to the implementation together with lack of baseline data, time series data, updated information on water bodies, fisheries composition; lack of a monitoring and evaluation system for the releasing program from central to local communities; limited budget and involvement of stakeholders in governing the releasing program. Thus, greater power and resources (human resource, budget) should be given to institutions to enforce the legislations. An underlying problem is lack of basic information about the distribution and abundance of fish species in general, and threatened species, in particular. Assessment of fish population and stocks is very limited. Consequently, knowledge of the status of stocks is weak. The participation of communities living in and near or around the water bodies in managing fisheries resources and related ecosystems is very important for successful fish stock enhancement program. To support this strategy, public awareness and co-management scheme should be implemented.

Recommendations and Way Forward

Fish stock assessment should be conducted in important water bodies and baseline data for releasing program should be compiled. Also, it is important to establish an effective monitoring and evaluation scheme for the releasing program. Stock enhancement is closely linked to habitat restoration, thus, the best option would be to integrate stock enhancement practices with habitat improvement. An active management strategy to support released fish populations and related habitats is necessary. Management should be implemented in the form of control over the exploitation and habitat manipulation. Water bodies have multi-purpose uses therefore, it is necessary to push for policies and legislations which safeguard fishing and people depending on it. To support this, an integrated fisheries resources management plan should be developed, based on ecosystem approach. It is also necessary to encourage the participation of all stakeholders in fish stock enhancement, especially the participation of communities living near and around water bodies in managing the fisheries resources.

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Decision 188/QD-TTg dated on February 13th 2012, approving the Program on protection and development aquatic resources to 2020

Fisheries *Refugia*: A Regional Initiative to Improve the Integration of Fisheries and Habitat Management

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Abstract

Fisheries of Southeast Asia are characterized by high levels of small-scale fishing. Increasing fishing pressure coupled with continued decline in the expanse and quality of coastal habitats critical to the life-cycles of most species, has raised serious concerns regarding the long-term sustainability of the region's fisheries. The process of establishing Fisheries *Refugia* and the outcomes of a regional initiative under the UNEP/GEF South China Sea Project (2002-09) to improve the integration of fisheries and habitat management are discussed briefly in this paper. The Fisheries *Refugia* concept as a fisheries management tool has been introduced in the Southeast Asian region with the objective of enhancing fisheries resources through the integration of fisheries and habitat management. The concept is defined as "spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle." To support the Fisheries *Refugia* approach, the ASEAN-SEAFDEC ministries responsible for fisheries endorsed the supplementary guidelines to substantiate the Regional Guidelines for Responsible Fisheries in Southeast Asia in 2006. In addition, the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security toward 2020 adopted in 2011 also supported the establishment of Fisheries *Refugia* for enhancing the fishery resources of the Southeast Asian region.

Introduction

The South China Sea, including the Gulf of Thailand, is a global center of shallow water marine biological diversity that supports significant fisheries that are important to the food security and export income of Southeast Asian countries. These fisheries are characterized by high levels of fishing effort from the small-scale sector. Accordingly, all inshore waters of the South China Sea basin are subject to intense fishing pressure. Growing global demand for fisheries products coupled with strong coastal community dependence on fisheries, is driving continued increases in fishing capacity and effort (UNEP, 2007a).

An obvious impediment to the reduction of inshore fishing effort is that small-scale operators are often entirely dependent on fish for income, food and well-being (Paterson *et al*., 2006). The most important fish species are considered fully fished or overexploited. As a result of 'fishing down marine food webs' (Christensen, 1998), small pelagic species now dominate landings as most demersal fisheries are overfished (Lundgren *et al.,* 2006). Consequently, the investment of time and household expenditures on fuel for fishing has increased in coastal communities that attempt to secure adequate dietary nutrition and income from fishing (UNEP, 2007a). This situation of high small-scale fishing pressure and declining fisheries resources has contributed to the adoption of unsustainable fishing methods to maintain catch and increase incomes in the short-term. These include the use of destructive fishing gear and practices, such as the operation of demersal trawls and push nets in seagrass areas, and the use of explosives and release of fish poisons in coral reef areas. Small-scale inshore fishing pressure has therefore been identified as a significant cause of the degradation and loss of coastal habitats in the South China Sea (UNEP, 2008a).

Although action aimed at reducing the rate of loss of coastal habitats has been implemented by countries bordering the South China Sea, the decadal rate of loss of such habitats remains high (UNEP, 2008a), *e.g.*, seagrass beds (30%), mangroves (16%), and coral reefs (16%). This continued decline in the total area of habitats critical to the life cycles of most aquatic species, combined with the high levels of coastal community dependence on fish, has raised serious concerns for the long-term sustainability of small-scale fisheries in the region.

With fish production being intrinsically linked to the quality and area of habitats and the heightened dependence of coastal communities on fish, a need exists to improve the integration of fish habitat considerations and fisheries management in the region. The dilemma for the fisheries and environment sectors is that conservation of habitat does not necessarily result in increased fish stocks while lowering fishing effort does not necessarily result in the improvement of habitat.

Therefore, given the complexity of the key threats to fish stocks, fish habitats and associated biodiversity in Southeast Asia, it is imperative that mechanisms for effective cross-sectoral consultation and coordination be established, particularly in terms of the identification and designation of priority 'places' (Pauly, 1997) for management.

The fisheries *refugia* concept, defined as "spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle for their sustainable use" (UNEP, 2005), was developed as a novel approach to the identification and designation of priority areas in which to integrate fisheries and habitat management in the context of high and increasing levels of small-scale fishing pressure in the South China Sea.

This paper reviews the barriers to effective integration of the work of fisheries and environment departments and ministries in the context of high and increasing levels of small-scale fishing pressure in the South China Sea and Gulf of Thailand. The effectiveness of the fisheries refugia concept in harnessing stakeholder support for the use of area-based planning to strengthen the integrated management of critical fishery and habitat linkages is highlighted. Country experience in applying the *refugia* approach via an initiative to establish a regional system of fisheries *refugia* is presented in terms of improved communication between the fisheries and environment sectors and enhancing community acceptance of area-based management tools.

The question arises as to how the concept of fisheries *refugia* differs from other forms of area-based management used in fisheries. Marine reserves, for example, have been called many things, including 'no-take zones', 'fishery reserves', 'fully protected marine reserves', 'highly protected marine reserves' and, recently, 'fish stock recovery areas' (Roberts and Hawkins, 2012). Regardless of the name applied, the underlying principles are the same, *i.e.* restriction or banning of fishing activity in fishing grounds. In contrast, the fisheries *refugia* concept focuses on the nature of the particular habitat and its critical significance to the life-history of the fished species. Management of *refugia* therefore focuses on the habitat rather than simply restricting access, either temporally or spatially, to fishing grounds.

This paper also presents the outcomes of a regional initiative to improve the integration of fisheries and habitat management from the project on "Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand" (referred to hereafter as the UNEP/GEF South China Sea Project) was funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) in partnership with seven riparian states bordering the South China Sea, namely: Cambodia, China, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam). Although planning commenced in 1996, the project became fully operational in February 2002 and was formally closed at the end of January 2009. The results have been recently published as part of a Special Issue of the journal 'Ocean and Coastal Management' on the UNEP/GEF South China Sea Project (Paterson *et al*., 2012).

The complexity of the key threats to fish stocks and their habitats in the South China Sea necessitate adequate cross-sectoral consultation between fisheries and environment departments, particularly in relation to the identification and designation of priority places for the integration of fisheries and habitat management. The dilemma for the fisheries and environment sectors is that conservation of habitat does not necessarily result in increased fish stocks while lowering fishing effort does not necessarily result in the improvement of habitats.

Approach: Development of the fisheries *refugia* concept

Fisheries component of the UNEP/GEF South China Sea Project

As mentioned earlier, the fisheries component (Note: China did not participate in this project component) of the UNEP/GEF SCS Project on "Over-exploitation of Fisheries in the Gulf of Thailand" focused on the links between fish stocks and coastal habitats, and was designed to secure an agreement on the establishment of a regional system of fisheries *refugia* to maintain important transboundary fish stocks.

This was aimed at achieving one of the overall objectives of the Project, specifically on "Improved integration of fisheries and biodiversity management in the Gulf of Thailand". This component was nested with other project components focusing on habitat degradation and loss, land-based pollution, and regional coordination within the broader management framework of the project (Pernetta

and Jiang). National activities of the fisheries component were executed by departments or research institutes of the government ministries responsible for fisheries in Cambodia, Indonesia, Malaysia, Philippines, Thailand and Viet Nam. The government-nominated focal points for fisheries from these countries led the execution of regional activities through the Regional Working Group on Fisheries (RWG-F). Ten formal meetings of the RWG-F were convened between 2002 and 2008. The work of this group benefitted from the participation of five (5) regional experts on fisheries, and senior advisors and technical staff of the Southeast Asian Fisheries Development Center (SEAFDEC), Food and Agriculture Organization of the United Nations (FAO), WorldFish Centre, and the International Union for the Conservation of Nature (IUCN).

The direct linkages and feedback loops that were established between and among these fisheries experts and habitat specialists, pollution scientists, lawyers, and economists involved in the broader UNEP/GEF South China Sea Project, became the first for a marine fisheries working group in Southeast Asia. Collaboration between the RWG-F and SEAFDEC was established to ensure that fisheries component activities complement rather than duplicate, the work being undertaken as part of larger SEAFDEC and FAO fisheries projects and programs.

During its preliminary planning stages, the RWG-F realized that initiatives to integrate fisheries and habitat management in Southeast Asia would be constrained by several factors, which could include: limited experience in national fisheries and environment departments and ministries with respect to the implementation of integrated fisheries and habitat management approaches; limited information regarding fish life-cycles and critical habitat linkages and the role that coastal habitats play in sustaining fisheries; and low level of community acceptance of 'protected' area approaches to marine management in Southeast Asia.

Barriers to effective integration of fisheries and habitat management

In developing the framework for a regional system of fisheries *refugia*, specific regional, national and local actions were planned from the perspective of overcoming barriers to the integration of fisheries and habitat management. The RWG-F identified the key barriers that included:

- Limited practical experience in integrating fisheries and environmental considerations

  The need to integrate fisheries and habitat management has received high-level international recognition, particularly within the framework of the approved Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem (FAO, 2002). The Reykjavik Declaration states that in an effort to reinforce responsible and sustainable fisheries in the marine ecosystems, States "will individually and collectively work on incorporating ecosystem considerations into that management to that aim". Even though FAO released the Technical Guidelines for Responsible Fisheries dealing specifically with the ecosystem approach to fisheries (EAF) as part of the FAO Code of Conduct for Responsible Fisheries (CCRF) in 2003 (FAO, 2003). In a note regarding the preparation of the document, FAO highlights that "at the time of writing (the guidelines), there was little practical experience in implementing EAF anywhere in the world".

  Similarly, the ASEAN-SEAFDEC Regional Guidelines on Responsible Fisheries in Southeast Asia provide guidance with regard to minimizing the negative impacts of fishing on the environment and critical fisheries habitats (SEAFDEC, 2006). In this connection, the RWG-F also identified, in the early stages of its work, that a central problem faced by fisheries ministries and departments in building environmental considerations into fisheries management is a lack of examples relevant to the region on how to implement such policies at the local level (UNEP, 2006a).

- Limited knowledge of fish life-cycle and critical habitat linkages

  Regarding the lack of knowledge concerning fish life-cycles and critical habitat linkages in the South China Sea basin, the RWG-F noted that, while the life-cycles of most fished species in the region were thought to follow the generalized three-phase ontogeny of marine fishes (*i.e.* (1) pelagic larvae and pre-settlement juveniles, (2) dispersal to shallow inshore habitats, and (3) migration to deeper offshore habitats and spawning grounds), very little information existed at the regional level regarding specific habitats and locations used by most fish species during critical phases of their life-cycles (UNEP, 2005; 2006a). Spawning sites and the influence of ocean processes on transport of fish larvae are also poorly known (UNEP, 2006b).

This situation resulted from the past fisheries research programs that focused on determining sustainable yields of fish stocks with little emphasis placed on fish life-cycle research. The fact that most fish life-cycle and habitat data and information in the region are qualitative in nature, provides general information regarding the presence or absence of fish and the life-cycle phase of fish species observed in a given habitat area. While this work is useful in developing an inventory of habitats and locations utilized by fished species at different phases of their life-cycle, the RWG-F therefore identified the need for regional level research on the role of specific habitat areas in terms of fisheries production and sustaining fish stocks under scenarios of increased fishing effort (UNEP, 2006b).

- Low level community acceptance of 'protected' area-based approaches

  During the meetings of the RWG-F, it was noted that Marine Protected Areas (MPAs) were increasingly being promoted or conceived, as essential fisheries management instruments (Roberts and Polunin, 1993). Gell and Roberts (2003) concluded that "nature conservation in the oceans cannot be achieved without marine reserves neither can the world's fisheries be made sustainable". FAO had initiated an evaluation of the effectiveness of Marine Protected Areas as management and conservation tools for fisheries, and it was agreed that, while fisheries ministries and departments in the region would need to improve their working relationships with organisations promoting MPAs, the key barrier would be in achieving acceptance among communities at the local level of the value of MPAs. The consensus view within the working group was that MPAs in Southeast Asia were widely understood by fisheries stakeholders to be the areas that were closed to fishing.

  The initial global promotion of the MPA concept clearly distinguished between the establishment of MPAs for the protection of biodiversity and fisheries, respectively (Hilborn *et al*., 2004). The distinction between these two purposes has recently been blurred by MPA advocates who have presented general MPA benefits not only in terms of biodiversity protection but also in terms of enhanced fisheries yields. The RWG-F noted with concern that most MPAs in Southeast Asia had been established under a broad banner of 'improving the state of fisheries', whereas the criteria for the selection of MPA sites had typically been related to achieving the objectives for biodiversity conservation or political gain rather than for fisheries management (UNEP, 2006a). This was further complicated when an objective review of the various MPA definitions suggested that the entire Exclusive Economic Zones (EEZs) of Southeast Asian countries are technically, MPAs because fishing in these EEZs is restricted through long-standing fisheries management measures.

Approach of the Regional Working Group on Fisheries

A review of fisheries and habitat management initiatives in the Southeast Asian region revealed that no initiative with a direct focus on improving the integration of fisheries and habitat management in the South China Sea either existed or had previously been implemented. It was agreed that, given the important role of fisheries habitats in sustaining fish stocks and production, the trends in the degradation and loss of these habitats, and the intense small-scale fishing pressure in inshore areas, a regional system of fisheries management areas (fisheries *refugia*) would be established in the South China Sea and Gulf of Thailand. This system would focus on the improved management of the critical links between fish stocks and their habitats toward the longer-term goal of building resilience of Southeast Asian fisheries to the effects of high and increasing levels of small-scale fishing pressure (UNEP, 2006a).

The Regional Working Group on Fisheries (RWG-F) for the UNEP/GEF South China Sea Project agreed that any approach aimed at fostering integrated management should:

- Build the capacity of fisheries and environment departments and ministries to engage in meaningful dialogue regarding how broader multiple use planning can best contribute to improving the state of fisheries habitat management in areas of the South China Sea and the Gulf of Thailand;
- Improve understanding among stakeholders, including fisherfolk, scientists, policy makers and fisheries managers, of habitat and fishery linkages as a basis for integrated fisheries and habitat management; and
- Enhance and sustain the participation of local fishing communities and the private sector in management interventions for improved fisheries habitat management and biodiversity conservation through a focus on sustainable use rather than the prohibition of fishing.

The RWG-F also recommended that initiatives should address the barriers to integration by drawing on fisheries management concepts that are easily understood by fishing communities and emphasis sustainable use rather than simply the prohibition of fishing. The latter is considered detrimental to efforts to harness community support for area-based approaches to fisheries management in Southeast Asia. The first step involved consideration of the applicability of the Marine Protected Area concept in addressing these barriers.

Supporting Evidence

In developing the framework for a regional system of fisheries *refugia* in the South China Sea, the RWG-F recognized the need for two separate but related sets of goals and objectives (**Table 1**). The first is related to the resource itself and the second to the institutional framework under which management is brought about. The RWG-F developed and agreed on the listings of pelagic and demersal fish species, cephalopods, and crustaceans of transboundary significance during its second meeting in October 2002. In considering the species of transboundary significance for which the development of a regional system of fisheries *refugia* should focus, the RWG-F revised the lists during its ninth meeting convened on Phu Quoc Island, Viet Nam on 10-13 July 2007. The agreed species listings are contained in Annex 5 of the report of that meeting (UNEP, 2007c). Overall, the resource related goal is meant to enhance the resilience of regional fish stocks to the effects of fishing. The institutional goal is to integrate fisheries and habitat management at the national level, a task which is formidable given the past history of interactions between fisheries and environmental managers in most countries in the region. Consideration of these goals and objectives enable evaluation of whether or not areas subject to seasonal closures and fisheries management zones within multiple-use MPAs can be classified as fisheries *refugia* and form part of a regional *refugia* system.

Table 1. Goals and objectives for a regional system of fisheries *refugia*

***Resource-related goal*: increased resilience of regional fish stocks to the effects of fishing**	***Institutional-related goal*: fisheries and habitat management conducted in an integrated manner**
Longer-term objectives • Increased average size of important species. • Increased egg production of important species • Increased recruitment of important species • Increased biomass of important fish species	**Longer-term objectives** • Community-based management of fisheries *refugia* for integrated fisheries and habitat management • National and regional level commitments for integrated fisheries and ecosystem management • Appropriately represented fisheries agenda in broader multiple use marine planning initiatives.
Shorter-term objectives • Safeguarding natural *refugia* • Reduced capture of juveniles and pre-recruits of important species in critical fisheries habitats • Reduced targeting and capture of important species when forming spawning aggregations • Reduced targeting and capture of migrating fish	**Shorter-term objectives** • Community-based management of fisheries *refugia* for fisheries management • Understanding among fishing communities of critical habitats and fish life-cycle linkages • Enhanced capacity of fisheries departments/ministries to engage in meaningful dialogue with the environment sector

Building the capacity for identification, designation and management of fisheries *refugia* would involve:

- *Defining and disseminating information on the fisheries* refugia *concept*

  The RWG-F identified two key assumptions regarding the potential success of the fisheries *refugia* concept in improving fisheries and habitat management in Southeast Asia. The first was that cross-sectoral co-ordination of activities between the fisheries and environment sectors in the participating countries would be successful. The second assumption was that small-scale fishing communities would support the initiative and interventions proposed as many fishing families, fisheries managers, and local government officials in the region equate area-based approaches to fisheries management (zoning) as the equivalent of no-take MPAs.

  As noted above, the latter are often viewed as unacceptable at the community level because they are rarely designated in locations of importance to the life-cycle of fished species and neither improve fish stocks nor the community's income. The net result of such MPA establishment is largely viewed as a loss of fishing areas for small-scale fishers and non-compliance with fisheries management measures in the 'protected' areas as a result of minimal buy-in from communities. In order to promote mainstreaming of the concept within the fisheries and environment sectors and to enhance and sustain community participation in the initiative, the RWG-F disseminated information on the *refugia* concept through: regional and national fisheries and environmental forums; national expert, stakeholder, and community consultations; regional and national publication of a series of popular articles about the concept; and online syndication of information through the Fisheries *Refugia* Information Portal of the South China Sea Project website (http://refugia.unepscs.org).

- *Identification of fisheries* refugia*: critical spawning and nursery areas*

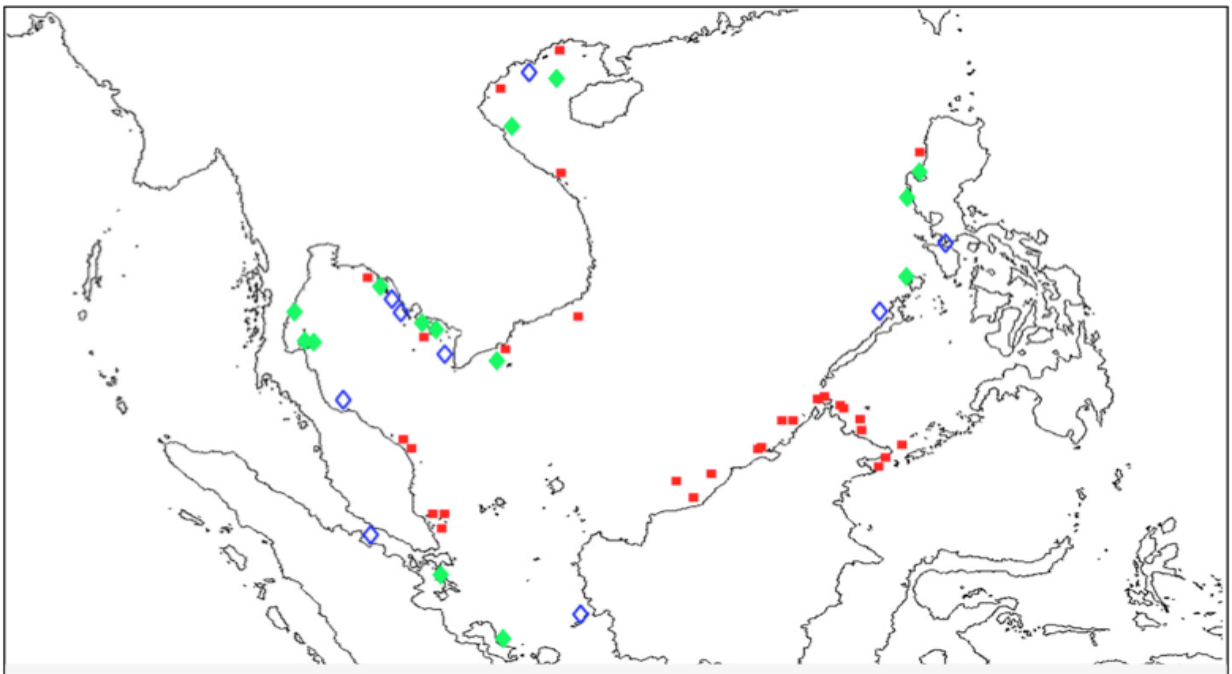
  The Sixth Meeting of the RWG-F noted that most fish populations are vulnerable to the impacts of over-fishing in areas and at times where there are high abundances of (a) stock in spawning condition, (b) juveniles and pre-recruits or (c) pre-recruits migrating to fishing grounds.

  The impact of over-fishing is intensified in instances where small-scale fishers and commercial fishers share the same stock, often leading to disputes regarding the relative impact of each group (UNEP, 2006a).

  The RWG-F agreed that this situation is characteristic of the over-fishing problem in many marine fisheries in the South China Sea. Juveniles and pre-recruits are often caught in inshore areas by small-scale fishers while commercial fisherfolk catch adults of the same species offshore. In circumstances such as this, high levels of fishing effort in inshore waters may drive growth over-fishing, while the same circumstances in offshore areas may cause recruitment over-fishing of the same stock. Growth over-fishing is caused by levels of fishing beyond that required to maximise yield per recruit, and typical involves a size at first capture in the fishery that results in an unsustainably high percentage of juveniles and pre-recruits being captured (Pauly, 1984), while recruitment overfishing is caused by a level of fishing in which the adult stock is reduced to the extent that recruits produced are insufficient to maintain the population (Pauly, 1984). FAO (2007), for example, reported that 18-32 percent of low value 'trash' fish caught primarily by demersal trawling in the Gulf of Thailand are juveniles of commercially important species often targeted by other fisheries.

The RWG-F agreed that management of 'nursery *refugia*' to safeguard fish during the juvenile and pre-recruit phases of their lifecycle and the habitats utilised as nurseries can assist in the prevention of growth over-fishing. Similarly, management of 'spawning *refugia*' may assist in the prevention of recruitment overfishing (Annex 5 of UNEP, 2006a). In considering the work of the RWG-F, the Regional Scientific and Technical Committee (RSTC) of the UNEP/GEF South China Sea project discussed *refugia* approaches that have often been used as a fisheries management tool when more conventional techniques, such as effort or gear restrictions, have failed to achieve the desired management objectives, particularly in regions where fisheries are subject to intense and unmanageable fishing pressure, such as in the Gulf of Thailand. In other instances, fisheries *refugia* have been used to separate potentially conflicting uses of coastal waters and their limited resources.

The RSTC noted that the effectiveness of fisheries *refugia* will likely depend on an appropriate consideration of known critical spawning and nursery areas in the selection of sites. In this connection, the RSTC directed the RWG-F to: review known spawning areas for fish stocks of transboundary significance with the aim of evaluating these sites as candidate spawning *refugia*; and evaluate South China Sea habitat sites as potential juvenile/pre-recruit *refugia* for significant demersal species (UNEP, 2006c). This information was compiled and reviewed by the seventh meeting of the RWG-F and was subsequently considered during the eighth meeting of the RWG-F and used to list and characterize known fish spawning and nursery areas in the Gulf of Thailand and the South China Sea (UNEP, 2007b). The RWG-F reviewed the list of sites in relation to: information on the distribution and abundance of fish eggs and larvae in the South China Sea during the post northeast monsoon periods from 1996 to 1999; and the outcomes of country consultations on the identification of fisheries *refugia*. The group subsequently agreed on 14 priority sites for inclusion in an initial system of fisheries *refugia* and an additional 9 sites for which additional information was required prior to their inclusion in the system. National maps of the agreed locations for *refugia* sites are included in Annex 6 of the eighth RWG-F meeting report (UNEP, 2007b). The locations of these sites are shown in **Fig. 1.**



Location of: initial sites selected for inclusion in the regional system of refugia [ ]; sites of high priority for inclusion in the regional system once the initial set have been established [ ]; and other known spawning and nursery areas for fish species of transboundary significance [ ].

- *Improving the scientific basis for the identification of fisheries* refugia

  As noted above, a constraining factor in the further development of a regional system of fisheries *refugia* is the scarcity of information relating to the early-life history of the majority of significant transboundary species in the South China Sea and Gulf of Thailand. This led, during 2006-2008, to the development of a collaborative program of technical consultations, working group meetings and training workshops with SEADFEC aimed at improving the scientific basis for the identification of fisheries *refugia*. This involved a comprehensive review of past and ongoing fish early-life history research and the compilation of information on known spawning and nursery areas for important fish species in the Gulf of Thailand and South China Sea. It was noted that past research activities conducted in the 1970s and 1980s largely focused on the identification of spawning areas and migratory routes for short mackerel (*Rastrelliger* spp.), round scads (*Decapterus* spp.), anchovy, and neritic tuna.

The RWG-F agreed that there may be some limitations in the research on identification of spawning *refugia* due to possible effects, during recent decades, of oil and gas industry development in the Gulf of Thailand on fish migratory routes (UNEP, 2007b). The RWG-F concluded that information and data collected through collaborative research activities initiated by SEAFDEC in the mid 1990s would provide a temporary relevant information base for identifying current spawning and nursery areas. These research activities involved cruises conducted using the M.V. SEAFDEC in the Gulf of Thailand and the East Coast of Peninsular Malaysia; the West Coast of Sabah, Sarawak, and Brunei Darussalam; the West Coast of Luzon, Philippines; and in Vietnamese Waters. Larval fish sampling was undertaken at 249 stations using bongo nets during the post-northeast monsoon (April-May) from 1996 to 1999. Results of these larval fish surveys were used to assist in developing a better understanding of spawning (sources) and nursery (sinks) locations for important species. Drawing on these data, the group worked with SEAFDEC scientists to map the distribution and abundance of the larvae of important demersal and pelagic fish species in the South China Sea.

- *Building regional capacity for the operation of a regional system of fisheries* refugia

  A key constraint in the future development of the regional system of fisheries *refugia* is a shortage of information regarding fish life-cycles and critical habitat linkages in Southeast Asia. SEAFDEC has been working to fill this information gap by including larval and juvenile fish surveys as part of its regular fisheries research cruises. However, the region has faced difficulties in the processing of samples due to limited expertise in national fisheries departments. In this connection, a joint UNEP/GEF South China Sea Project and SEAFDEC "Regional Training Workshop on Larval Fish Identification and Fish Early Life History Science" was convened at the SEAFDEC Training Department from 16 to 31 May 2007. This was aimed at building regional capacity in the processing and identification of larval fish samples collected during regular SEAFDEC research cruises. This was followed by the "Advanced Regional Training Workshop on Larval Fish Identification" (25 May to 14 June 2008) which led to the formal establishment of a 'Network of Southeast Asian Larval Fish Scientists' within the framework of SEAFDEC. In addition to the larval fish identification training initiative, the RWG-F also identified the need to build capacity of among middle to senior level fisheries managers for the establishment and management of fisheries *refugia* in the region. The A joint UNEP/GEF South China Sea Project and SEAFDEC 'Regional Training Workshop on the Establishment and Management of Fisheries *Refugia*' was therefore convened at the SEAFDEC Training Department from 28 October to 10 November 2007 with 25 young fisheries and environment professionals attending from SCS project countries. The participants in these training events subsequently conducted national 'echo-seminars' on the fisheries *refugia* concept involving staff of national and provincial fisheries and environmental agencies.

Incorporation of targeted actions for a regional system of fisheries *refugia* in the revised strategic action programme for the South China Sea

- *Strengthened enabling environment*

  The Regional Guidelines on the Use of Fisheries *Refugia* in Capture Fisheries Management was developed and endorsed inter-governmentally for inclusion in the ASEAN SEAFDEC Regional Guidelines for Responsible Fisheries in Southeast Asia. As a result, the *refugia* concept was then included in national fisheries policies and plans as a priority tool for improved fisheries habitat management, *e.g.* Fisheries Law of Cambodia; South China Sea Fisheries Management Zone Plan in Indonesia; Comprehensive National Fisheries Industry Development Plan in the Philippines; Thailand's Marine Fisheries Policy; and the National Plan for the Management of Aquatic Species and Habitats in Viet Nam. In this conenction, a program of targeted actions for operating a regional system of fisheries *refugia* was developed and included in the intergovernmental Strategic Action Programme for the South China Sea.

- *Development of a regional project to implement the fisheries component of the South China Sea Strategic Action Programme*

  The 44th Meeting (June 2013) of the Global Environment Facility (GEF) Council endorsed the development of a full-sized GEF International Waters project on "Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand" to test the *refugia* approach. This project will be executed regionally by SEAFDEC in partnership with six participating countries.

Discussion

Experiences in the uptake of the fisheries refugia *concept*

- Use a concept relevant to stakeholders

  The fisheries *refugia* concept has been well received at all levels and has been utilized in participating countries to build partnerships and to enhance communication between the fisheries and environment sectors. A relevant example is the experience of Viet Nam in the use of fisheries *refugia* as a tool for integrated fisheries and habitat management in Phu Quoc Archipelago. The extensive seagrass meadows adjacent to the Ham Ninh commune of Phu Quoc represent 8% of the total known area of seagrass in the South China Sea (UNEP, 2008b), supporting a variety of economically important species including swimming crab, cuttlefish, shrimp, rabbitfish, octopus, strombus snail, and seahorse. These species are harvested using a wide range of fishing gear and practices, including gill nets, demersal seines, pelagic purse seines, demersal trawl, push netting, traps, intertidal gleaning and raking, and hookah diving (UNEP, 2007d). The intensity of fishing operations in the nearshore waters of the site is such that a serious community concern was expressed regarding the degradation and loss of seagrass habitat as a result of fishing and consequent effects of longer-term availability of local fish resources critical for local income and food. The widespread use of active fishing gears such as demersal trawls and push nets, in seagrass areas of the site was noted as a key source of conflict among fisherfolk. As a strategy to improve communication between fisheries and environment managers and address this issue, the fisheries *refugia* concept was introduced to the Phu Quoc Management Board responsible for coral reef and seagrass management as a means of improving the management of fish stocks and habitat links at Ham Ninh (UNEP, 2007d). The fisheries *refugia* concept was well received by the Kien Giang Provincial Department of Science and Technology (DoST) and Department of Fisheries (DoF) as well as representatives of the Ham Ninh commune, as it aligned closely with local knowledge on fish migrations and patterns of availability, seasons of reproduction, and areas in which fish are caught. In several commune consultations, it was noted that the *refugia* concept and its focus on life cycle and habitat linkages was more relevant to local stakeholders than scientific concepts such as representativeness, comprehensiveness, and uniqueness that community members had previously been introduced to in discussions on MPA planning.

- Emphasize on sustainable use rather than prohibition of fishing

  Subsequent consultations undertaken with commune fisherfolk, fish traders, and women involved in inshore gleaning and processing at Ham Ninh revealed that, by emphasising the sustainable use aspects of *refugia* rather than the no-take approach adopted as part of conventional MPA systems, adverse reactions at the community level were avoided. This was a necessary prerequisite to any dialogue regarding improved fishing practices within the site. The acceptance of the approach enabled the development of a collaborative pilot activity by DoST, DoF, and the Phu Quoc MPA Authority, Border Army, fisherfolk and fish traders of the Ham Ninh Commune to establish and manage a pilot fisheries *refugia* site at the Ham Ninh seagrass area. This pilot initiative was meant to improve the integration of fisheries and seagrass habitat management at Ham Ninh through the establishment and management of fisheries *refugia*, improve the longer-term security of fisheries yields, and reduce the rate of seagrass degradation and loss. Specific activities included the development of inventory of fisheries *refugia* sites for important fish species including seasonality of spawning and age/size of recruitment from nursery areas for key species; preparation of a fisheries profile for Ham Ninh commune; identification of specific fisheries and habitat management issues at the site; and cooperative management of the Ham Ninh *refugia* site by Kien Giang's Department of Fisheries and local MPA Authority. The fisheries *refugia* concept was also used successfully by the National Fisheries Research and Development Institute of the Philippine Bureau of Fisheries and Aquatic Resources to facilitate the resolution of a long-running conflict between the fisheries and environment sectors in the Visayan Sea. As a result of intensive inshore fishing pressure, environmental NGOs had lobbied for the prohibition of fishing that was not feasible, at least, in the short term, due to high levels of local community dependence on fishing.

Parties to the dispute subsequently reached an agreement to use the fisheries *refugia* approach in identifying critical areas of habitat to be regulated and managed rather than adopting total closure (UNEP, 2007b).

- Focus on fish life-cycle critical habitat linkages

  In many Southeast Asian communities with traditions of local fisheries management, the rapid development of fisheries over the past 50 years has contributed to the erosion of these structures. Prior to the rapid uptake of demersal trawl fishing in the 1960s, fisheries were characterized by the use of mainly passive fishing gear to target small pelagic species supplying local markets (Pauly and Chuenpagdee, 2003). Community level management at that time included rules controlling the times and locations of fishing based on community knowledge of fish movements and reproduction (Ruddle, 1994).

  In contrast, the imposition of closed areas and seasons by central governments over past decades has been largely focused on restricting the levels of overall trawl fishing effort. While this has recently been refined to restrict the use inshore of destructive push nets and trawl fishing in some areas, existing closed areas have rarely been designated from the perspective of the nature of habitats contained in such areas and the essential contribution of those habitats to fisheries (UNEP, 2007a). This emphasis on fish life-cycle and critical habitat linkages will likely assist regional efforts in developing co-management in small-scale fisheries as it will allow for the design of community level rules that align more narrowly and explicitly to the needs of communities.

  At the time of the Ham Ninh pilot activity development, information regarding the links between fish stocks and habitats at Phu Quoc was scarce. Little or no data on the distribution and abundance of fish eggs and larvae were available for the identification of spawning locations or important nursery locations for fish stocks. This problem was largely overcome by the high level of local commune fisherfolk involvement in all consultations and exercises to identify *refugia* sites. The level of acceptance by fisherfolk of the *refugia* concept was such that they ultimately led activities to identify specific spawning and nursery areas in consultation with local fisheries and environment department staff and border army officials (UNEP, 2008c).This provided a sufficiently high level of interaction among all sectors that management issues and solutions could often be discussed and agreed at sea aboard small-scale fishing vessels. Such dialogue was necessary to enable the degree of sharing of ideas and perspectives among stakeholders that was required to identify solutions to problems directly related to the primary source of food and income for the local community. Sientists from Viet Nam's Institute of Oceanography assisted in the interpretation of knowledge in local community and among fisherfolk. This enabled the identification of critical spawning and nursery areas using inputs from local fisherfolk that has led to a high level of community ownership of the resultant maps of fisheries *refugia* at Phu Quoc (UNEP, 2008c).

  In the Philippines, the academe supported the efforts to model fish egg dispersal and larval settling in Coron Bay area of Palawan Island. Oceanographic information and fish egg and larvae data were used to identify spawning *refugia* (sources) and nursery *refugia* (sinks) for fish species of significance in that area of the South China Sea coastline. This information was used during local stakeholder consultations for the designation of *refugia* sites. In Thailand, the fisheries *refugia* concept's focus on fish life-cycle and critical habitat linkages has recently been used to manage demands from the fishing sector to reduce the area of Prachuap Khiri Khan-Chumpon seasonal closure for short mackerel (*Rastrelliger brachysoma*) in the western Gulf of Thailand by 3000 ha. The *refugia* concept is now seen as key tool in reducing the impact of intensive fishing on stocks of this species at times and in places when it is most vulnerable. Pilot activities focused on developing management at priority *refugia* sites have also been initiated with the support of fishing communities at Kampot in Cambodia and in Indonesia's West Kalimantan Province.

Comparisons of MPAs and fisheries refugia

Empirical evidence of an overall increase in fishery benefits following the establishment of an MPA is still controversial as increased catches frequently do not compensate for the decreased area of fishing grounds. In addition, MPA models have shown that the effects on fisheries yield are highly dependent on a number of factors, *e.g.* dispersal in the larval, juvenile and adult stages, configuration of the reserve, and the status of the fishery. Traditional MPAs are unlikely to enhance fish stocks and catch in the South China Sea as these are directed towards achieving the wider objective of biodiversity conservation that often precludes adequate consideration of the life history and population dynamics of fishery species.

The fisheries *refugia* concept has been developed to redress this imbalance. Experience in its application suggests that the *refugia* approach may potentially bring greater long-run benefits to the fisheries and environmental sectors in achieving mutually acceptable outcomes. The pilot fisheries *refugia* activities described above focused on testing the approach as a tool for improving cooperation among fisheries and environment stakeholders. While experience indicates that the *refugia* concept has significant potential for overcoming barriers to integrated fisheries and habitat management, the concept has not been tested from the perspectives of the identified resource-related goals and objectives defined for the regional system of *refugia*. The need to establish and monitor the effectiveness of individual and networks of *refugia* sites was acknowledged by the RWG-F in the development of a detailed results framework for the *refugia* system, which forms a component of the revised South China Sea SAP (UNEP, 2008a). The planned national and regional actions for the *refugia* system aim to build on preliminary initiatives to establish baselines and to undertake both formal scientific and community-level monitoring of *refugia*.

A key perspective in the Southeast Asian region is that overexploitation in fisheries may be a sign of community failure. Community values, norms and knowledge are critically important in guiding sustainable fisheries practices and the erosion of past community arrangements for the management of fisheries, including traditional rules covering the times and locations for fishing, may have opened the door to the adoption of unsustainable practices. In light of the competing demands on fish to drive export earnings and to secure a sustainable supply of protein and income for coastal communities, significant effort has been made in recent years to decentralize the responsibility of fisheries management with the aim of establishing co-management approaches. Accordingly, the ASEAN/SEAFDEC regional guidelines for responsible fisheries call for fisheries *refugia* to be used as a complementary tool to broader regional initiatives focusing on: co-management; illegal, unreported and unregulated fishing; alternative and supplementary livelihood creation in support of broader capacity reduction needs; data collection and statistics; and the promotion of responsible fishing gear and practices. With the designation and management of *refugia* being the responsibility of fisheries ministries and given the evident stakeholder support for the *refugia* approach, the conditions for effective coordination of these complementary initiatives are enhanced. This provides for *refugia* management to be equitable and to best respond to broader drivers in regional fisheries management, including capacity reduction needs.

The question arises as to whether or not MPAs qualify as fisheries *refugia* and vice versa? The simple answer in response to the traditional no-take MPA is "no". However, parts of multiple-use IUCN category VI 'Sustainable use of natural ecosystems' MPAs, such as fisheries management zones, may qualify as fisheries *refugia* if such zones promote the concept of sustainable use rather than prohibition of fishing and the selection of the zone is based on criteria relating to the critical linkage between the area and the lifecycle of the species for which the area is managed. Similarly, while it is currently not possible to compare the direct resource-related benefits of no-take MPAs and *refugia*, an additional institutional related benefit of the *refugia* approach could potentially be the longer-term broadening of management objectives at individual *refugia* sites to accommodate non-fishery related conservation goals. The *refugia* approach provides a suitable platform for improved dialogue and the development of practical experience in the use of area-based management tools in integrating fisheries and habitat management that had not been previously achieved due to the emphasis on no-take MPAs by environment agencies in Southeast Asia.

Significance of the fisheries refugia *approach*

At project outset there was a widespread recognition among stakeholders of the need for coordinated action to address fisheries and habitat issues. This had not been previously addressed due to the lack of regionally-relevant management approaches that fostered the establishment of common ground and improved dialogue between the fisheries and environmental sectors and between the community and government. The fisheries refugia concept has met this need via a focus on fish life cycle and critical habitat linkages and an emphasis on sustainable use rather than the prohibition of fishing.

Conclusions

The *refugia* concept appears to be a successful approach in addressing a significant barrier to the integration of fisheries and habitat management, namely the adverse reaction to the Marine Protected Area concept that elicited from fishing communities and fisheries officers at local and provincial levels during the past decade. The designation for management of *refugia* being the ASEAN-SEAFDEC ministries responsible for fisheries, and given the evident stakeholder support for the *refugia* approach as one of fisheries management tool, it is anticipated that the experiences gained from this novel approach to the use of spatial management tools in fisheries management will be suitable for scaling-up in the South China Sea and replication in other aquatic habitats. This experience is considered important because of the potential global fisheries and biodiversity conservation benefits associated with effective fisheries and habitat management at the local level. This is particularly relevant in Southeast Asia where the contribution of fisheries to food security and the maintenance and improvement of the livelihoods of coastal fishing communities is so substantial.

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Session Papers
Session 3: Habitat Rehabilitation (Coral Reefs, Seagrass Beds, Mangrove Forests, Inland Habitats)

Together with Session Facilitator *Dr. Tetsuo Yanagi* were seven Session Paper Presenters, namely: (1) *Mr. Lieng Sopha* on Habitat Rehabilitation with the Participation of Community Fishers in Cambodia; (2) *Mr. Akhane Phomsouvanh* on Resources Conservation and Enhancement in Nam Houm Reservoir, Lao PDR; (3) *Ms. Nilar Kywe* on Inland Fisheries Habitat Management of Myanmar; (4) *Dr. Firdaus Agung* on Critical Fish Habitat Management to Secure Marine Fisheries Production in Indonesia; (5) *Dr. Adelaida L. Palma* on Restoration and Enhancement of Fisheries in Philippines Lakes and Reservoirs; (6) *Mr. Albert Apollo Chan* on Coral Reef Rehabilitation and Restoration: Experience of Malaysia; and (7) *Dr. Nopporn Manajit* on Habitat Conservation and Resources Enhancement in Seagrass Beds in Sriboya Island, Krabi Province, Thailand. Capping off the Session was the paper of *Dr. Tetsuo Yanagi* on Seagrass Bed Restoration by Fishermen at Hinase in Japan.

In his paper, ***Mr. Lieng Sopha*** introduced the methodology and implementation of activities on habitat rehabilitation in Cambodia, considering that fishery resources are very important for food security and source of income for the country's rural fishers. He cited that decline in resources has led to fishing competition and conflicts in fishing while the use of modern fishing techniques has resulted in the gradual degradation of the fish habitats. In addition, the fluctuating depths and temperature of the waters have created impacts on the fisheries resources as refuges are lost that eventually causes mass fish kills while in some cases, the capacity of fish to reproduce is lessened. In an effort to address such concerns, the Fisheries Administration (FiA) of Cambodia divided the responsibilities of managing the fishing grounds and conservation areas with the community fisheries domain to be managed by community fishers. Thus, more than 350 conservation areas had been rehabilitated by the community fishers resulting in enhanced fish stocks and increased fish production. Mr. Sopha also explained that community participation in the rehabilitation activities had been enhanced through volunteerism and in order to raise funds for the said activities, persons interested in the activities are encouraged to pay certain amount of funds while financial assistance are also sourced from donors. He also explained that mangrove reforestation is a routine activity in the conservation areas where community fishers follow the rules and regulations on mangrove reforestation as prescribed by the FiA. In responding to the queries from the participants, Mr. Sopha emphasized that FiA always convenes a number of consultations in order to cover all the conservation areas under the community fisheries. As soon as the conservation areas had been rehabilitated, community fishers are encouraged to also engage in alternative livelihoods, *e.g*. tourism in the Tonle Sap Great Lake, upon thorough consultations among the members of the community fisheries. With regards to the installation of ARs in lakes as means of protecting the fishing grounds from encroachment which appeared to be successful in Cambodia, the representative from Malaysia expressed the apprehension that tree trunks used as ARs could pollute the inland waters and could be submerged and buried in the substrates, although the representative from Japan clarified that tree trunks have also been used successfully as ARs in inland lakes in Japan.

A review of the results of the implementation of a five-year project on rehabilitation of fisheries resources and habitat/fishing grounds for resources enhancement by SEAFDEC/TD in cooperation with the Department of Fisheries of Thailand and Department of Livestock of Lao PDR under the Japanese Trust Fund 5, was presented by ***Mr. Akhane Phomsouvanh***. With Nam Houm Reservoir in Lao PDR as the pilot site, the project carried out various activities, *e.g*. compilation of fisheries information and data, promotion of sustainable fisheries and the concepts of community-based and co-management in inland fisheries, strengthening the critical habitats by installing 50 pieces of high effective fish shelters as protective measures of broodstocks from illegal fishers, prohibition of certain fishing gears in conservation areas, transfer of technology on mobile hatcheries to fishers' groups in Nam Houm Reservoir for the breeding the common silver barb using hormones, and promotion of juvenile fish releasing techniques, among others.

In the discussion, Mr. Akhane explained that with water serving capacity 60 million m^3 in wet season, Nam Houm Reservoir also supports agriculture. It is known that there is 36 species of fish in the Reservoir, the most economically-valuable of which are tilapia (*Oreochromis niloticus*), featherback (*Notopterus notopterus)*, and common silver barb (*Barbonymus gonionotus*). He explained that mobile hatchery is being promoted since it is low-cost and easy to operate. He added that since illegal fishing operations still take place even in the conservation zones, ARs were installed in these zones by the Reservoir Fisheries Management Committee. The ARs are made of concrete and other materials that would not drift with the strong flow of water current.

To provide a bird's eye view of habitat management in inland fisheries being promoted by Myanmar, ***Ms. Nilar Kywe*** introduced the system of inland fisheries management adopted in Myanmar, where inland fisheries are divided into two categories: leasable fisheries and open fisheries. In leasable fisheries, DOF grants fishing rights to lease holders under a lease agreement subject to stipulations relating to the area, species, fishing implements, period and fishing methods used. In addition, lease holders must take the responsibility of carrying out stock enhancement and conservation of fisheries habitats. There are 3729 leasable fisheries in Myanmar and culture-based system is applied in most of these leasable fisheries. However, Ms. Nilar also pointed out that the inland fisheries and habitats have gradually degraded due to siltation, extension of agriculture, and road construction, among others. In order to conserve the fisheries habitats and fish stocks, the DOF has been conducting several activities in collaboration with leasable fisheries stakeholders to conserve and maintain the fisheries habitats and fish production in inland fisheries, including selective harvesting of stocks.

In presenting his paper, ***Mr. Andhika Anjaresta*** provided information on the efforts of the Ministry of Marine Affairs and Fisheries (MMAF) of Indonesia to rehabilitate and conserve habitats by undertaking mangrove reforestation, coral transplantation and installation of fish apartments. He pointed out that the engagement of the communities at the beginning of these activities has been important to support the maintenance, monitoring, and nursery of the rehabilitated habitats. During the discussion, Mr. Anjaresta explained that fish apartments are used to support the aggregation of fish and also serve as fish shelters. Made of durable plastic materials that could last for more than 25 years, fish apartments are installed near fishing communities to serve as refuge for fish stocks and prevent encroachment of the areas by illegal fishers. However, he also stated that the country would need concrete management actions to monitor the effectiveness of its fisheries resources conservation and habitat rehabilitation activities.

In order to introduce the efforts of the Philippines in habitat restoration and fisheries enhancement, ***Dr. Adelaida L. Palma*** explained that the inland fisheries resources in the Philippines comprise swamplands, lakes, rivers, and reservoirs, and host some 340 species of freshwater fishes. Considering their importance in increasing the country's fisheries production from inland fisheries, a National Program on the Fisheries Enhancement of Inland Waters was launched by BFAR covering 36 minor lakes and 320 small reservoirs in 16 regions of the country. This National Program is intended to rehabilitate and/or restore the physical conditions of the country's minor lakes and reservoirs, enhance fisheries, and repopulate indigenous species in support of biodiversity conservation, poverty alleviation and food sufficiency. While sharing a success story on resource enhancement in Dagatan Lake, Quezon Province, which is a small lake with a surface area of about 7.0 ha but almost totally covered by thick aquatic vegetation, Dr. Palma emphasized on the importance of mobilizing local communities, especially in resource rehabilitation activities, *i.e.* removal of aquatic plants that pose serious problems on the conservation of indigenous fish species, and promotion of economic activities.

Based on the lessons learned from the Dagatan Lake activity, Dr. Palma offered suggestions for successful implementation of rehabilitation activities. These include the need to harmonize legal and juridical mandate, enhance the management skills of fisherfolk, ensure sufficient supply of fingerlings, make rehabilitation sites accessible, and conserve indigenous species. In response to the query regarding the country's Center for Indigenous Fish Species, Dr. Palma explained that the Center maintains stocks of indigenous species, breeding the species, and restocking the juveniles in the various lakes of the country, taking into consideration the biodiversity of certain lakes of the country and ensuring that such introduction does not create negative impacts on the ecosystem of the host water system.

To introduce the experience of Malaysia on coral reef restoration, the Resource Person from the Department of Marine Parks (DMP) Malaysia of the Ministry of Natural Resources and Environment, *Mr. Albert Apollo Chan* summarized the coral reef restoration activities undertaken by DMP Malaysia in the waters off Pahang and in Perhentian Island of Terengganu Province from 2010 to 2014. He mentioned that Malaysia is reported to have about 1,687 km^2 of coral reef areas with more than 540 species of hard corals. However, only about 9% of the coral reef areas are protected under the country's MPA systems, while some of the coral reefs have been threatened by climate change, pollution, and illegal fishing among others, leading to massive coral bleaching and habitat loss. Mr. Chan added that in an effort to rehabilitate the coral reefs, DMP Malaysia embarked on a pilot coral reef restoration project through coral re-plantation, in the waters off Pahang and Terengganu starting in 2010.

In the discussion, Mr. Chan clarified that based on the experience of DMP Malaysia, site selection is considered a crucial aspect as the site should have moderate water current with unobtrusive sunlight, and should not be too near to adjacent natural reefs. In addition, the coral fragments used for transplantation must be larger than 10 cm, and the site should be maintained immediately after the corals had been transplanted. He cited some benefits of coral restoration which include increased live coral cover, recovery of targeted coral reefs, increased biodiversity, re-establishment of ecological balance, and stabilizing the surrounding environment.

The results of the project on "Rehabilitation of Fisheries Resources and Habitat/Fishing Grounds through Resources Enhancement" implemented by SEAFDEC/TD were reported by ***Dr. Nopporn Manajit***. The activities pursued under the project included selection of critical fishing grounds in marine habitats, and promotion of conservation and rehabilitation measures. A deteriorated seagrass bed area in Sriboya Island, Krabi Province, Thailand was selected as one of the pilot sites to mitigate the area's depleted stocks of an edible sea snail, the dog conch (*Strombus canarium*). Dog conch is commonly harvested by fishers and local communities by hand and/or labor-saving equipment using motorized boats, dredges, and diving with self-contained underwater breathing apparatus. However, such massive collection methods of harvesting easily led to the drastic degradation of the seagrass bed habitats as well as deterioration of the dog conch population. SEAFDE/TD, therefore promoted the conservation and optimum utilization of dog conch through public awareness activities.

Dr. Noppporn also explained that workshops aptly dubbed as the Andaman Sea Province Dog Conch Shell Resource Management Measures, had been conducted with participants from local stakeholders in Krabi and nearby provinces. These workshops led to a consensus and subsequent implementation of several management schemes, such as restriction on dog conch harvestable size (less than 6 cm) and allowable type of fishing gear (dredges), as well as banning the use of motorized boats. Furthermore, several types of media that support awareness building, such as posters, stickers, brochures and banners were produced and distributed to several provinces along the Andaman Sea coast. Through such activities, permanent dog conch conservation areas were established by the local fishing communities at Sriboya Island in Krabi Province, and Muk Island in Trang Province. During the discussion, it was suggested that for the replantation of seagrass beds, SEAFDEC should consider collaborating with experts/researchers on seagrass to support such activities, especially on the evaluation of seagrass bed resources. In addition, parameters and CPUE on dog conch harvesting should be considered in collecting the relevant data and information for comparison purposes.

Before the end of the Session, ***Dr. Tetsuo Yanagi*** presented a case study on seagrass beds restoration practices in Hinase City, Japan. He recalled that a drastic decrease of eelgrass in Hinase City from 590 ha in 1945 to 12 ha in 1985, had prompted the local fishers to undertake eelgrass bed restoration activity in 1985 which had been continued until the present. The area of eelgrass beds recovered is now 200 ha or 1/3 of the area in 1945, and the fish production using set net had also recovered starting 2011. In 1985, oyster culture was started in the same fishery ground so that together with the expansion of the eelgrass beds, harvest of oysters would be improved because eelgrass beds and oyster culture have a win-win relationship, that is, oyster culture helps the expansion of eelgrass beds by the assimilation of detritus and increase sunlight transmittance depths (transparency), while eelgrass beds tend to decrease the mortality of cultured oysters in summer by decreasing water temperature in the water column.

Moreover, the Hinase Fishermen Union plans to establish fish farms by integrating eelgrass bed, oyster culture rafts and artificial reefs in an arrangement where locally spawned fish grows in the designated farming area using the eelgrass beds, oyster rafts and artificial reefs as shelters. Dr. Yanagi added that the newly developed concept known as 'Sato-Umi' could be promoted as a fisheries management measure in coastal seas with high biodiversity and productivity, as adapted in Hinase as means to increase the abundance of eelgrass. Developed in Japan, the 'Sato-Umi' concept is a form of unified management system for land and sea, where management mechanisms for coastal waters move inland, one step away from integrated coastal management so that land and sea are brought under a unified management policy. In short, the "Sato-Umi" concept is meant for environmental conservation of coastal areas in harmony with human interaction on land. In the discussion, Dr. Yanagi emphasized that the methodology for replantation of seagrass beds could differ from place to place. In the case of Japan, the fishermen collect the seeds, preserve the seagrass seeds and spray these into the seagrass beds.

Habitat Rehabilitation with the Participation of Community Fishers in Cambodia

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Abstract

Natural fishery resources are very important for food security and income generation of Cambodian rural fishers. The high dependence on the fisheries has led to the decline of the resources due to high fishing pressure. This leads to fishing competition and causes conflicts in fishing and the application of modern fishing techniques. As a result, the fish habitats are gradually degraded. Specifically, the shallow and warm water in the dry season causes loss of fish refuges and results in fish kills, while the potentials of fish reproduction are reduced. Confronted with such problems, the Fisheries Administration (FiA) of Cambodian has set criteria separating the fishing grounds from the conservation areas. The Community Fisheries domain is responsibly managed by community fishers. Up to the present, 364 conservation areas of the Community Fisheries (CFi) had been established, protected and rehabilitated by community fishers in cooperation with development partners and governmental institutions. Fish habitats have been improved by deepening the water bodies, installing artificial reefs and replanting the flooded forests and mangrove areas. Thus, fish stocks have been maintained and enhanced with high density of fish stocks aggregating at the installed reefs. Moreover, fish reproduction has also been improved and broodstocks could be kept and survive in the dry season. Finding that habitat rehabilitation activity is useful, the community fishers expressed willingness to participate in the activity to protect and improve the fish stocks and enhance fish reproduction in the 364 fish conservation areas of the community fishing grounds and in the state-own conservation areas. This strategy should be recommended and promoted to maintain fish stocks and enhance multi-species fish production.

Keywords: freshwater fisheries, climate change, habitat rehabilitation, community participation

Activities

After 158 fishing lots equivalent to 953,861 ha of fishing grounds had been abolished by FiA, about 856,358 ha or about 90% was allotted for the use and conservation by CFi with the remaining 97,503 ha (10%) declared as conservation area by the national government. For the area allotted to CFis, the community fishers implemented various activities to rehabilitate the habitats. These include installation of 5633 demarcation poles and 426 sign boards in the CFi areas; installation of 32 concrete poles in the conservation areas outside the CFi areas; deployment of 500 concrete boxes to serve as ARs; replanting about 2200 ha of flooded forests and mangroves; and deepening of about 106,650 m of water canals. Moreover, 45 pcs of concrete poles were installed to protect the blood cockle conservation area in Koh Kchang Community Fisheries in Koh Kong Province, and another 200 pcs of cement poles are installed to protect the blood cockle *refugia* at Thmor Sar Community Fisheries also in Koh Kong Province. Moreover, 40 pcs of concrete boxes used as ARs (**Fig. 1**) were deployed to protect the marine biodiversity at Koh Rong Sanloeum Community Fisheries in Preah Sihanouk Province.

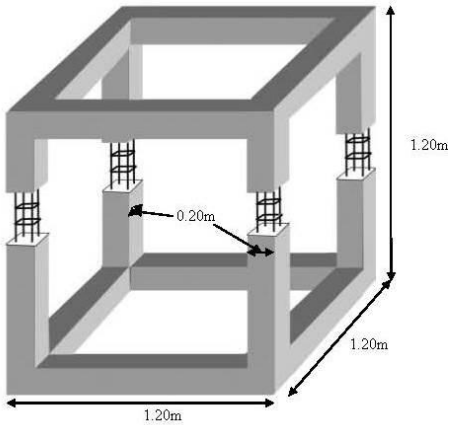

Fig. 1. Concrete box used as ARs in Preah Sihanouk Province, Cambodia

Issues and Concerns

Two years after the installation of concrete boxes as ARs, these were found buried in the mud, necessitating the conduct of a study on the stability of the bottom of habitats before installing ARs. Furthermore, fishes were not aggregating in the concrete boxes while the replanted trees were found dying. At any rate, the activity could not be pursued any further due to budgetary constraints.

Lessons Learnt and Conclusion

Although no study had been conducted to assess whether the habitat improvement has been successful or was a failure, community fishers observed an increase in fish species and other aquatic animals such as mud crab and shrimps especially in the marine conservation areas, as well as increase in fish abundance and broodstock. Near the ARs, fishes were found searching for food, taking refuge, breeding and spawning, especially after tree trunks were placed in the concrete boxes to serve as shelter. Moreover, appropriate techniques of replanting trees should be promoted in the flooded forests and mangrove areas to improve the fish habitats.

In the future, concrete boxes should be installed only in areas with stable bottom sediments, and that a study should be conducted by FiA on the effectiveness of installing ARs in inland and marine waters of Cambodia. Since the tree trunks put in the concrete boxes had served the purpose of providing shelters to the fish, this should be continued. However, for the flooded forests and mangrove areas, a study should be conducted on the appropriate species of trees that would suit the conditions of the areas. Above all, it is important that funds for habitat rehabilitation and stock enhancement be made available to ensure that habitat rehabilitation activities are sustained.

Resources Conservation and Enhancement in Nam Houm Reservoir, Lao PDR

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Abstract

In 2010, the Training Department of the Southeast Asian Fisheries Development Center (SEAFDEC/TD) in cooperation with Department of Fisheries of Thailand and Department of Livestock and Fisheries of Lao PDR embarked on a five-year project on Rehabilitation of Fisheries Resources and Habitat/Fishing Grounds for Resources Enhancement funded by Japanese Trust Fund 5 (JTF-5). The selected project pilot site was Nam Houm Reservoir in Lao PDR. Mainly used support agriculture, Nam Houm Reservoir has water serving capacity of 60 million m^3 in wet season. The total population from four villages near the Reservoir is 3,300 and as reported there are 36 species of fish in Nam Houm Reservoir. The main valuable and market species are tilapia *Oreochromis niloticus*, featherback fish *Notopterus notopterus*, and common silver barb *Barbonymus gonionotus* (Bleeker, 1849). The Project carried out various activities including improvement of fisheries information and data collection, promotion of sustainable fisheries and the concept of community-based and co-management in inland fisheries, strengthening of critical habitat protection measures by installing 50 pieces of highly effective fish shelter with fishing gear prevention tools in the conservation area to protect broodstocks from illegal fishers, technology transfer of mobile hatchery to the fishers group at Nam Houm Reservoir, as well as promotion of breeding techniques for common silver barb by injecting hormones to broodstocks and juvenile fish releasing techniques. All activities were successfully undertaken with the cooperation of Nam Houm Reservoir Fishery Management Committee (RFMR) and local fishers. The Project also demonstrated a good practice of co-management between local people and government in the inland fishery sector. Moreover, the technical knowledge and techniques from the team of experts had been transferred to local officers and local people during the Project period. Now, the local people can apply and develop more techniques appropriate for reservoir fisheries in the country to achieve the goal of sustainable inland fisheries management in the future.

Keyword: Resource Enhancement, Reservoir Management

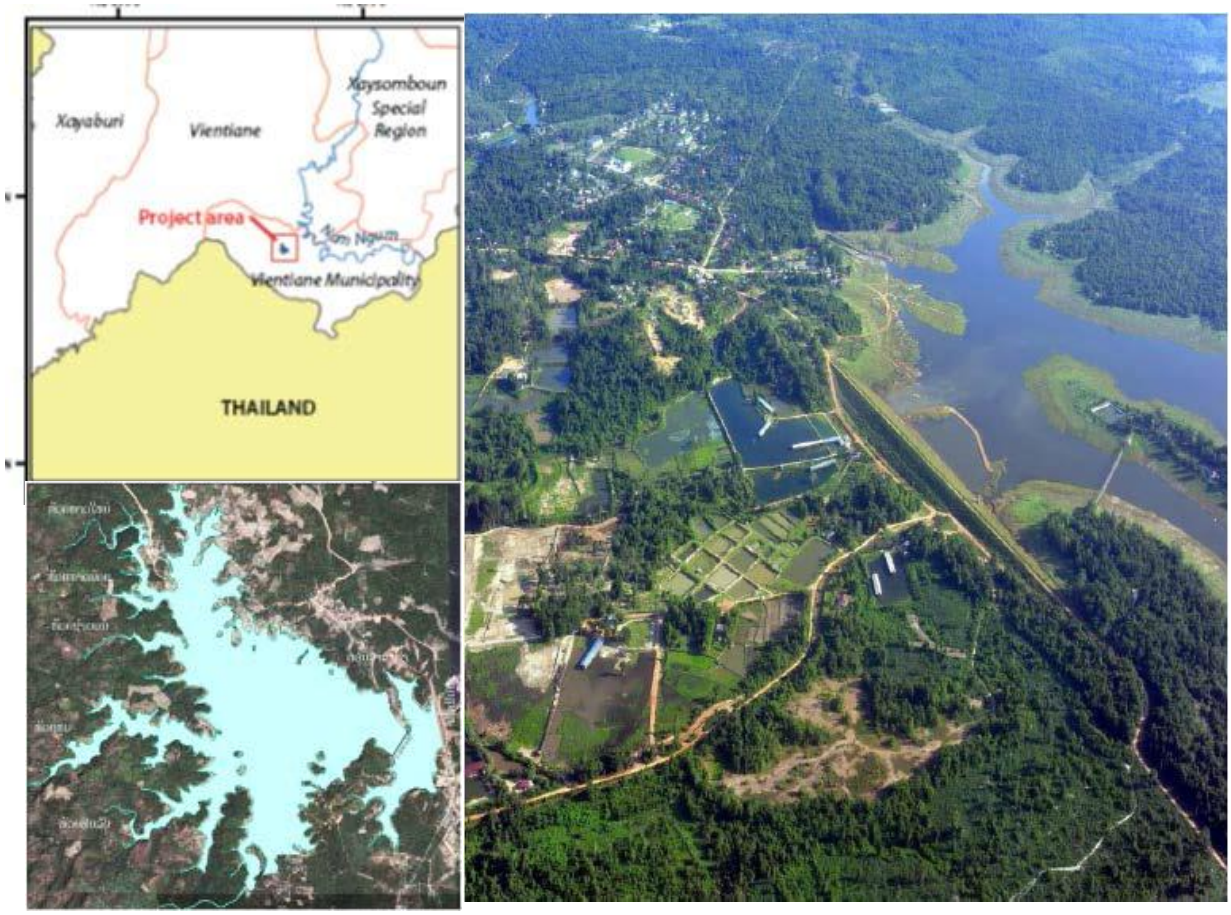
Introduction

In 2013, fisheries production of Lao PDR was recorded at 164,228 metric tons (MT) of which 76% came from freshwater aquaculture and 24% from inland capture fisheries. Most of the fisheries activities are concentrated in the Mekong River and its tributaries as well as in reservoirs and small water bodies, *e.g.* lakes, small natural pools, swamps and wetlands used for fishing activities. Most reservoirs in Lao PDR are used not only for irrigation purposes but also for fisheries activities.

The Fisheries Law of Lao PDR provides that communities have the right to management the resources through the establishment of community management systems. Nam Houm Reservoir was commissioned in 1981, and of the 3300 people inhabiting the four villages near the Reservoir, only 82 are registered fishers who use traditional fishing gears such as gill net, cast net, longline, and fish traps. Fish production from the Reservoir is reported to be about 57 MT per year.

Project Activities

In 2010-2011, the Project conducted an activity aimed at improving fisheries information and data collection in Nam Houm Reservoir. This was done through proper recording of catch landing, including recording of juvenile fishes caught by seine net, catch from gill net fishing, and updating of the over-all fish landing information from the Reservoir. In addition, fishing ground mapping was conducted by local fishers to determine the areas that need to be declared as close season, especially during the spawning season.



In 2012-2014, the Project carried out resource enhancement activities including the promotion of mobile hatchery for economically important freshwater fishes. In addition, installation of fish shelters was also promoted to protect the broodstocks from illegal fishers. From the aforementioned activities, it was found that many streamlets or tributaries to the reservoir are rich with nutrients and thus, could be tapped to serve as effective spawning grounds during the spawning season of important freshwater fish species. Moreover, since seasonal fish conservation zones are located in the headwater area or small tributaries/streamlets, these have been declared as areas wherefor no fishing zone during the fish spawning season from May to August.

Results

Results from a questionnaire survey on the socio-economics of fishers in Nam Houm Reservoir, indicated that of the Reservoir's registered fishers, 44% are part-time while 56% are full time. The boats used by the fishers are mostly engine-operated (64%) while 36% are row boats. Of the fish caught from the Reservoir, only 11% is for household consumption while the rest (89%) are sold in markets. The Project also demonstrated the most efficient mobile hatchery technique for breeding and juvenile fish production of the silver barb. Under the guidance of experts and in the first attempt of adopting the mobile hatchery technique, 100,000 eggs were produced, raised to juveniles and released in the reservoir in August 2012. In March 2013, a demo-training on fish breeding techniques was conducted for the local officers and fishers, and followed up with training on nursery techniques in December 2013. The training included hormone injection and artificial insemination methods to enhance the skills of fishers in producing fish seeds for re-stocking and enhancement. In January 2014, the fishers produced 500,000 eggs, which were nursed until juvenile stage and then released to the Reservoir. The introduction of mobile hatchery has been very much appreciated by the fishers, because it is easy to carry and set up, could be operated in rural areas, reduces injuries to broodstocks, low cost, could be operated by local fishers, and the technique is easy to transfer to neighboring villages.


Samples of mobile hatchery (*left*) and training on fish hatchery techniques (*right*)

Another very important activity in the Reservoir is the construction and installation of fish shelters. In August 2012, twenty pieces fabricated concrete box molds were installed by the fishers' groups in the Reservoir's conservation zone. Each mold weighs 150 kg and measures 40x40x50 cm.

Another design was introduced using gypsum concrete molds, of which 30 pieces were installed in July 2014. Each mold weights 200 kg and measures 50x50x50 cm. The fish shelters are meant to protect the broodstocks from illegal fishers and to serve as refuge areas during the dry season.



Concrete box mold (*left*), gypsum box mold (*center*), installation of fish shelters at the conservation zone of the Reservoir (*right*)

Lessons Learnt

Through training and demonstration, technical knowledge and techniques from experts on resources conservation and enhancement had been transferred to local officers and fishers. Now, the local officers and fishers are able to conduct enhancement activities by themselves.

In addition, the awareness of local officers and fishers had been enhanced, especially on the importance of conservation and management of inland ecosystems for the sustainability of inland fisheries.

Inland Fisheries Habitat Management of Myanmar

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Abstract

Leasable fisheries operate in fisheries waters in which fishing rights are granted under a lease by Department of Fisheries (DoF) of Myanmar, subject to stipulations relating to the area, species, fishing implement, period, and fishing methods. There are 3729 leasable fisheries in Myanmar, most of which operate in inland waters. Recently, inland fisheries habitats had been gradually depleted due to siltation, extension of agriculture, as well as construction of roads, bridges and dams. In order to conserve the fisheries habitats and fish stocks, DoF has been conducting many activities in collaboration with leasable fisheries stakeholders. One of the leasable fisheries is Myaung leasable fisheries (Inn) situated at Bamaw Township in Kachin State of northern Myanmar. It is a demonstration site for other leasable fisheries and the leasable fisheries owner (lessee) emphasizes on maintaining the waterways that connect with the Ayeyawady River as well as removal of aquatic plants, such as water hyacinth and lotus from the waterways. The lessee has also been conducting culture-based capture system and capture-based culture system in his leasable fisheries area. A 12-acre pen had been built to rear indigenous species and commercially-cultured species. The fish outside the pen had been fed with rice bran and ground nut cake to grow. The local people depend on this fish for consumption in closed season (May, June, July) since this leasable fisheries has been practicing selected fishing and managed to maintain the fish production.

Introduction

Myanmar is one of the largest mainland countries in Southeast Asia with a land area of 656,578 km^2 and population of about 51.5 million based on the 2014 Myanmar Census. The country is endowed with inland water resources composed of riverine and estuarine systems. Its extensive river system comprises the Ayeyarwady (formerly known as Irrawaddy) River is about 2,170 km long and its tributaries are the Chindwin which is about 960 km long, Sittaung (560 km), and Thanlwin (1,300 km). Ayeyarwady River which originates from Mainland China, traverses the entire length of the country from north to south, and drains into the Andaman Sea.

Management of Inland Fisheries in Myanmar

Inland fisheries has been practiced in Myanmar since 1864 during the British Rule of the country and managed in accordance with fisheries rules enforced since 1872. Since then, inland fisheries had been managed in accordance with the fisheries rules. Management of inland water fisheries has been promoted in Myanmar as means of developing the country's fisheries in a sustainable manner, preventing the extinction of fishery resources, and safeguarding the health of freshwater fishery resources and habitats. For management purposes, the country's inland fisheries had been divided into: leasable and open fisheries. In leasable fisheries (locally known as Inn leasable fisheries), the fishing rights are granted through a lease agreement with the Department of Fisheries (DoF) of Myanmar subject to stipulations relating to the area, species, fishing implements, fishing period, and methods used. Open fisheries are operated in all other inland areas and waters adopting all kinds of fishing operations, with the right to fish in such areas also licensed by DoF including the fishing gears used.

The leasable fisheries at Myaung in Bamaw Township, Kachin State which had been adopting sustainable management, serves as a demonstration site for other leasable fisheries in Myanmar. However, considering that the country's fisheries production had been decreasing, the government promoted leasable fisheries and enacted the Fisheries Act in 1905, which identified the boundaries of leasable fisheries, auction system and fishing period in the leasable fisheries. After a change of the country's administrative system in 1991, the country enacted the Freshwater Fisheries Law.

Leasable fisheries also serve as conservation areas and production promotion sites based on collaborative arrangements among the lease owners and the DoF. However, the short-term lease period of one-year created some concerns as this led to over-exploitation of resources as the lessees tended to maximize their catch without having thoughts on the sustainability of the fishery resources.

Thus in 1909, the long-term lease system was adopted as means of preventing the extinction of indigenous species and depletion of fisheries habitats, sustaining fish production of leasable fisheries, monitoring and controlling illegal fishing in the lease areas, and promoting responsible fisheries practices in the lease areas.

In 1988-1989, the long-term lease permission program was suspended but was restarted in 1992. Under this resumed program, lease owners granted the long-term permission have to undertake various activities such as repairing the water ways where fish migrates, enhancing the fish stocks in the lease areas, and promoting the conservation of fisheries habitats. Considering that such activities could not be completed in one year, DoF grants the lessees long-term permission from 3 to 9 years. Thus, the lessees do not have to bid again for the auction and pay high fees for their lease areas during the lease period. In order to promote the production and conservation of indigenous species, DoF has initiated culture-based system and capture-based system in leasable fisheries since 1997. At present, most of the lessees have been conducting these systems since these have provided them beneficial returns. Such practices in leasable fisheries have been promoted by the DoF as ways and means of obtaining sustainable fish production and at the same time promoting conservation measures. Since then, nearly 500 leasable fisheries have been permitted to operate long-term lease arrangements annually. Among the long-term leasable fisheries, Myaung leasable fisheries in Bamaw Township, Kachin State which adopted sustainable management, had served as demonstration site for other leasable fisheries in the country. As leasable fisheries progressed, some of the lease areas had been observed to be deteriorating due to siltation, agriculture operations, mining, and road and dam construction. The deteriorated habitats coupled with illegal fishing and overfishing resulted in the depletion of the fishery resources that eventually led to overall decreases in the country's fish production from inland capture fisheries. Thus, the DoF finally established guidelines for preventing further decline of habitats and fish stocks, especially in the lease areas based on long-term lease agreement of three years. The Guidelines detailing the responsibilities of lease holders (lessees) in the lease areas, include the following:

- Submit to DoF proposal for long-term operation of lease area including workplan;
- Upon issuance of lease agreement, implement the workplan under the supervision of DoF;
- Conduct regular repair of waterways where fish migrates, and promote stock enhancement and conservation of fisheries habitats based on culture-based and capture-based systems;
- Promote conservation of indigenous fishes by adopting capture-based system;
- Enhance fisheries production using culture-based system by stocking fish seeds during the transition, i.e. nursing fish seeds in net enclosures in pens or cages or earthen ponds prior to releasing them to lease areas; and
- Rehabilitate the habitats in order that wild fish would reach the spawning and nursing grounds in the lease areas, *e.g.* deepening of shallow water ways, removing fallen trees and small bushes as well as other aquatic growth, creating spawning and nursery grounds in some areas along the migration route.

Model Leasable Fisheries in Myanmar

With the main objective of conserving the inland fisheries habitats and fish stocks, the DoF has been conducting many activities in collaboration with leasable fisheries stakeholders. One of the most successful long-term leasable fisheries is located in Myaung of Bhamo Township, Kachin State in the northern part of Myanmar. Recognize for its successful management that led to increase in fish production, the Myaung leasable fisheries had been used as model and demonstration site for other leasable fisheries to learn lessons from. Awarded during in auction in 2013-2014, the Myaung lease area consists of river channels connected to the Ayeyarwady River, where the main channel is managed by the lease holder while in the small channels, other fishers are allowed by the lessee.

Based on the proposal submitted to DoF for the operation of Myaung leasable fisheries, the lessee has been allowed to operate in the lease area for a period of three years from 2014 until 2017.

The stakeholders of Myaung leasable fisheries established that one of the most important factors that led to their success in managing the lease area is to regularly clean the waterways or canals as well as remove vegetations that grow in the waterways, to facilitate the migration of spawners. Furthermore, the activities that have been conducted in the lease area are in accordance with the work plan submitted to DoF and other relevant conditions. The lessee also adopts culture-based and capture-based culture systems in the lease area, and a fishpen is constructed inside the area to rear indigenous fish species and culture some commercial species.

The fish outside the fishpen is also nurtured and fed to enable the fish to grow to marketable size. The concerned stakeholders depend on the fish harvested outside the fishpen for their consumption especially during the closed season (June-August). Selective harvesting has also been applied in the Myaung leasable fisheries in order to maintain its fish production.

Legal Framework Relevant to Inland Fisheries Management

The DoF of Myanmar formulated a new Freshwater Fisheries Law in 1991 to ensure that the changing conditions in the country's inland fisheries are taken into account, which the 1905 Burma Fisheries Act had inadequately covered. In addition, having been empowered by the Forest Law of 1992, the Government has declared that all mangrove forests are protected areas, and fishing within three hundred yards of such mangrove areas is strictly prohibited. Meanwhile, the most relevant regulations under the 1991 Freshwater Fisheries Law are shown below:

Closed fishing areas: 30 areas reserved for leasable fisheries had been identified for protection and management to ensure survival of juveniles of commercially important fish species, and these are located in Yangon, Pago, Sagaing, Mandalay, and Ayeyarwady Region.

Closed fishing season: for all freshwater fisheries, fishing is not allowed from May to July.

Protection of spawners, breeders and fingerlings of freshwater fishes. Species that should not be caught, exported, killed or kept in captivity without permission from the Director General of DoF, especially during the closed season are identified.

Prohibited trading of spawners, breeders and fingerlings of the giant freshwater prawns *Macrobrachium rosenbergii* and *M. malcolmsonii*: catching, exporting, selling, killing or keeping in captivity of such species especially during the closed season is not allowed without permission from the Director General of DoF. In case of accidental catch, these should be released immediately to natural water bodies.

Prohibited trading of the African catfish *Clarias gariepinus*: import, export, culture, production, sale, propagation or possession of the African catfish (*Clarias gariepinus*) is not permitted.

Prohibited fishing gears: fishing gear that is destructive to the environment and fishery resources are banned, as well as electric fishing and fishing that uses poisons, chemicals and explosives, and other gears that obstruct the waterways such as those in dams and banks of rivers.

Issues and Concerns

Various approaches and related activities had been tried by the DoF of Myanmar for the sustainable management of leasable fisheries, *e.g.* giving back 1.0% of revenues to the inland fisheries sub-sector through a stocking program; return of 30% of revenues to long-term lease holders in the form of grants for improved management that includes: environmental rehabilitation, restoration and enhancement; clearing of floodplain channels to allow improved access of fish to the feeding and breeding grounds; and rearing of fish in pens within the lease area. Although the impacts of these factors are difficult to monitor and record, production and revenues are however reported to DoF, especially with respect to the trend of production from leasable fisheries. Nonetheless, one of the main concerns of the inland fisheries sub-sector of Myanmar is proper compilation of production and other data for planning and policy-making purposes. For example, data from reservoir fisheries are not compiled by DoF because reservoirs are under the control of the Ministry of Agriculture and Irrigation. Even if fishing in reservoirs is officially not allowed as means of allowing fish stocks to recover, fish is still harvested from reservoirs since these water bodies are restocked regularly. As a consequence from such practice, the catch is not included in the country's statistical reports until 2000.

The Union of Myanmar is divided into States and Divisions, which are then divided into Districts then to Townships then lastly to Villages. All fisheries license holders are required to report their catch to DoF through designated local township officials.

Specifically for leasable fisheries, the lessees keep records of the fisheries, especially the catch records which are collected by designated local officers. In all cases, there is no sampling of the catch although reports are required especially for large gear, while some township officers were reported to have estimated the catch when these are not available from the lessees. After compiling the reports every two weeks, the township officers submit the reports to the central offices of DoF on a monthly basis. The officers are supposed to verify the catch records and other information through ocular inspection and field visits in the lease areas or fishing locations for open fisheries. However, such approach is not usually undertaken since many officers at township level only work part-time on fisheries statistics, as they have other duties in the township that include fisheries extension. In the case of leasable fisheries, the catch is reported in terms of value and quality (*i.e.* high and low quality), but information from open fisheries is reported by volume only and not by any category. Nevertheless, in both fisheries, there is very limited information on species composition.

It is in this aspect that collection and compilation of fisheries information should be improved, and could include: weight and species of fish caught, weight of feeds for fish outside and inside the fish pens, information on stock assessment of cultured species and wild species, and results of analysis of monitoring and evaluation of fish production. Nonetheless, it should also be considered that the Government has been giving more focus on agriculture extension, mining and industrial development.

Given the importance of fisheries, especially inland fisheries to food security of the country, the fisheries sector in general and inland fisheries in particular, should also be given equal attention as these other sectors. Specifically for leasable fisheries, support from the Government is needed in the reconstruction and/or maintenance of water ways considering the high labor and machinery costs. In addition, since the process of annual auctioning of leasable fisheries had been found to result in over-exploitation, such system should be reviewed and revised accordingly.

Conclusion and Recommendations

For the sustainability of inland fisheries, habitat conservation should be promoted as this is important for the growth and propagation of fish. In leasable fisheries, selective fish harvesting should be enhanced to ensure sustainable fish production and resources conservation while leasable fisheries should be sustained as these have the potentials for resources and habitat conservation compared with open fisheries. Information collection and sharing of knowledge and experiences among stakeholders should be improved. Moreover, sufficient supply of quality seeds of indigenous species should be produced in hatcheries for stock enhancement of the species.

Based on the experience of Myaung leasable fisheries, similar approach should be promoted in other areas of the country for the sustainable production of fish which could supply the nutritional requirements of local people especially during the closed season. Since conservation of indigenous species is already developed, lessees should be encouraged to provide breeders to DoF-operated hatcheries as well as to backyard hatcheries operating near the lease areas. In general, there is a need for the Government to put more emphasis in the conservation of freshwater fishery habitats and resources as well as in the extension of long-term lease awarded to responsible lease holders.

On the part of the DoF of Myanmar, an analysis of the impact of cultured species on the wild species should be conducted based on regular surveys. There is also a need for DoF to conduct R&D on the rehabilitation of critical fisheries habitats and the results of which could be applied in leasable fisheries. Over-all it still remains a great challenge for Myanmar to manage its fisheries, more particularly its inland fishery resources.

Critical Fish Habitat Management to Secure Marine Fisheries Production in Indonesia

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Abstract

As one of major economic sectors in Indonesia, fisheries had been targeted to contribute approximately 7% to the national GDP in the next five years. This target relies on the capacity of marine habitats and its biodiversity to support fisheries production and food security. Maintaining habitats' functions and services while mitigating the negative impacts from land-based and marine-based pollution and climate change is very challenging. Rapid development and population growth in coastal areas have been considered as among the driving forces toward habitat degradation due to habitats loss, overfishing, and pollution. In order to sustain fisheries production, national programs have been focused on the conservation of fisheries habitats rather than on rehabilitation. Marine habitat conservation has been undertaken since 1990s and has covered about 15.7 million ha of MPAs as of 2015. Totally, approximately 22.7% of the country's coral reefs, 17.3% sea grass beds, and 22% of mangrove habitats have been protected. These three habitats are critical for fish recruitment. Nevertheless, complementing such conservation efforts are direct habitat rehabilitation activities such as mangrove rehabilitation, coral transplantation and installation of fish apartments. These efforts are intended to provide artificial habitats for fish, and in the long term, facilitate natural habitat regeneration. Although these activities have been implemented in many areas and over years, its effectiveness in improving fish stocks has not been investigated intensively. The challenges in the future are related with effective management of MPAs to support fisheries, engagement of multi-stakeholders participation in habitat management, and improving the effectiveness of rehabilitation efforts to include monitoring and evaluation.

Introduction

Report of the Ministry of Marine Affairs and Fisheries (MMAF) of Indonesia indicated an increasing trend in the country's fisheries GDP from 4.20 in 2009 to 6.97 in 2014 (**Table 1**). Production from capture fisheries had also increase during the same period from 5.11 million metric tons (MT) in 2009 to 6.20 million MT in 2014. In spite of such increasing trend, Indonesia has been undertaking conservation measures (**Table 2**) to ensure the sustainability of its fishery resources. Under the country's Fish Resources Conservation Law (Law 31/2004), conservation of fish resources is defined as the protection, preservation, and utilization of fish resources, including ecosystems (e.g. mangroves, sea grass, coral reef, estuary, coast, lake, river, swamp, reservoir), species (including endangered, threatened, charismatic), and genetic to ensure **the existence, availability, and continuity** while maintaining and improving the quality of the value and diversity of fish resources.

Table 1. Performance of Indonesia's capture fisheries sector (2009-2014)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**
Fisheries GDP	4.20	6.00	7.00	6.50	6.90	6.97
Production from capture fisheries (million MT)	5.11	5.38	5.71	5.83	6.12	*6.20
Fish consumption (kg/capita/year)	29.08	30.48	32.25	33.89	*35.21	*37.89

Source: MMAF (2014)
***** preliminary data

Table 2. Conservation and management of critical fish habitats in Indonesia from 2010 to 2014

2010	**2011**	**2012**	**2013**	**2014**
• Management of 900,000 ha of critical habitats	• Management of 2.5 million ha, and additional 700,00 ha new conservation areas	• Management of 3.2 million ha, and additional 500,000 ha new conservation area	• Management of 3.6 million ha, and additional 500,000 ha of new conservation area	• Management of 4.5 million ha, and additional 300,000 ha of new conservation area

Moreover, in accordance with the country's Coastal and Small Islands Management Law (Law 27/2007), rehabilitation of marine and coastal habitats should be carried out through stock enhancement, habitat restoration, and conservation. From 2015 to 2019, Indonesia intends to establish new conservation areas (**Table 3**) considering that the number of conservation areas that attained improvements in management effectiveness had increased. Although the proportion of marine conservation areas (MCA) to the fisheries management areas (FMA) could be minimal, the MCAs had protected most of the critical habitats in each FMA.

Table 3. Habitat conservation target (2015-2019)

	2015	2016	2017	2018	2019
New conservation areas to be established (ha)	500,000	600,000	800,000	900,000	1,000,000
Number of conservation areas that attained improvements in management effectiveness	15	28	30	33	35

Indonesia is presently intensifying its efforts in conserving and enhancing critical fisheries habitats, which comprise mangrove areas, coral reefs, and sea grass beds. In the next five years (2015-2019), Indonesia must have converted some existing critical habitats into MCAs (**Table 4**). With the plan to adopt 30% conservation target, it is expected that more than 500,000 ha of these habitats would be conserved and enhanced.

Table 4. Planned conservation of existing critical habitats (2015-2019)

	Existing critical habitats	To be developed as MCAs	To be conserved(30% conservation target)
Mangroves	3.5 million ha	758,470 ha	227,540 ha
Coral reefs	3.3 million ha	747,190 ha	224,160 ha
Seagrass beds	1.8 million ha	304,870 ha	91,460 ha

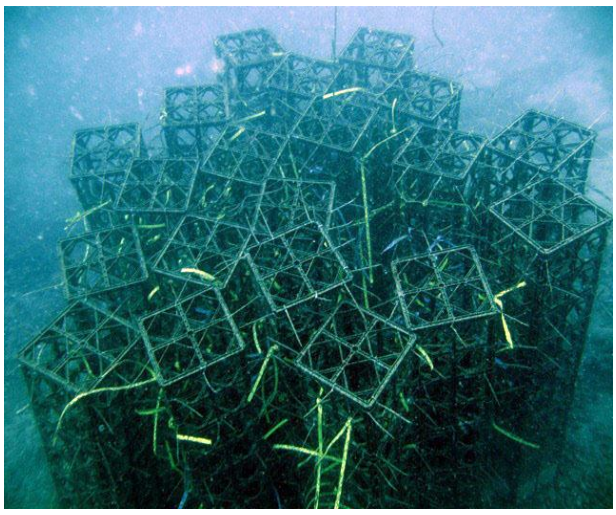
Habitats Conservation/Rehabilitation

Mangrove rehabilitation

- Mostly conducted in northern coast of Java and eastern coast of Sumatra
- Targets not only for the purpose of restoring fish habitats but also for education, tourism, and coastal protection
- Using most abundant local species (mostly *Rhizopora* spp.)
- Engages the communities in planting and nursery
- Addresses issues related to land status, land use change, and long-term maintenance.

Installation of fish apartments

- Supports fish aggregation and shelter
- Using environmental friendly materials, constructed near fishing communities
- Indicators of change: fish diversity, abundance, size composition, other associate biota
- Monitoring of effectiveness is still limited, increase pressure to fisheries



Results of the monitoring study conducted by Kriswan (2013) indicated that the composition of the catch (weight and length of individuals) surrounding fish apartments was better than those caught outside the apartments. Inside the fish apartments, catch was 1.4 times more than outside, while target species caught was about 80% higher inside the fish apartments than outside (59%).

Coral reefs rehabilitation

- Focuses on reducing stress and damaging factors such as fishing, pollution, sedimentation, and coastal development
- Several direct rehabilitation activities include transplantation and artificial reefs
- Transplantation is carried out to provide new habitats, seed gardens (for ornamental corals), areas for diving activities, and coral adoption
- Indicators: fish biomass, coral health index (coral cover, fish target, and megabenthos)

Constraints

Since the geographic coverage that is very large, various concerns had been raised, such as:

- Information on specific locations that are essential for fish recruitment (spawning, nursery, feeding) is still limited
- Monitoring on effectiveness of conservation and rehabilitation activities is still minimal
- Long-term impacts of conservation and rehabilitation of fish habitats are difficult to determine
- Involvement of multi-stakeholders is still challenging due to benefits and impacts on their own interests

Recommendations

- Secure land use and spatial planning (terrestrial and marine) for habitat conservation and rehabilitation sites
- Engage communities since the beginning of activities to support maintenance, monitoring, and nursery of rehabilitated habitats before these could be left to grow on their own.
- Apply multi-purpose objectives for conservation and rehabilitation of critical habitats to optimize stakeholders' inputs and maximize benefits

Conclusion and Lessons Learnt

- Most of marine fisheries habitats are already conserved but there is still a need for concrete management actions to maintain coverage and quality
- Rehabilitation of fish habitats in Indonesia is complementary actions to conservation efforts
- Its effectiveness to improve fish stocks depends on good understanding and proper selection of specific sites for spawning, nursery, and feeding areas
- Monitoring and evaluation on the results of conservation and habitat rehabilitation should be undertaken regularly and as a long-term activity

Restoration and Enhancement of Fisheries in Philippine Lakes and Reservoirs

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Abstract

Inland water resources of the Philippines host some 348 freshwater fishes, of which 16% are endemic and 56% indigenous (Fishbase 2013). Although production from inland capture fisheries accounts for only 7.8% of the total fish production (BFAR Fisheries Profile, 2012) it plays a significant role in providing livelihood to small fisherfolks and source of fish protein to the rural landlocked areas. With proper intervention and the application of scientific approach to fish stocking, production from these resources could be increased. The Bureau of Fisheries and Aquatic Resources (BFAR) implements a National Program on the Fisheries Enhancement of Inland Waters, which aims to enhance fish production in 36 lakes and reservoirs in the sixteen regions of the country. The Program includes water quality and productivity profiling; social preparation and capacity building; habitat restoration and fisheries enhancement through the establishment of habitat structures; and culture-based open water fisheries. In support of the Program, the BFAR-National inland Fisheries Technology Center conducts research and rehabilitation measures for indigenous species like the *Leiopotheraponplumbeus, Anabas testudineus, Clariasmacrocephalus* and *Ophicephalusstriatus.* A component of the Program is the development of a network of private hatcheries to sustain the fingerling requirements. A prototype model of the Program is the successful physical restoration and the reconstruction of fisheries in the 7-hectare Dagatan Lake. Through collaborative efforts to pool funds and resources; mobilization of the local communities and the application of technical tools; the lake was restored to its natural condition and its fisheries reconstructed through managed open water stocking.

Key words: inland water resources, freshwater fishes, scientific approach to fish stocking, lakes and reservoirs, habitat restoration, fisheries enhancement, culture-based open water fisheries, indigenous species, hatcheries

Introduction

The inland freshwater resources of the Philippines consist of 106,328 ha of swamplands; 200,000 ha lakes, 19,000 ha reservoirs and 31,000 rivers. These resources host some 340 freshwater fishes (Fishbase, 2015), 16% of which are endemic, 56% indigenous, and 28% are exotic. As a traditional activity in inland waters, fish capture plays a significant role in providing livelihoods to small fisherfolks and source of fish protein to the rural landlocked areas. Worldwide, inland capture fisheries accounts for 7.8% of the total fish production. An analysis of the inland fisheries production trend (**Fig. 1**) showed that from 2008 to 2012, production has stagnated to 180,000 metric tons (MT) falling short of the FAO estimated predictive yield of about 250,000 MT for freshwater resources.

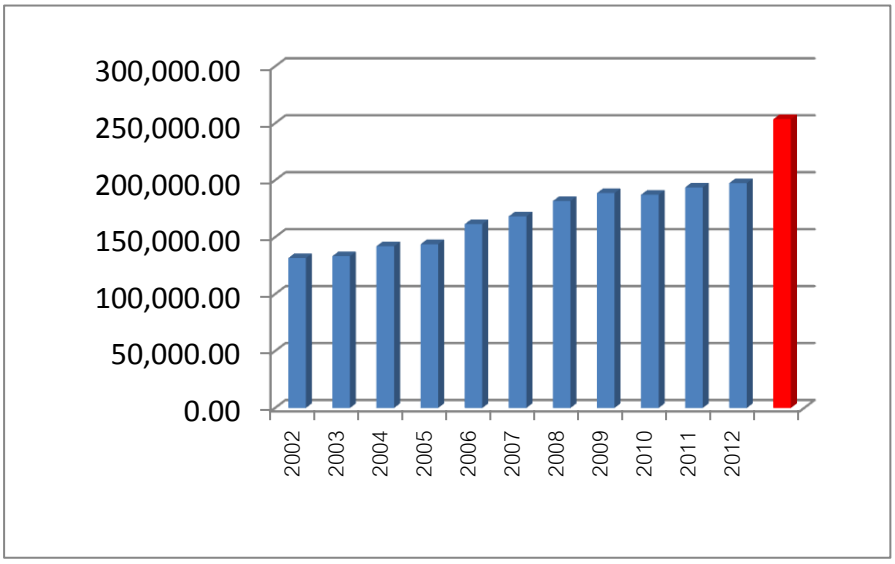

Fig. 1. Production trend in inland capture fisheries (in metric tons)

Philippines National Inland Fisheries Enhancement Program

The Philippine Bureau of Fisheries and Aquatic Resources (BFAR) has been implementing a National Program on the Fisheries Enhancement of Inland Waters, covering 36 minor lakes and 320 small reservoirs in the 16 regions of the country (**Fig. 2**). This Program aims to rehabilitate/restore the physical conditions of minor lakes and reservoirs; enhance the fisheries; and repopulate the indigenous species in support of biodiversity conservation, poverty alleviation and food sufficiency. The Program has five major components, namely: (1) **Social Preparation and Capacity Building** which include organization of management teams (regional focal persons) and strengthening of the fisherfolk beneficiaries; (2) **Resource Profiling** (Validation of Project Sites, Upgrading of Regional Water Quality Laboratories, Water Quality and Productivity Profiling); (3) **Habitat Restoration** (*e.g.* clearing of aquatic weeds, buffer zone rehabilitation, , monitoring and evaluation); (4) **Rationalized Fisheries Enhancement** (using food base approach to pen water stocking through establishment of habitat structures as specific management areas (in coordination with local government units) and culture-based open water fisheries; and (5) **Monitoring and Evaluation** (fish production/catch survey).

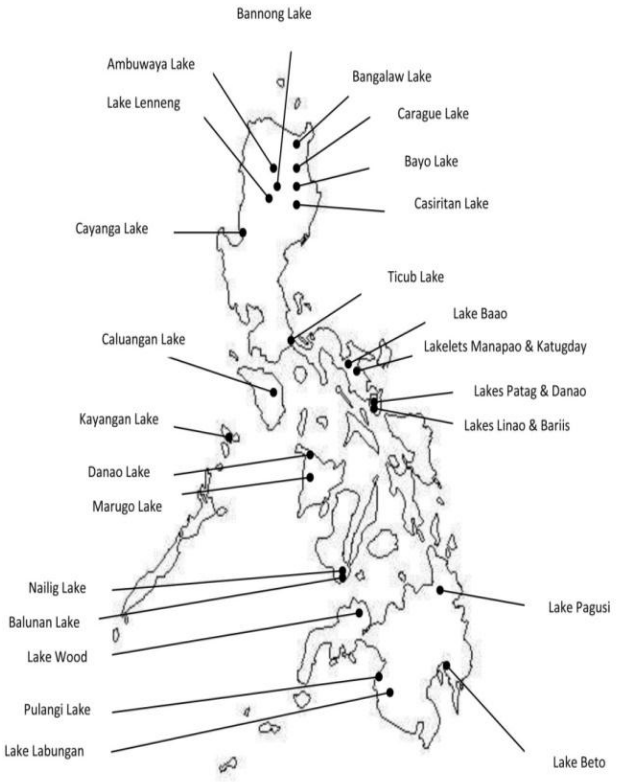

Fig. 2. Map of the Philippines showing the location of priority lakes for the National Inland Fisheries Enhancement Program

On-going Inland Fisheries Enhancement Activities

Table 1 shows the ongoing inland fisheries enhancement activities under the National Inland Fisheries Enhancement Program. Some constraints and challenges have been encountered during the conduct of the enhancement activities. These include the need to: harmonize the legal and juridical mandates between BFAR and the local government units (LGUs), enhance the management skills of fisherfolks as these are still very inadequate, ensure sufficient supply of fingerlings, establish the source of indigenous species, and improve the accessibility of the pilot sites.

Strategies and Interventions

- Establishment of a national center for indigenous fishes

- Establishment of gene bank for commercially important indigenous fishes.
- Development of breeding protocols for low trophic species
- Repopulation, management and conservation of indigenous fishes


- Development of a network of satellite regional government hatcheries and private hatcheries to supply the fingerling requirements


Table 1. Inland fisheries enhancement activities conducted by BFAR

Region	Location of Pilot Sites	Activities
Cordillera Administrative Region	Ambuklao Dam and Binga Dam, Benguet Province 	• Water quality monitoring • Fish culture management • Open water stocking • Repopulation of indigenous fish species
Region II	Magat Dam	• Water quality monitoring • Fish culture management • Open water stocking • Repopulation of indigenous fish species • Establishment of Magat Inter-agency Task Force
CARAGA Region 	Lake Mainit, Surigao 	• Management of goby fishes • Capacity building
	Lake Mahucdam, Surigao	• Water quality profiling • Establishment of brush park (proposed) • Open water stocking
Region IV-A 	Bal-on Reservoir, Quezon Province	• Habitat restoration
	Six river sanctuaries in Rizal Province	• Maintenance of fish refuge • Open water stocking
	Laguna de Bay	• Maintenance of municipal fish sanctuaries • Control of invasive species
	Seven lakes of San Pablo City and Tadlak Lake, Laguna	• Capacity building • Open water stocking
	Dagatan Lake, Quezon Province	• Habitat restoration • Buffer zone rehabilitation • Water quality monitoring • Maintenance of fish refuge • Fisheries repopulation




Restoration of Dagatan Lake and its Fisheries – A success story

Dagatan Lake is a 7-ha freshwater lake located at 13° 44' N and 121°18' E in San Antonio, Quezon Province, Luzon Island. In spite of its small size, the Lake plays a significant role in biodiversity being one of the last remaining frontiers for some indigenous freshwater fishes like the native catfish *Clarias macrocephalus*. The Lake had been covered with thick aquatic vegetation posing serious problem on the conservation of the native species that prevented any economic activity. The physical restoration of the Lake and reconstruction of its fisheries had serious challenges and called for the harmonization of legal and juridical mandates between BFAR, national agencies mandated under the Philippine Fisheries Code for the management and conservation of the fishery resources, LGUs with jurisdiction over the Lake under the Philippine Local Government Code, and the fisherfolk beneficiaries. Restoration of the Lake was finally achieved through collaborative efforts that facilitated the pooling of funds and resources; mobilization of the local communities and application of technical tools to revive the Lake to its natural physical state; reconstruction of its fisheries through managed open water stocking of indigenous fishes; improvement of the coastal buffer zone by planting of freshwater mangrove trees; and organization of the Municipal Fisheries and Aquatic Resource Management Council for capacity building. The restoration and management of the Lake not only led to revival of its fisheries but also expansion of its water resource services to provide irrigation and development of eco-tourism activities.

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Coral Reef Rehabilitation and Restoration: Experience of Malaysia

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Abstract

After the event of mass coral bleaching in 2010 and the ever vulnerability on the marine environment due to climate change, the Department of Marine Park Malaysia starts to look at ways to address the future of coral reefs through coral reef restoration. Approaches such as mitigation, adaptation and resilience need to be enhanced in Malaysia marine protected areas (MPAs). A coral restoration project was initiated in 2011 in collaboration with stakeholders such as Reef Check Malaysia. It takes about three years to reach maturity and two pilot sites had been established with encouraging result. The design of the coral frame structures goes through three different stages of which the present *Cores 3* frame hopefully will enhance the spatial coverage for the project. The first two frame's design can hold about 24 coral fragments (nubbins) whereas the present *Cores 3* can holds up to 70 coral fragments. A breakthrough of improved survival rates after the transplanted coral sources had been substitute using the "coral of opportunity" as a "seed" and increasing the size of each of the coral seed fragments to more than 10 cm length. Suitable site selection is an important factor in determining the success of the project. At the moment the genus from *Acropora spp.* and *Pocillopora spp.* are used for the coral transplant.

Keywords: climate change, coral reef restoration, marine protected areas, coral transplant.

Introduction

Malaysian coral reefs are mostly fringing type, and the country has more than 540 species of hard corals (Reef Revisited, 2012). Sipadan Island is an oceanic island of Malaysia encircled by corals. Although Malaysian sea waters could be about 566,285 km^2, at the moment only 9% of the country's coral reefs (**Fig. 1**) are protected through the establishment of marine protected areas of MPAs (CT Atlas.WorldFish, 2012).

Fig. 1. Malaysia's coral reefs

Moreover, considerable portion of Malaysia's live coral cover had been reported to be beaching. In an effort to address such concern, Malaysia had implemented since 1998 coral rehabilitation program (**Table 1**) in many locations shown in **Fig. 2**. There had been many cases of coral bleaching starting in 2010, such as in Renggis Island off west central Tioman in Pahang where coral bleacing was reported at depth of 12 m and temperature of 31°C (**Fig. 3**), and in Lima Island east of Redang, Terengganu at depth of 10 m and temperature of 30-32°C (**Fig. 4**).

Fig. 2. Locations of Malaysia's Coral Reef Rehabilitation Program

Table 1. Malaysia's Coral Reef Rehabilitation Program (1998-2014)

Year	Sites	Activities	Stakeholders	Status
1998	Sarawak	Installation of Reef Ball ARs	Sarawak Forestry Corporation	Conservation
2003	Semporna Island, Sabah	Coral transplantation	Islamic Financial Services Board	Commercial
2005	Sabah	Coral transplantation	Tropical Research and Conservation Centre	Semi-conservation
2006	Layang-Layang, Sabah	Coral transplantation	Department of Fisheries Malaysia (DOFM)	Conservation
2009	Gaya (off Kota Kinabalu)	Electrophoresis for DNA/RNA analysis	Gayana Eco Resort	Conservation
2011	Buhay Dulang, Sabah	Coral transplantation	DOFM/Sabah Park	Conservation
2011	Tioman, Pahang	Coral transplantation	Department of Marine Parks Malaysia (DMPM)	Conservation
2012	Perhentian, Terengganu	Coral transplantation	DMPM	Conservation
2014	Bidong, Terengganu	Coral transplantation	DOFM	Commercial

Also in 2010, coral bleaching was reported in Teluk Bakau, Redang Island (**Fig. 5**), and in Batu Malang, Tulai Island, Tioman, Pahang (**Fig. 6** and **Fig. 7**). In 2014, coral bleaching was observed in Pinang Island off Redang, Terengganu at 3-5 m deep waters and temperature of 31-32°C (**Fig. 8**).

Fig. 3. Coral bleaching in Renggis Island, off west central Tioman, Pahang, Malaysia

Fig. 4. Coral bleaching in Lima Island, east of Redang, Terengganu, Malaysia

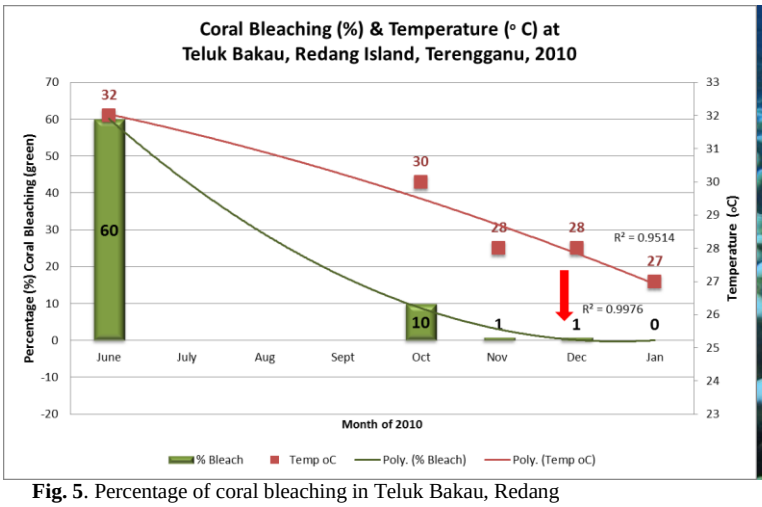

Fig. 5. Percentage of coral bleaching in Teluk Bakau, Redang Island, Terengganu, Malaysia

Fig. 6 Coral bleaching in Batu Malang, Tulai Island, northwest of Tioman, Pahang, Malaysia

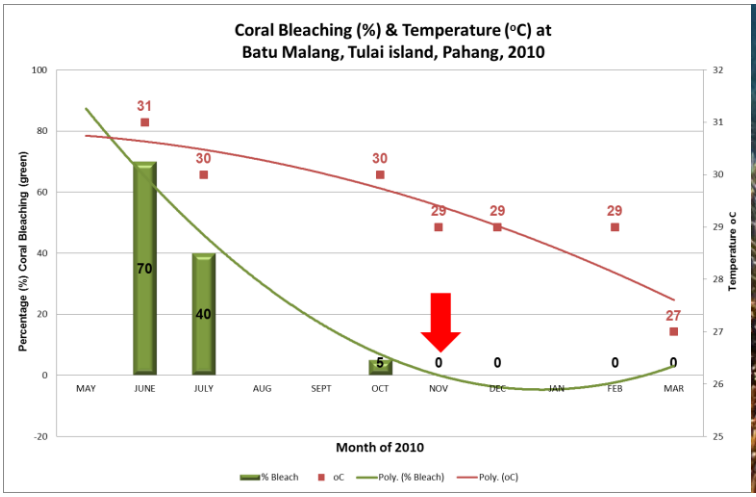

Fig. 7. Percentage of coral bleaching in Batu Malang, Tulai Island, northwest of Tioman, Pahang, Malaysia

Fig. 8. Coral bleaching in Pinang Island, off Redang, Terengganu, Malaysia

Analysis

Many factors threaten the health of coral reefs. These include climate change, pollution, habitat loss, invasive species, coral disease, and illegal fishing. It is therefore necessary to develop mitigation and adaptation measures as well as resilience. Efforts have been made by various agencies in Malaysia to restore its corals, such as coral transplantation carried out by DMPM (**Fig. 9**) in Tioman Island, Pahang (**Fig. 10**) which had achieved positive results (**Fig. 11**), and in Perhentian Island, Terengganu (**Fig. 12**).

Fig. 9. Coral transplantation carried out by DMPM in Tioman Island, Pahang, Malaysia

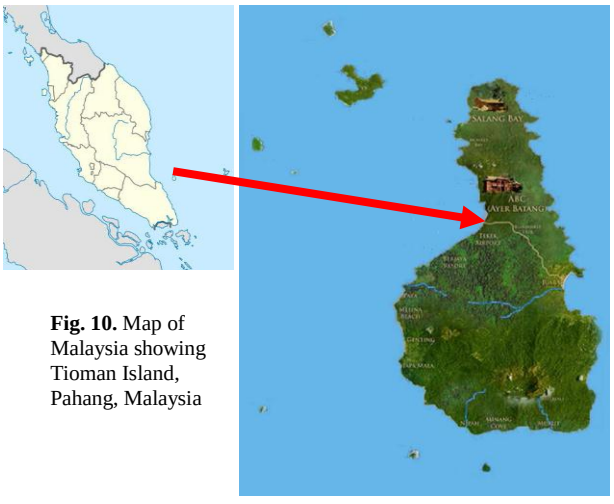

Fig. 10. Map of Malaysia showing Tioman Island, Pahang, Malaysia

Fig. 11. Development of transplanted corals in Tioman Island, Pahang, Malaysia

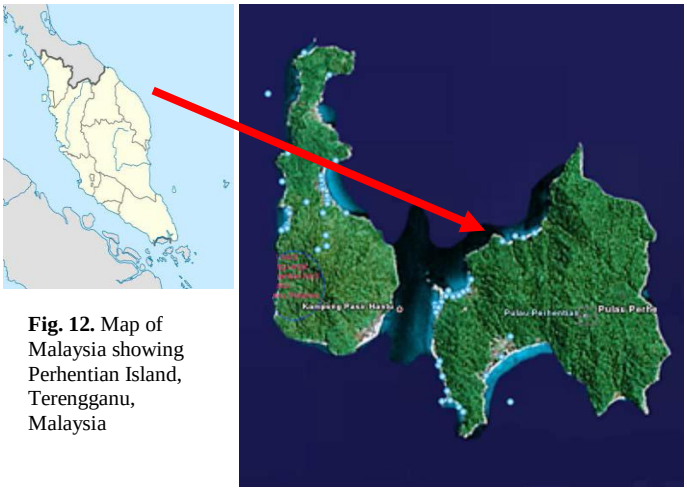

Fig. 12. Map of Malaysia showing Perhentian Island, Terengganu, Malaysia

Fig. 13. Development of transplanted corals in Perhentian Island, Terengganu, Malaysia

Lessons Learnt

Although the coral transplantation carried out by DMPM, there are lessons that should be shared for the benefit of countries that might embark on a similar activity. Firstly, the sites should have moderate current and unobtrusive sunlight. The fragments of corals to be transplanted must be more than 10 cm. In addition, sites should not be too close and adjacent to natural reefs. Finally, maintenance of the installations is necessary immediately after the transplantation.

Benefits of Coral Restoration

Many benefits could be gained from coral restoration through transplantation. These could include increased live coral cover, hastened recovery of target coral reefs, increased biodiversity, re-established ecological balance, stabilized surrounding environment.

Risks of Coral Restoration

While there are benefits from coral restoration, there could also be risks that come with it. As experienced by DMPM, the transplantation sites could be destroyed by freak weather, while infestation of predators could occur, *e.g.* oysters. High man-hour is needed for the maintenance of the installations. There could also be inadequate coral fragments that are available in nearby donor reefs. High mortality could also be encountered during the transplantation.

Concerns on Coral Restoration

Some concerns had been raised regarding coral restoration, which should be taken into account if countries intend to carry out such activity. These are: possible alteration of donor reef ecosystem especially is collection of fragments to be transplanted is unsustainable; could create false sense of hope among the stakeholders; transplanted corals could compete with local recruits; low diversity due to selective coral species transplanted; and could create unintentional species dominance with mono-species mix distribution.

Further Studies Needed

In order to demonstrate the viability of coral restoration, it is necessary that relevant studies should be conducted. These could include: fish population at restored coral reefs; other marine biotic populations on site; biodiversity abundance and species richness (for conservation purposes); choice of massive coral or non-branching species (for resilience purposes), among others. Moreover, it is also necessary to conduct capacity building of stakeholders on new handling methods of transplantation.

Habitat Conservation and Resources Enchancement in Seagrass Beds in Sriboya Island, Krabi Province, Thailand

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Abstract

The project on "Rehabilitation of Fisheries Resources and Habitat/Fishing Grounds through Resources Enhancement", has been undertaken by Southeast Asian Fisheries Development Center/Training Department (SEAFDEC/TD) since 2010 to identify appropriate resource enhancement tools, develop strategies and guidelines for resources enhancement for various types of aquatic habitats, and support capacity building for the ASEAN Member States in the implementation of their respective resource enhancement programs. The activities pursued with local communities in sites selected as critical fishing grounds in marine habitats, included conservation and rehabilitation measures that had been conducted. A deteriorated seagrass bed area in Sriboya Island, Krabi Province, Thailand was selected as one of the pilot sites to mitigate the depleted stocks of a species of an edible sea snail, the dog conch (*Strombus canarium*) which is commonly harvested by fishers and local communities by hand and/or labor-saving equipment as motorized boats, dredges and diving with air pump supply. However, such massive collection methods of harvesting easily led to drastic degradation of the seagrass bed habitats as well as deterioration of the dog conch population. TD therefore promoted the conservation and optimum utilization of dog conch through public awareness activities. The workshops on Andaman Sea Province Dog Conch Shell Resource Management Measures on August 2013 and 2014 in Krabi Province, Thailand, which was participated in by local stakeholders in Krabi and nearby provinces, led to an agreement and subsequent implementation of several management schemes, such as restrictions on dog conch harvestable size (<6 cm) and types of fishing gear (dredges), as well as banning the use of motorized boats. Furthermore, several types of media that support awareness building, such as posters, stickers, brochures and banners were produced and distributed to several provinces along the Andaman Sea coast. Through such activities, permanent dog conch conservation areas were established by local fishing communities at Sriboya Island in Krabi Province, and Muk Island in Trang Province. Demarcation of conservation areas at Sarai Island in Satun Province and some other areas had been proposed and under consideration by their respective local fishing community.

Keywords: seagrass bed, dog conch, *Strombus canarium*, resources enhancement, conservation areas

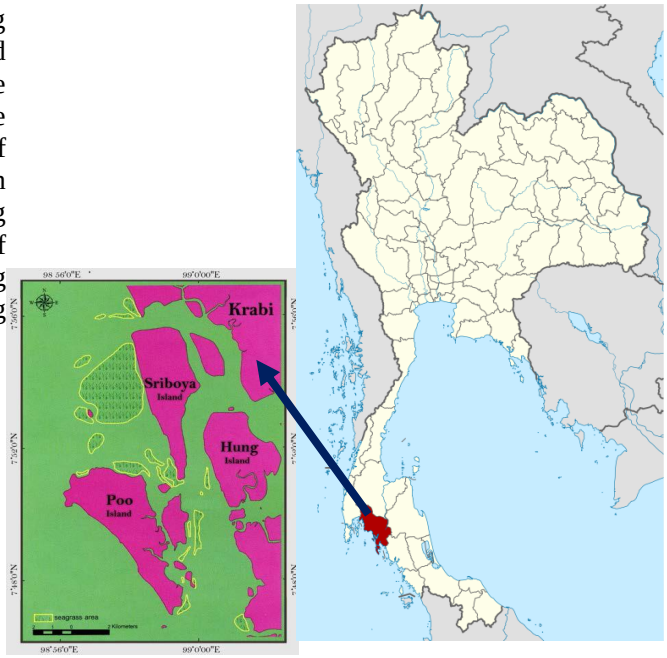
Introduction

Southeast Asian Fisheries Development Center/Training Department (SEAFDEC/TD) implemented the project on "Rehabilitation of Fisheries Resources and Habitat/Fishing Grounds through Resources Enhancement" since 2010 to identify appropriate resource enhancement tools, develop strategies and guidelines for resources enhancement in various types of aquatic habitats, and support capacity building for the ASEAN Member States (AMSs) on the implementation of their respective resource enhancement programs. Still ongoing, the project targets the local sites that had been diagnosed and selected as critical fishing grounds or marine habitats, for the implementation of conservation and rehabilitation measures.

During the project implementation, investigations of the current status of critical fishing grounds, *e.g*. sea grass beds, coral reefs, freshwater reservoirs, were carried out to determine those habitats that were found to be degraded, and where rehabilitation and conservation measures would be implemented. During the diagnostic phase of the project, it was found that the marine resources of Sriboya Island in Krabi Province of Thailand are already in the state of degradation and thus, such resources need to be conserved. Moreover, it was also observed that Sriboya Island hosts the natural stocks of the sea snail or dog conch (*Strombus canarium*). Sriboya Island was therefore selected as one of the pilot sites to mitigate the state of depletion of the stocks of such economically important species, considering that wild stocks of dog conch had been abundant in the Island and commonly harvested by fishers and local communities by hand and/or using labor-saving equipment such as motorized boats, dredges and by diving using air pump-supplied equipment.

Such massive methods of collecting the dog conch in the sea grass beds of Sriboya Island had become uncontrollable affecting the marine habitats, not only degrading the condition of the sea grass beds but also depleting the stocks of dog conch which had been abundantly thriving in the sea grass beds. Such irresponsible harvesting also decreased the size as well as the number of dog conch living in the sea grass beds, affecting the local communities that depend on the dog conch for their livelihood.

Dog conch (*Strombus canarium*)



Map of Thailand showing Krabi Province and Sriboya Island

Activities

- 1st preliminary study survey on the seagrass beds site for resources enhancement was conducted in Sriboya Island, Krabi Province, Andaman Sea, Thailand (21-26 March 2011)
- Follow-up survey and investigation on fish species compositions using juvenile fish traps, trammel net, collapsible crab trap and hand-held push net operations (July and November 2011)
- Seed releasing of dog conch was simultaneously conducted in the selected site, where two rearing cages were constructed and dog conch were released to study their surviv al and growth rates
- Fish composition survey using trammel nets, collapsible traps, juvenile fish traps and a hand-held push net completed in April 2012
- Discussion with stakeholders on area demarcation for conservation of the dog conch; dog conch seeds prepared for release
- Demarcation of conservation area as agreed by local fishers' community for the dog conch successfully done in August 2012
- Marked buoys installed in the conservation area of 25 rai (200x200 m2 or 4 ha)
- 30,000 seeds of dog conch were released in the demarcated area by local fishers and officers concerned
- 1st and 2nd Local seminar on Dog Conch Resource Management organized and attended by 70 participants representing stakeholders from the Andaman Sea areas, Department of Fisheries of Thailand and SEAFDEC/TD on August 2013 and 2014, respectively, in Krabi Province, Thailand
- Dog conch conservation campaign posters, brochures, stickers and banners were distributed for public awareness
- 2 permanent dog conch conservation areas sign boards were established by local fishing community in Sriboya Island, Krabi Province in October 2014

Fabrication of dog conch rearing cages (*above*) and releasing of dog conch seeds (*right*)

Results

During the workshops on Andaman Sea Province Dog Conch Shell Resource Management Measures in Krabi Province, Thailand in 2013 and 2014, an agreement was reached and subsequent implementation of several management schemes, such as restrictions on dog conch harvestable size (<6 cm) and types of Specifically, the workshops agreed to ban the harvesting of under-sized dog conch (< 6 cm); only hand collecting of the dog conch is allowed; using dredges or trawl net, push net with or without motorized boat is prohibited; and diving by air supplied equipment or tanks to collect the dog conch is also prohibited. Furthermore, declaration was made to promote conservation area for dog conch shell for each area; dog conch conservation zone in sea grass beds area were proposed for all Andaman Sea Provinces; leading to the establishment of permanent dog conch conservation areas by the local fishing communities such as those in Sriboya Island in Krabi Province, and Muk Island in Trang Province while in some areas demarcation of conservation areas had been promoted such as those in Sarai Island in Satun Province. Some other areas had also been proposed as conservation areas but these are still under consideration by their respective local fishing communities.

fishing gear (dredges), as well as banning the use of motorized boats. In addition, several types of media that support awareness building, such as posters, stickers, brochures and banners were produced and distributed to several provinces along the Andaman Sea coast.

Banner on dog conch conservation (*left*), juveniles (*center*) and broodstock (*right)* of dog conch for release

Constraints Encountered during Implementation of Activities

- Local communities not very much aware on the importance of resources management
- Limited/lack of participation of fishery users of various levels of decision-making
- Insufficient budget to implement the activities by local fishing communities
- Limited dog conch seeds collected for release
- Inadequate data on dog conch catch and sale records to be able to understand the trend and indicators for successful implementation and planning in the future
- Need to monitor and follow-up the activities, for evaluation purposes

Lessons Learnt

The pilot site seagrass beds in Sriboya Island showcases the achievements and lessons learned in the management of seagrass beds as well as protection of breeding/spawning areas through the establishment of dog conch and seagrass beds conservation areas. A successful coastal zone management requires the participation of multi-stakeholders, local communities, government authorities, NGOs, scientists or researchers, and investors. All the parties should have the chance to express and present their opinions as well as exchange experiences, when discussing the needs and problems; while scientists or researchers could provide their expertise in formulating the management plans. Similar activities could be carried out to expand the initiative to other provinces in Andaman Sea.

Conclusion and Recommendations

In view of the current situation of the marine resources in Sriboya Island, it is recommended that the sea grass bed areas and dog conch stocks should be conserved and managed through the following measures:

- Promotion of a collaborative working mechanism between the government sector and local communities who directly utilize the resources in the sea grass beds;
- Increasing the awareness of stakeholders on the need to protect and conserve the sea grass areas including the marine resources inhabiting these areas;
- Conducting research and enhance knowledge of stakeholders on sea grass restoration as well as disseminate the information to local communities
- Prohibiting the use of some fishing gears that destroy the sea grass beds such as trawl nets, seine nets, dredges and the massive harvesting by diving with air pump-supplied equipment, and promoting the use of small fishing gears for fishery in sea grass beds
- Enhancing the knowledge of stakeholders on the benefits and importance of sea grass ecosystem as habitats for the economically-important species such as dog conch through mass media specifying various aspects, *i.e.* as nursery ground, shelter and feeding habitats of marine fauna
- Conducting seminars on sea grass and dog conch conservation targeting fishers and local communities that exploit the resources in sea grass beds

Finally, for the sustainability of dog conch fishery in Sriboya Island, it is necessary that a national master plan should be developed for sea grass management to be used as conservation framework for government agencies and communities. In order to facilitate the implementation of such master plan, the local people exploiting the dog conch stocks in Sriboya Island should be organized into an association to ensure that the fishing grounds are protected and conserved. The association should be given a free-hand to develop their regulations on dog conch fishery in Sriboya Island based on the abovementioned resource enhancement measures in order that the degraded sea grass of Sriboya Island could be revived and the dog conch stocks are made to recover for the benefit of the local communities that depend on these resource for their livelihood.

Seagrass Bed Restoration by Fishermen at Hinase in Japan

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Abstract

Habitat rehabilitation which is very important for fishery resources enhancement should be conducted following the community-based management and ecosystem-based management. In Japan, the *Satoumi* concept is introduced as one of integrated coastal management concepts for habitat rehabilitation. Fishermen at Hinase Fishermen Union in Japan began the eelgrass bed restoration activity in 1985, when the area of eelgrass bed decreased to 80 ha from 590 ha in 1945, and have continued such activity until now. The area of eelgrass bed recovered 200 ha and fish catch by set net also recovered in 2011. The fishers' group began the oyster culture in the same fishery ground around 1985. Together with the expansion of eelgrass bed, the harvest of oysters had increased because the eelgrass bed and oyster culture have the win-win relation, that is, the oyster culture helps the expansion of eelgrass bed by the assimilation of detritus and increase sun light transmittance depth, and the eelgrass bed helped decrease the mortality of cultured oysters in summer by lowering water temperature in the water column. Moreover the Hinase Fishermen Union plans to establish a fish farm by combining eelgrass bed, oyster culture in rafts and artificial reefs arrangement, that is, the spawned local fish grows in the designated farming area using eelgrass bed, oyster raft and artificial reef, resulting in increased fish harvest.

Keywords: eelgrass bed, oyster culture, fish farm

Activities

Seagrass bed restoration was carried out in Hinase of Seto Inland Sea, Japan. This activity was aimed at enhancing the already degraded eelgrass bed which had decreased from 590 ha in 1945 to 82 ha in 1965, and then to 12 ha in 1985. Many factors have led to such deterioration, which included occurrence of typhoon; turbidity of the water due to human activities on land as well as in rivers and coasts; chemicals from farms in land. As a result, fish catch from set net had also decreased.

Results

In order to enhance the status of eelgrass in Hinase, concerned fishers started the restoration activity in 1865, which was continued for 30 years. In 2011, the eelgrass bed was found to increase to 200 ha, about 1/3 that of 1945. As a consequence, catch from set net had also increased.

In the restored eelgrass bed, oyster culture was started in 1963 which had expanded in 1980s. From such activity, the fishers are able to produce the famous Okayama Oyster brand starting in 1996.

There exists a win-win relationship between oyster culture and eelgrass bed. While the eelgrass facilitates decrease in water temperature (from leaves of eelgrass) this has led to decreased mortalities of the oysters.

Moreover, the attached diatoms and small animals on leaves of eelgrass also contributed to increased growth rate of the oysters.

Eelgrass bed is known to have many functions. It serves as nursery of juveniles especially rock fishes; decreases water temperature from shading effect of eelgrass leaves; promotes water purification due to assimilation of nutrients through the eelgrass roots; produces oxygen and decreases CO_2 emission from photosynthesis; provides food for fishes from diatoms, polycheates, and other small animals that attach on eelgrass leaves; and facilitates distribution of nutrients. Due to the slow decomposition property of eelgrass, there is no pollution from the water of origin.

In May 2012, the Agreement for Hinase Fisheries was forged by concerned stakeholders, such as the Fishermen's Union, Okayama Prefecture, Okayama COOP, and Research Institute for Sato-umi Creation. The agreements included provision on the adoption of integrated coastal management based on the Sato-umi concept. As a new concept for coastal area management, Sato-umi aims to create a coastal sea with high biodiversity and productivity under human interaction. There are now 12 areas in Japan that have been created by Japanese fishers following the Sato-umi concept.

Theme 2
Fishery Resources Enhancement through Artificial Propagation and Stock Release

Similar to Theme 1, **Theme 2** had also been arranged into three (3) sessions, namely: **Session 4**: Stock Enhancement and Restocking: Potentials and Limitations; **Session 5**: Release Strategies and Ecological Interaction with Natural Stocks; and **Session 6**: Aquaculture-based Enhancement and Restoration.

Introductory Paper

An introduction of **Theme 2** was provided by *Dr. Ma. Junemie Hazel Lebata-Ramos* through the paper on **Fishery Resource Enhancement: An Overview of the Current Situation and Issues in the Southeast Asian Region**. While illustrating that in the global fisheries production aquaculture production has been growing since 2013 overtaking capture fisheries production, Dr Lebata-Ramos also highlighted the condition of the world's fishery resources which had been over-exploited and that the fishery resources would be seriously depleted if the trend of exploitation continues. Dr. Lebata-Ramos also outlined the main objectives of stock enhancement activities, which among others are to increase/enhance stock, increase food supply, protect endemic species, maintain endangered species, rehabilitate degraded habitat, as well as promote aquaculture.

While providing a brief elaboration of the resources enhancement activities undertaken in each Southeast Asian country, Dr. Lebata-Ramos pointed out some of the issues on resource enhancement in the region. These include among others, insufficient baseline data/survey, inaccessibility of good quality seeds, undetermined release seed size/age, releases of exotic species that eventually become invasive species affecting the biodiversity, difficulty in maintaining genetic diversity, and insufficient budget for stock release.

In updating the information provided by Dr. Lebata-Ramos, the representative from Thailand shared the information that the DOF of Thailand has also been undertaking stock enhancement for the tiger shrimp (*Penaeus monodon)* and giant freshwater prawns (*Macrobrachium* spp.) in Songkhla Lake. In addition, research on stock enhancement of some species of marine mollusks had also been conducted by the DOF of Thailand. Meanwhile, the representative from the Philippines added that silver carps, bighead carps and common carps are the main species used for stock enhancement in the Philippines carried out by BFAR, since stock enhancement of barbs had not been very successful.

Moreover, the representative from the Philippines cited that although releasing of exotic species for stock enhancement could possibly contribute to resource enhancement, accidental releasing, especially ornamental fish species, into the wild that become invasive species should be avoided. Releasing of stocks into the wild should therefore be carried out in accordance with the Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms.

Fishery Resource Enhancement: An Overview of the Current Situation and Issues in the Southeast Asian Region

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Abstract

The total global production from capture fisheries has plateaued since the mid 90s. This stagnation in production or reduced productivity of the world's coastal and marine wild fisheries is caused by overfishing and degradation of habitats through coastal development and destructive fishing methods. Reports have shown that if the current fishing trends continue, all of the commercial fisheries will have collapsed by 2050. To boost production, scientists, fisheries managers, government agencies, and NGOs have been looking at ways of enhancing fish stocks. Replenishing depleted stocks may be done by regulating fishing effort, restoring degraded nursery and spawning habitats or through resource enhancement. Resource enhancement using individuals reared in aquaculture facilities or seed stocks abundant in the wild is becoming a popular method of supplementing depleted stocks. It is one of the many strategies that could help address the decreasing fisheries production in the wild. A brief history of resource enhancement, the aquatic species released in the different countries in the region, the reasons for releasing stocks, and the issues involved, are discussed briefly in this paper. Among the main reasons for resource enhancement are to increase production or enhance stocks and increase food supply and/or family income. Other reasons include protection of endemic and maintenance of endangered species, rehabilitation of degraded natural habitats and for recreation fisheries, among others. Age or size of seeds, seed quality, genetics, governance, economics, biodiversity conservation, politics, and the introduction of exotics are among the resource enhancement issues identified in the region.

Keywords: Resource enhancement, Southeast Asia, species released, status, issues

Introduction

Southeast Asia has a total coastline of 105,070 km, almost 30% of the total coastline of all the countries in the world. The coastal zones of Southeast Asian countries are endowed with some of the world's richest ecosystems, in terms of both biodiversity and productivity. About one-third of the world's coral reefs and a quarter of the world's mangroves are found in this region. Consequently, the center of marine biodiversity is also located in the region, specifically in the Philippines (Carpenter and Springer, 2005). It is not surprising, therefore, that fisheries constitute the largest and the most important renewable resources in the area.

Fish remains the most important source of protein for Southeast Asians with10.2-54.8% of their protein needs sourced from fish. The per capita fish consumption ranges from 14 to 35 kg. Such dependence on fish as the main protein source for 593 million population with an average annual growth rate of 1.33 (based on 2010 data; Jones, 2013) creates high demand for fishery products, locally and regionally. Overgrowing concern on overexploitation of fish stocks emanate from high harvest of fish in the wild keeping the global trend for marine capture fisheries on a steady state since mid 90s. Global trends in the state of marine fish stocks showed that since 1974, the number of overexploited stocks grew from 10 to 30% in 2009 and the opposite trend was observed with the non-fully exploited fish stocks (FAO, 2010).

Resource enhancement using individuals reared in aquaculture facilities is becoming a popular method of supplementing depleted stocks (Bert *et al*., 2003). However, according to Bell and Nash (2004), the capability to produce and release juveniles from aquaculture facilities is not enough reason to conduct resource enhancement. Success in resource enhancement depends on knowing enough about the ecology of the species, its nursery habitat, and the survival of cultured juveniles in the wild (Bell *et al*., 2005). This means gathering information about the population of the species concerned and its habitat prior to any attempts on resource enhancement. It has been stressed by Gulland and Carroz (1968) that the essential basis of any management is proper biological understanding of the status of stocks concerned and emphasized that proper management requires good scientific knowledge based on adequate data.

Blaxter (2000) further added appropriate size-at-release, season of release and area for release as keys to stock enhancement success. To ensure success, 10 components of a responsible approach to developing, evaluating and managing marine stock enhancement programs have been prescribed by Blankenship and Leber (1995). An evaluation of the different strategies applied by Southeast Asian countries in managing resources to address the declining fish stocks in the wild were examined from available published materials.

Activities/Results

Table 1 shows some of the reasons why resource enhancement is being done in Southeast Asia. Early stock enhancement activities focused on increasing the supply of fish in inland water bodies known to be fishing grounds for the communities. With the exception of countries that practiced fish release ceremonies as part of their traditional religious practices, resource enhancement in the form of fish stocking activities was done as early as 1912 during the Dutch occupation in Indonesia (Maskur, 2010). The main purpose of stocking in those early times was to increase the population and diversification of fish species in the wild. Other countries such as Thailand, Philippines, Myanmar, and Malaysia conducted fish stocking activities in much later years in 1950, 1961, 1967, and 1970, respectively. Fish stocking was considered as a major input in increasing and sustaining fish yields in these Indo-Pacific areas (Sreenivasan, 1989). Fish species commonly used for stocking were catfish, tilapia and various species of carps. Species used in stocking include both exotic and indigenous species (**Table 2**). No biological assessments were conducted prior and after fish release. Its impact on the diversity of the fish species in the environment where the stocks were release was not assessed and success was merely based on increase in the volume of fish harvested after stocking activities.

Table 1. Reasons for conducting resource enhancement in Southeast Asian countries

Reasons for Resource Enhancement	Bru	Cam	Ind	Lao	Mal	Mya	Phi	Sin	Tha	Vie
Population/production	✔		✔	✔	✔	✔	✔		✔	✔
Food supply/income		✔				✔			✔	
Endemic species			✔							
Endangered species			✔			✔	✔			
Degraded natural habitats		✔	✔		✔	✔		✔	✔	✔
Spawning and feeding grounds		✔	✔			✔			✔	✔
Fish sanctuaries		✔	✔			✔	✔		✔	
Biological control		✔					✔			
Promote aquaculture		✔								
Recreational fisheries					✔					

Inland fishery resources for enhancement were given wider attention compared with marine fishery resources (**Table 2**) as manifested by the number of reports, as well as proceedings available on this subject. Pioneer works on mollusks and perhaps on stock enhancement in the Pacific and Southeast Asia was on the conservation of the endangered tridacnid clams (Yamaguchi, 1995). Earlier than that, marine conservation works were focused on rehabilitating degraded reefs and establishment of marine protected areas. Starting in the late 1970s, artificial reefs were employed and the effective of use of fish aggregating devices were tested all over Southeast Asia.

Successful development of breeding techniques on *Macrobrachium rosenbergii* in the late 1980s made it the only freshwater crustacean species used for resource enhancement in different areas of Southeast Asia. Prawn larvae were usually provided by the fishery agencies of the governments. Release of prawn larvae in reservoirs and river systems were considered successful despite the lack of data on the increments on their harvest as a result of the stocking activities. More marine species were considered for conservation and natural resource enhancement lately when depleted fish stocks in the world's oceans became more evident.

Table 2. Freshwater and marine species released in Southeast Asia for resource enhancement

Species Released for Resource Enhancement	Bru	Cam	Ind	Lao	Mal	Mya	Phi	Sin	Tha	Vie
FRESHWATER										
Barbs										
Barbonymus gonionotus		☐	☐	☐	☐		☐		☐	
Puntius orphoides					☐	☐				
Carps										
Aristichthys nobilis									☐	
Catla catla						☐				
Cirrhinus cirrhosus				☐		☐				
Cirrhinus molitorella					☐				☐	
Ctenopharyngodon idella					☐	☐			☐	
Cyprinus carpio			☐		☐	☐	☐		☐	
Cyprinus mrigala									☐	
Hypophthalmichthys nobilis				☐	☐					☐
Hypophthalmichthys molitrix					☐	☐			☐	☐
Catfish										
Clarias batrachus			☐							
Pangasianodon gigas									☐	
Cyprinid – *Barbonymus altus*		☐								
Goby - *Oxyeleotris marmoratus*					☐					
Gourami										
Helostoma temminckii					☐					
Osphronemus gouramy					☐					
Trichogaster pectoralis		☐	☐		☐					
Rohu – *Labeo rohita*				☐		☐				
Iridescent shark – *Pangasianodon hypophthalmus*		☐				☐				
Tilapias										
Oreochromis mossambicus			☐		☐	☐	☐			
Oreochromis niloticus			☐	☐	☐	☐	☐		☐	
Giant freshwater prawn – *Macrobrachium rosenbergii*	☐								☐	
MARINE										
Fish										
Lates calcarifer								☐		
Sea horses							☐			
Crustaceans										
Charybdis			☐							
Portunus		☐	☐							
*Scylla*spp.			☐				☐			
Penaeus merguiensis								☐		
Penaeus monodon							☐			
Mollusks										
Chicoreus ramosus									☐	
Haliotis asinina							☐			
Trochus niloticus			☐				☐			☐
Placuna placenta							☐			
Tridacnids							☐		☐	
Echinoderms										
Holothuria scabra							☐			
Sea urchins							☐			

Lessons Learnt

Major enhancement activities were mostly linked or associated with government initiatives and were purposely done to increase production in a particular area with the aim of increased harvest for fishers. Success or failure was based only on the volume of the stocked species during harvest. Enhancement activities in marine environment were access is open to all users were mostly limited to habitat enhancement and regulation of catch. Resource enhancement activities involving the release of fish in such environments were best done in sanctuaries or marine protected areas where access or entry is controlled.

Poaching is a major problem if stocking activities were done outside these areas. Most reported release activities were done on small-scale or experimental scale. The knowledge on propagating seeds of highly exploited marine organisms for stocking purposes remained a wide gap to fill in. A common limitation in government funded resource enhancement project is the limited budget. Long term monitoring or assessment of the impacts of these activities is mostly overlooked. Political matters sometimes interfere in the proper implementation of the project that may be brought by limited understanding and appreciation of policy makers on resource enhancement and conservation of aquatic resources.

Recommendations and Way Forward

A resource enhancement protocol developed for a particular area, in a particular ecosystem and for a particular purpose is ideal. Decisions to take up resource enhancement as a programme could be better implemented if supported by accurate and reliable fishery statistics data on species composition, density and production in a particular aquatic system over a reasonable period of time. Release strategies for various species used for resource enhancement should be determined to establish stocking protocols in order to ensure higher probability of success of the released stocks. The issue on the preference for non- native species over native species for resource enhancement on a heavily utilized fishery area with the purpose of increasing economic benefits from fishing should be carefully evaluated.

Arthur *et al*. (2010) showed that stocking of non-native fish species in wetlands significantly increased total fish biomass and does not affect the biomass of the native species. If profitability or economic benefits is the factor used to measure success of an enhancement activity, an investment cost of resource enhancement and estimate of returns should be considered to evaluate completely the economic benefits derived from resource enhancement. In order to maintain environmental integrity and the genetic integrity of the population, a long term monitoring of the impact of enhancement activities should be included in most plans.

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Session Papers
Session 4: Stock Enhancement and Restocking - Potentials and Limitations

With the Chief of SEAFDEC Aquaculture Department (SEAFDEC/AQD) *Dr. Felix G. Ayson* as the Facilitator, the Session discussed the issues and constraints in stock enhancement through four presentations, namely: (1) Community-based Stock Enhancement of Abalone, *Haliotis asinina* in Sagay Marine Reserve: Achievements, Limitations and Directions by *Dr. Nerissa D. Salayo*; (2) Potentials and Limitations of Stock Enhancement Programs in Japan by *Dr. Tetsuo Fujii*; (3) Success of Fish Stock Enhancement and Restocking in Inland Waters of Indonesia by *Dr. Endi Setiadi Kartamihardja*; and (4) Current Status of Fish Stock Enhancement in Thailand by *Dr. Suchart Ingthamjitr*.

The progress of the project on community-based stock enhancement of abalone, *Haliotis asinina* in Sagay Marine Reserve in Negros Occidental (central Philippines) was presented by ***Dr. Nerissa D. Salayo***, who explained that this project had been conducted through tri-party collaboration among concerned fishers, local government units and SEAFDEC/AQD. In the process of the project implementation, the activities undertaken included social baseline surveys and establishment of a community-based stock enhancement demo-site accessible to and replicable by the fishers. Through the involvement with strong engagement of the stakeholders, the communities agreed in 2010 to regulate the catch size at of abalone at 6 cm. The involvement of the communities had also helped in the successful implementation of activities that deal with stock enhancing and restocking.

During the discussion, Dr. Salayo clarified that the appropriate release size should have been 2.5-3.5 cm based on research results, but stocking bigger juveniles would entail higher investments in hatchery rearing. Dr. Salayo added that sincere collaboration is necessary to enhance the participation of stakeholders which could lead to successful project implementation. In order to enhance the sharing of responsibilities in stock management, Dr. Salayo emphasized the need to maintain camaraderie with the stakeholders, establish a good working team, conduct of regular consultations with stakeholders and occasional meetings with concerned local government units, and intensification of information, education and communication (IEC) activities, among others. As for the exit strategy and to enable the stakeholders to sustain in project, Dr. Salayo added that giving the stakeholders thorough independence is important, especially in carrying out the management responsibilities and also to make them recognize and take up ownership of the project. Equal sharing of proceeds from the project is also important for the livelihoods of the stakeholders. For example, in the case of the community-based stock enhancement of abalone, the fisherfolk organization developed their own sharing scheme, so that 30% of the proceeds go to the fisherfolk organization; 30% to the fisherfolk (to be equally shared); 30% to the administration of Sagay Marine Reserve; and the remaining 10% to fund other operating expenses.

The potentials and limitations of stock enhancement based on the experience of Japan were elucidated by ***Dr. Tetsuo Fujii***, who also explained the several stock enhancement programs in Japan carried out during the last fifty years that aim for cost-effectiveness and stocking efficiency. To date, seeds of about 85 species of fish, mollusks, crustaceans and other aquatic organisms have been released for the purpose of stock enhancement. These include the chum salmon (*Oncorhynchus keta)* and barfin flounder (*Verasper moseri)* in northern Japan, red sea bream (*Pagrus major)* in central and western Japan, and Spanish mackerel or sawara (*Scomberomorus niphonius)* in Seto Inland Sea, the largest inland sea in Japan. Dr. Fujii explained that there are protocols to be considered in stock release. First is **diagnosis** for stock assessment which includes investigation of the ecology of target species considering that there is no need to release seeds if the natural stock is abundant; and investigations of the environment of nursery grounds as a prerequisite for effective seed release. Second is **planning** of the stock strategy (when, where, how, how many) and checking the quality of seeds for stocking (size, shape). Third is **establishing cooperation** with concerned fisherfolk for the fisheries management, habitat improvement and/or rehabilitation.

Dr. Fujii continued that the fourth protocol is **monitoring** the market of target species through market survey taking into consideration the yield per release (YPR), **and evaluating** the impacts of stocking. Last is **implementing** the most efficient stocking strategy based on the results of the protocols considered.

During the discussion, Dr. Fujii mentioned that although over-fishing could sometimes result in high "recapture rate" of the released fish, it is neither economically effective nor sustainable, thus, a suitable fisheries management would be necessary. In addition, the carrying capacity of the nursery grounds also restricts the allowable number of released seeds. In the case of *hirame* or the Japanese flounder (*Paralichthys olivaceus)*, the number of release seeds tends to be higher in northern Japan than in south-western areas. To evaluate stocking efficiency, the YPR which is equal to the weight of landed "recaptured fish" divided by the number of released seeds, should be determined. In this case, the YPR for successful cases should be more than 50 metric tons per 1.0 million seeds stocked. Nevertheless, since increased production often results in decline of price, Dr. Fujii therefore suggested that socio-economic studies which are important should also be carried out.

A brief history of stock enhancement and restocking of fish in inland waters of Indonesia since 1990s was presented by ***Dr. Endi Setiadi Kartamihardja***. He cited that with scientific support, the Indonesia's stock enhancement activities include determining the bio-limnological characteristics of the release sites, development of fisheries co-management approach, and making use of local wisdom or knowledge. Dr. Endi added that stock enhancement and culture-based fisheries are considered options to optimize the utilization of inland waters for producing fish, ensuring food security, creating additional income, and promoting human welfare. However, he suggested that governments should also support and take active part in the activities by providing local fish seeds for restocking purposes.

During the discussion, it was recommended that parameters on nutrition of fish feeds should be considered to support the promotion of food security while policy support on stock enhancement should be sought. Dr. Endi therefore explained that in Indonesia, many agencies are involved in restocking programs in inland waters such as the Research Institute for Inland Water Fisheries in Palembang; Research Institute for Stock Enhancement in Java; and the SEAFDEC Inland Fishery Resources Development and Management Department in Palembang. Thus, a number of research activities on stock enhancement in inland waters have been undertaken in Indonesia that could address the various technical concerns on and management of the released stocks.

Capping off Session 4, ***Dr. Suchart Ingthamjitr*** emphasized that fisheries stock enhancement could be achieved through combined strategies on law enforcement, habitat rehabilitation and stocking program. Like in most Southeast Asian countries, several agencies of Thailand are also involved in the country's stocking programs such as the Department of Fisheries (DOF), local administration organizations, provincial agencies, the Electricity Generating Authority of Thailand and other private sector, and government agencies. For DOF, several projects had been implemented that focused on aquatic animal stocking. While providing examples of successful cases in restocking, Dr. Suchart pointed out that the achievements of restocking efforts would depend on the participation of local communities which is a core aspect in fisheries management.

In the discussion, Dr. Suchart cited that the new Management Strategies of Thailand had been approved for adoption starting in 2015. It is an important tool that could be used to manage the sustainable production from fisheries and maintain fish diversity, as well as means to enforce relevant laws and regulations to combat illegal fishing in country. Dr. Suchart mentioned that in Thailand, this approach could be effective in enforcing control measures as determined from the catch although production could vary depending on the environments. He added that while production trend would tend to increase after the introduction of the new Management Strategies, this could be a good indicator of the effectiveness of such management measure. As for the economic returns from giant freshwater prawn culture, Dr. Suchart explained that positive returns could be gained from restocking than natural reproduction taking into account the life cycle of the giant freshwater prawn. Regarding the restocking of giant freshwater prawn in enclosed water bodies, 2-3 cm seeds have been used. Population of the stocks could be easily controlled since there are no recruitments as the prawns cannot reproduce in freshwater environments and could not migrate. As for the recapture rate, Dr. Suchart mentioned that this would vary depending on various factors such as the size at stocking.

Community-based Stock Enhancement of Abalone, *Haliotis asinina* in Sagay Marine Reserve: Achievements, Limitations and Directions

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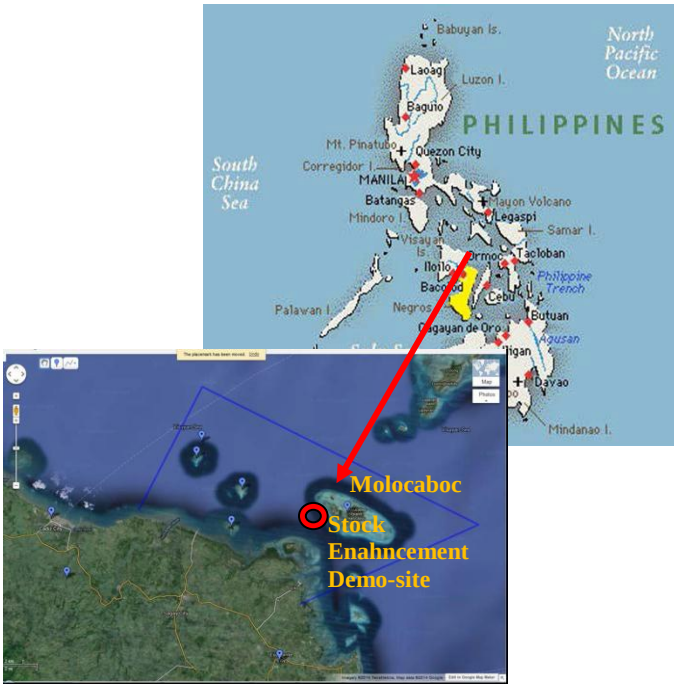
Abstract

The Sagay Marine Reserve (SMR) under the National Integrated Protected Area System (NIPAS) is one of the many reef areas in the Visayan Sea in the central part of the Philippine archipelago. The SMR covers 32,000 ha or 59% of coastal waters north of the mainland Sagay City. Donkey's ear abalone is one of the most sought mollusks traded by small-scale fishers in Molocaboc Island located within the SMR. High buying prices in local and international markets compared with other fish catch motivated fishers to target abalone and caused its overfishing. SEAFDEC/AQD, with support from the Government of Japan Trust Fund (JTF), conducted a community-based stock enhancement through a tri-party collaboration between the fisherfolks of Molocaboc Island, the Sagay local government at the village and city levels, and SEAFDEC/AQD. The study showed that the decision and implementation of stock enhancement and the definition of its objectives and relevance involves the strong engagement with stakeholders. For over a period of eight years (2007-2014), we learned that stock enhancement necessarily involve high financial investments and enormous transaction cost over a long period of time which are often not affordable to local governments of coastal communities in Southeast Asia. Thus, community-based collaborations may help achieve enhancement and restocking goals.

Introduction

Under the JTF Program, SEAFDEC/AQD pursued a collaborative project on stock enhancement (SE) of threatened species in SMR. SE initiatives showed that while releases have the potential to yield substantial benefits, the actual outcomes, in terms of yields, distribution of benefits and institutional sustainability, are often different from those initially expected. These were attributed to the complexity of the environments into which enhancements is introduced, involving the dynamic interactions between the 1) biological characteristics of the resource, 2) the technical intervention of enhancement, and crucially, 3) the people who use and manage it (Garaway, *et al*. 2006; Bell, *et al*. 2006). The involvement of people as a major factor affecting SE outcomes distinguishes SE from aquaculture (Garaway, *et al*. 2006). Thus, this study explored some community-based fisheries management options following the updated responsible approach to SE (Lorenzen, *et al*. 2010) to sustain enhanced abalone stocks.



Activities and Results

Socioeconomic Baseline Survey

The study was started in 2007 by conducting some social preparation measures for stakeholders to facilitate the implementation of community-based SE (Salayo, *et al*. 2015). For a start, a socioeconomic baseline assessment survey of the primary stakeholders was conducted in February 2007 to determine level of awareness, capacity and training needs of stakeholders who will collaborate and implement a community-based SE. The survey of fishery stakeholders in Sagay showed low levels of awareness as only 17% of the respondents reported being aware about SE as a fisheries management option for reversing the depletion of threatened species. Fishers also reported that similar with most fish species, the catch of abalone continue to decline from 5 kg per 4-hour fishing trip before 1995 to only 1 kg during the 2007 survey. Hence, fishing households expect to directly benefit from SE projects through improved catch and higher income.

Establishment of Collaboration

Social preparation measures also include establishing collaboration with fishery stakeholders in SMR such as fishers and their households as primary stakeholders, local government units (LGU) who are law-mandated to manage coastal fisheries (Republic Act 8550), traders who significantly influence fish markets, and research/academic institutions such as SEAFDEC/AQD that can introduce science-based interventions through resource enhancement. There is no active fisherfolk organization in the study site when the SE project started in 2007. Thus, after conducting relevant IEC activities, about 60 fisherfolks signed up to be members of the Molocaboc Barangay Fisheries and Aquatic Resources Management Council (BFARMC) in November 2009 in accordance with the Fisheries Administrative Order 196 of the Bureau of Fisheries and Aquatic Resources (BFAR). The stakeholders agreed to form a tri-party collaboration to identify, implement and assess strategies for managing enhanced stocks of abalone. The tri-party collaborators include: (1) the fishers organized as BFARMC who participate mainly by protecting the enhanced stocks; (2) the LGU provide oversight through its Protected Area Management Board of Sagay Marine Reserve (PAMB-SMR) and together with abalone traders who provide logistical support; and (3) SEAFDEC/AQD that provide technical expertise in the biological and social aspects of SE.

Information Dissemination

Guided by the outcomes of the baseline survey, periodic information, education and communications strategies (IEC) were conducted. On-site lectures on the biology, life-cycle and aquaculture-based production of abalone juvenile were among the first IEC activities held. IEC is a continuing activity throughout the duration of the project and their content aims to address the varying needs and issues arising in the implementation of the project. For example, lectures for school children were periodically conducted since children often glean for abalone and other species during low tide to obtain food and supplement household income. The project also participates in the local *Sinigayan Festival* to improve awareness and cooperation in abalone SE.

Demonstration of Community-Based Stock Enhancement

This tri-party collaboration implemented a community-based SE of abalone by conducting periodic releases of tagged hatchery-bred abalone juveniles in the 4,000 sq m coral patch, mainly *Porites sp*., in the intertidal flats of Brgy Molocaboc. A total of 14,020 diet-tagged hatchery-bred abalone juveniles with 2.5 mean SL have been released periodically in 12 batches from June 2011 to September 2014. Since the first release of tagged hatchery-bred juveniles in June 2011, SEAFDEC/AQD researchers together with fishers conduct monthly monitoring by taking samples to evaluate indicators of growth of released abalones as well as wild stocks that were able to recover due to protection of the SE demonstration site. Starting August 2012 when data monitoring showed abundance of >6cm size, partial harvests were periodically being done to increase appreciation of SE and provide sustainable operating funds for the project. A cumulative total of 2,247 pieces of abalones > 6 cm SL (148kg) were harvested. Total sales proceed from August 2012 to December 2014 amounted to PhP 42,738 and was allocated by BFARMC as follows: spent for organizational operating expenses (48%), petty cash for demo-site maintenance (6%), small loans for members (20%) and bank deposits (26%).

1-a

1-b

1-c

Fig. 1-a. The community-based stock enhancement demonstration site in a 4,000 sq m coral patch (*Porites sp*.) in Brgy. Molocaboc, Sagay City, Philippines
Fig. 1-b. Gleaning is not allowed (*Bawal manginhas*) in the release site called by fisherfolks as "*Semilyahan*" or breeding area
Fig. 1-c. Periodic releases of diet-tagged hatchery-bred abalone juvenile attached to plastic pipes were participated by various stakeholders

Enhancement of Participatory Governance

Since the formation of the Molocaboc BFARMC in November 2009, the officers and members have been collaborating with the LGU at the Barangay and City level. Participatory governance was demonstrated when, arising from IEC discussions on the correlation of abalone sizes and spawning, the >6cm SL catch-size regulation was endorsed by a *Barangay* Councilor who also signed-up to be a BFARMC member; and it became a *Barangay* Ordinance in June 2010. In September 2012, the Sagay City Environment and Natural Resources Office that manage the SMR endorsed to PAMB-SMR the up-scaling of the catch size regulation into a city-wide ordinance. The voluntary participation of the fisherfolk members of the BFARMC in maintaining and securing the community-based SE demo-site, and in the protection of the coral habitat is most invaluable demonstration of participatory governance.

Social and Biological Impact Assessment

In November 2014, an assessment survey interview of 80 BFARMC members and 80 non-members in Brgy Molocaboc was conducted. Results showed that 94% of the 160 respondents expressed awareness about SE in general. Awareness about the SEAFDEC/AQD-initiated SE of abalone is at 98%. Seventy-three percent reported participating in community-based SE, majority of which are the BFARMC members or 96% of the 80 members surveyed. Awareness of the abalone catch size regulation is high at 93%; and 96% agree to it, including those few who have only been made aware during the interview. Biological impact assessment is yet to be conducted as appropriate. Although, monthly monitoring of growth of abalone samples indicate that the released abalone juveniles matured and established in the demonstration area. Fishers reported higher number of abalones or spill-overs gleaned in areas outside the release site.

Lessons Learned

Table 1 lists the lessons learned from a community-based SE project according to its various component activities. Social preparation encompasses a wide range of activities involving as much people and stakeholders in the community. Hence SE is costly, especially because the opportunity cost of fishers or foregone income to attend meetings were accounted by the project. SE is also characterized by long investment and gestation period before benefits could be realized. Since SE is not often the first choice among the fisheries management tools, there is dearth of SE-specific IEC tools to guide information campaign and impact evaluation.

Table 1. Component activities in community-based stock enhancement (SE), lessons learned and recommendations

Component Activities	Lessons from Implementation Experience	Recommendation
1. Baseline survey, establish collaboration	High cost, long investment and gestation period	Tri-party collaboration, i.e. fisher's organization, LGU and technical agency
2. Information dissemination	High cost; need for SE-specific IEC tools	Develop IEC tools
3. Enhance participatory governance	Variable participation; "political & electoral disruptions"	Develop variety of strategies involving many stakeholder groups
4. Demonstrate & monitor stock enhancement	High cost; critical protection & monitoring; sustainable seed supply	Motivate collaboration & voluntary work; link with or establish hatchery
5. Social and biological impact assessment	Lack of SE-specific techniques	Further research to develop assessment tools
6. External factors (market, consumer preferences)	Price decline; export price dependency	Product promotion in local markets to reduce export- dependency; dry-processing

In terms of inclusive organizational strengthening and engagement of fisherfolks in coastal resource management, the Molocaboc BFARMC has since then been known to be in the frontline in SE and other fishery-related activities in the locality and collaborates with the LGU in fisheries management. The success of the BFARMC provided directions for the formation of sub-groups of fishers in 2014, namely, the Matabas Small Fisherfolks Association (MASFA) and the Molocaboc Sea Ranchers Association (MOSRA). However, participation of fishers in SE activities remained variable. This suggests that even if the released abalones successfully established in the release site and there are already economic benefits from regulated partial harvest, the social aspects of SE remain a challenge.

In addition, markets situations, price movements and consumer preferences are some external factors that influence the success or failure of SE as a fishery management option that may provide sustainable income to fishing households. Local buying price of live abalone was PhP 350/kg at the start of the project in 2007 when harvest was scarce. However, local buying prices declined to as low as PhP 120/kg live in 2014 due to a number of market factors, local and international.

Recommendations and Way Forward

Table 1 above also summarizes the recommendation according to the key activities and limitations encountered by this project. In view of the high cost and long investment period in SE, fishery enhancement projects are generally government-funded. This study therefore concludes that SE can be accomplished through a tri-party collaboration involving the fishers who are the direct fishery resource users, the LGU who are the resource managers, and a research organization that provide technical advice in resource management. In all of these collective activities, the participation of stakeholders is a key factor leading to a successful SE initiative. Furthermore, the cooperation of fishery stakeholders in protecting the released stocks distinguishes SE as a fishery production process vs. aquaculture which involves rearing of aquatic animals in controlled enclosed environment.

The market for abalone seems export-dependent as most harvest are intended for northeast Asian who consume and prefer abalones. Filipinos do not generally consume abalones, hence, local campaigns are need to increase domestic demand and consumption.

However, while aquaculture technologies at SEAFDEC/AQD enabled the production of hatchery-bred seeds for release to enhance natural stocks, the present project accomplishments are limited by access to sufficient abalone seeds for release. Under the GOJ-TF6, the tri-party collaboration will continue to support the project and the Sagay City LGU agreed to fund the construction of a pilot hatchery in the Molocaboc; the BFARMC will run the daily operations of the hatchery; and with technical support from SEAFDEC/AQD.

Acknowledgment

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Potentials and Limitations of Stock Enhancement Programs in Japan

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Abstract

In Japan, a lot of stock enhancement programs have been carried out in the last fifty years. Such programs have been successful in terms of cost-effectiveness as well as stocking efficiency. Seeds of 85 species of fishes, mollusks, crustaceans, and other aquatic organisms have been released for stock enhancement, including those of chum salmon *Oncorhynchus keta* and barfin flounder *Verasper moseri* in northern Japan, red sea bream *Pagrus major* in central and western Japan, and sawara *Scomberomorus niphonius* in Seto Inland Sea. To be successful, assessments of the natural stocks and investigations on the environment of their nursery grounds are necessary prior to seed release. However, if the natural stock is abundant compared with the capacity of hatcheries there would be no need for seed release. Healthy marine environment in the nursery ground is a prerequisite for effective seed release. Though overfishing sometimes results in high "recapture rate" of released fish, most of these cases are neither economically effective nor sustainable. A suitable fisheries management is needed. The carrying capacity of the nursery ground restricts the allowed number of released seed. In the case of hirame *Paralichthys olivaceus*, it tends to higher in northern Japan than in the southwestern areas. To evaluate both stocking efficiency and cost-effectiveness, YPR (Yield per Release = weight of landed "recaptured fish" divided by number of released seeds) is recommended. YPR for successful cases is estimated to be more than 50 metric tons per 1 million seeds. Furthermore, since increased production often results in decline of price, socio-economic studies are also important.

Keywords: seed release, stock assessment, carrying capacity, YPR (Yield per Release), socio-economic studies

Introduction

In Japan, a lot of near-shore nursery grounds had been reclaimed leading to the degradation of the environment of coastal waters mainly because of the development of industries. Degradation of the environment and overfishing resulted in the exhaustion fishing resources. Stock enhancement programs were therefore started to recover natural resources by releasing artificial seeds. A total of more than 80 species of fish, mollusk, crustacean, and other aquatic organism seeds have been released in the last 50 years. Although these programs could be successful in terms of cost-effectiveness as well as stocking efficiency, some of them were evaluated and found to be failures.

Activities and Results

Successful Cases

The red sea bream *Pagrus major* is very popular and one of the most important fishes for the coastal fisheries in Japan and was selected as first target species for stock enhancement. The seed production technology of red sea bream was developed in 1960s and 1970s, and the ecology of this species was studied in 1970s and 1980s, and mass-release of artificial seeds was started in 1980s. In the central area of the southern coast of Japan, the amount of landings increased after the mass-release started and maintained around 1,500 metric tons in these 20 years (**Fig. 1)**. Between 10% and 50% of newly recruited fish were occupied by the released fish (**Fig. 2**). Released fish seem to play an important role when the recruitment of natural fish is not abundant. In this region, fishers have positively carried out the resource management and environmental remediation. It is considered that seed release lifts up the motivation of these activities.

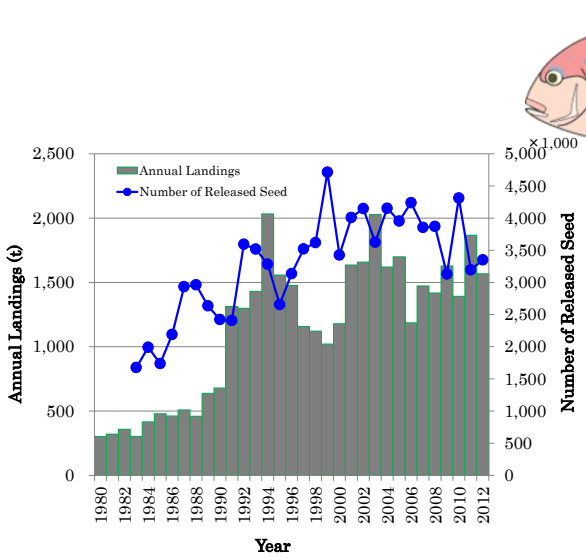

Fig. 1. Annual landings and number of released seeds of red sea bream in the central area of southern coast of Japan

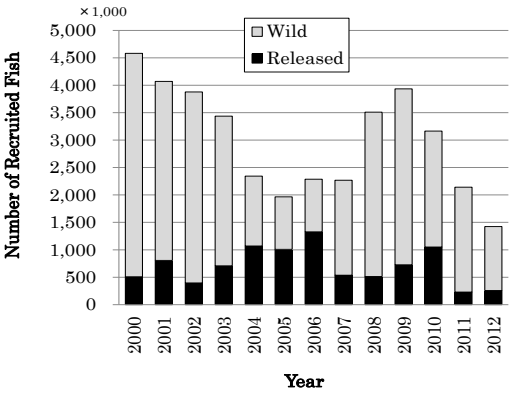

Fig. 2. Number of newly recruited red sea bream

The stock enhancement program for sawara *Scomberomorus niphonius* in Seto Inland Sea is also considered to be successful. Annual landings of sawara had reduced rapidly in the latter half of 1980s and 1990s mainly because of over fishing. Fishers started self-regulations in 1998. In 2002, governmental regulation, which consists of mesh size limitation of the gill net and closed season, and upper limit of catch by purse seine, was imposed, and mass release of artificial seeds started. After these activities, the stock size of sawara recovered (**Fig. 3**). Although the impact of releasing seeds is estimated to be small compared with that of the red sea bream, seed release have changed the attitude of fishers to be positive about fisheries management.

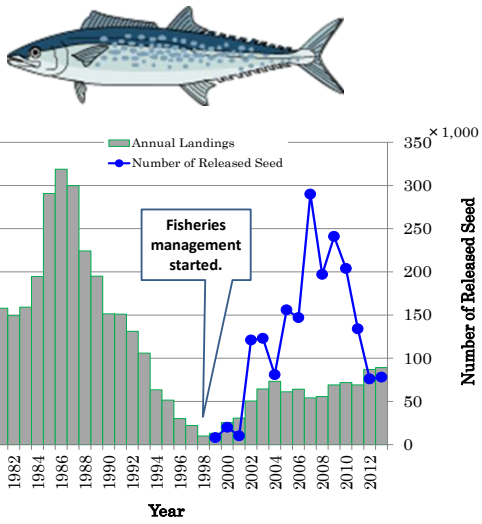

Fig. 3. Annual landings and number of released seeds of sawara in the central area of southern coast of Japan

Limitation of Carrying Capacity

In the case of hirame *Paralichthys olivaceus*, the stocking efficiency tends to be higher in northern Japan than in the southwestern areas (**Fig. 4**). It is considered that nursery ground in northern Japan have higher surplus productivity for stocking of hirame. Yamashita *et al.* (2004) suggested that lower density of wild hirame and higher productivity of prey organisms were the main factor for the difference in the carrying capacity.

Break-Even Point of Stocking

The Break-Even Point of Stocking is calculated from cost of releasing seeds and benefit of recaptured released fish. The benefit per cost should be greater than 1. Break-Even Points under different costs of seeds and YPR (amount of recaptured released fish (metric tons) / number of released seed / 1,000,000) are shown in **Fig. 5**.

For example, when the cost of seeds is 100 JP yen, the price of recaptured fish should be more than 1,000 JP Yen when YPR = 100, and more than 2,000 JP Yen when YPR = 50.

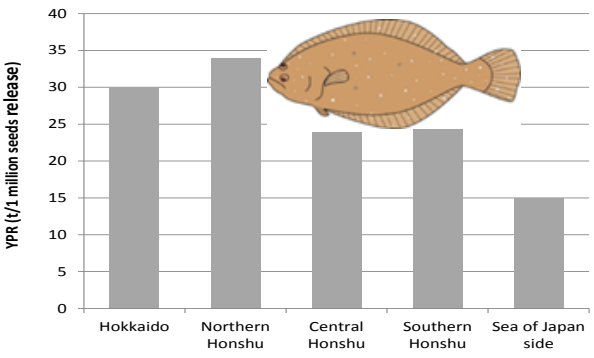

Fig. 4. Difference in stocking efficiency of hirame among the areas studied

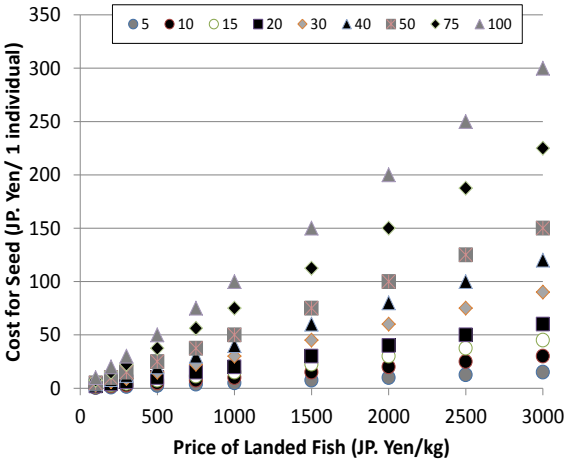

Fig. 5. Break-Even Points under different costs of seeds and YPR

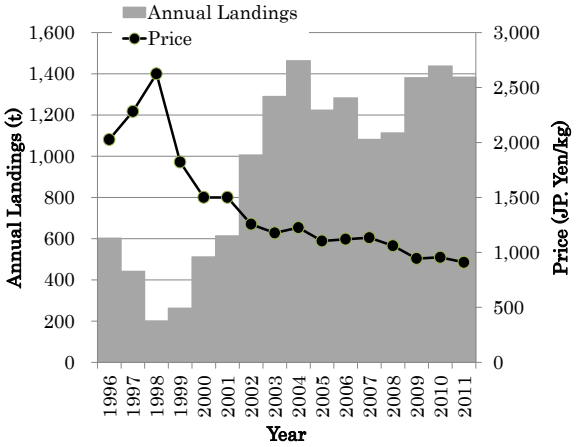

Fig. 6. Annual landings and price of sawara in Seto Inland Sea

Socio-economic Issues

Although the stock size of sawara in Seto Inland Sea recovered in recent years, its price declined as the amount of landing increased (**Fig. 6**). On the other hand, the price of cultured red sea bream declined in 1980s as its production from aquaculture increased. In 1990s, production of aquaculture surpassed the quantity of captured fish, thus, the price of captured fish declined (**Fig.7**). Sawara and red sea bream had been very precious fish for the Japanese, but these fish species seem to lose their status at present.

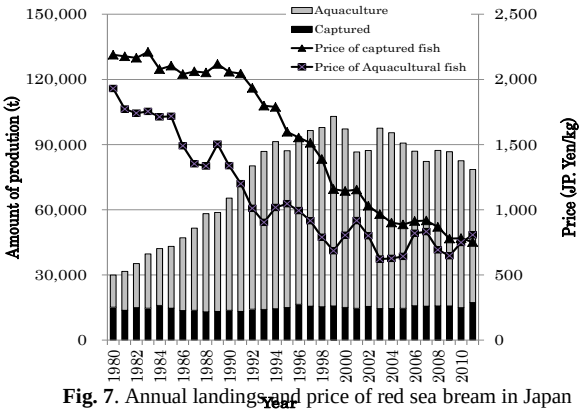

Fig. 7. Annual landings and price of red sea bream in Japan

Lessons Learned

For successful seed release, assessments of the natural stocks and investigations on the environment of their nursery grounds are necessary at first. There is no need of seed release if the natural stock is abundant compared with the capacity of hatcheries. Healthy marine environment in the nursery ground is a prerequisite of the effective seed release. Although overfishing could sometimes result in high "recapture rate" of released fish, most of these cases are neither economically effective nor sustainable. A suitable fisheries management is needed. Carrying capacity of the nursery ground restricts the allowed number of released seeds. To evaluate both stocking efficiency and cost-effectiveness, YPR (Yield per Release; weight of landed "recaptured fish" divided by number of released seeds) is recommended. YPR of successful cases is estimated to be more than 50 metric tons per 1 million seeds released. Furthermore, increased production often results in decline of price, therefore, socio-economic studies are also important.

Recommendations and Way Forward

First of all, **diagnosis** (stock assessments, investigations on the ecology of target species, and investigations on the environment), followed by the so-called **PDCA Cycle,** *i.e.* **Plan** (releasing strategy (when, where, how, how many) and seed quality (size, shape, activity etc.), **Do** (cooperation with fisheries management, and habitat improvement, rehabilitation, and conservation), **Check** (monitoring by market survey, evaluation of stocking efficiency and cost- effectiveness), impact on environment including genetic impact), **Act** (improve, expand, spread, or decide to discontinue), is recommended.

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Success of Fish Stock Enhancement and Restocking in Inland Waters of Indonesia

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Abstract

Stock enhancement and restocking of fish in inland waters of Indonesia has been practiced for a long time. Since 1999, the stock enhancement and restocking practices were based on scientific evidence which include limnological characteristics, productivity and ecological niche of water bodies, structure of fish communities, life cycle and biology of the fish stocked, and development of fisheries co-management and local wisdom or knowledge approach. Some species used in stock enhancement were reviewed, and the causes of programs' successes or failures were analyzed in an attempt to determine the best approach for future stocking. Recent successes in fish stock enhancement are mainly determined by species which can be reproduced naturally in the water bodies and regularly stocked at optimum level. The Government should facilitate and support stock enhancement activities by providing local fish seeds for restocking purposes. Introduction of fish species should be done with precautionary approach especially in the lakes of Sulawesi and Papua that are inhabited by endemic species.

Keywords: stock enhancement, restocking, scientific evidence, precautionary approach, inland waters, Indonesia

Introduction

Indonesia's Fisheries Act No. 31 of 2004 amended by Act No. 45 of 2009 stated that the inland waters of Indonesia is one of the Fisheries Management Areas which can be used for fisheries and aquaculture development. The total area of Indonesia's inland waters is 54 million ha, composed of 12 million ha of rivers and flood plains, lakes 1.8 million ha, man-made lakes or reservoirs 0.5 million ha, and swampy areas of 39.5 million ha. The country also has 5,590 major rivers (94,573 km in length) and 65,017 tributaries, 840 major lakes, 736 small lakes, 162 major reservoirs and 1,341 small reservoirs (Ministry of Public Work–Directorate General of Waters Resources, 2013).

Indonesia is also endowed with high diversity of freshwater fish species. Records with FishBase (2011) indicate that the number of fish species inhabiting the inland waters of Indonesia could reach to 1169. Kottelat *et al*. (1996) stated that the number of freshwater fish species in Indonesia is approximately 1300 species, and also suggested that the biodiversity of Indonesian freshwater fish species is the second richest in the world next to that of Brazil.

More than 798 species inhabit the Sundaland (the large islands of Borneo, Java and Sumatra, and surrounding islands), more than 68 species in the Wallacea zone (includes Sulawesi and Mollucas Island as well as Lombok, Sumbawa, Flores, Sumba, Timor, and many smaller islands), and about 58 species in the Sahulland (Papua Island) zone of the country. Of the total of about 1300 species, about 30% are endemic species which mainly inhabit the lakes and rivers of Sulawesi and Papua.

The total fisheries production of Indonesia in 2012 which was about 18.8 million metric tons accounted for 47% of the total fisheries production of Southeast Asia, and contributed about 12% to the world's total fisheries production. The country's production from inland fisheries in 2008-2012 had been increasing at an average rate of 27% per year in terms of volume and 18% per year in terms of value, the highest increase of which was attained in 2012 (MMAF, 2012).

This trend signifies the relevance of inland fisheries to the country's food fish supply, hence, the need for sustainable management of the inland fishery resources justifying the efforts of the Government of Indonesia to carry out stock enhancement and restocking activities in the country's water bodies in order to enhance the contribution of inland fisheries not only to the economy of the country but also to the food security of it people.

Activities and Results

The history of fisheries enhancement in inland waters of Indonesia can be divided into two periods, *i.e.*, the first period before 1999, and the second period after 1999 until at present. In the first period, fish stock enhancement is the introduction of fish in lakes and reservoirs of Indonesia which had been conducted since the Dutch colonization of the country. During that time, as much as seventeen cultured species had been stocked in some lakes (Sarnita, 1999; Kartamihardja, 2012). Generally, the objectives of stock enhancement were for increasing fish production and fish consumption of the people in the surrounding water bodies. Although the history of fish introductions dates back several hundred years, relatively little is known about the reasons for successes or failures of introduced species and the ecological consequences as these had been poorly documented. Nevertheless, it is generally agreed that introductions involve a level of risk and the certainty of success is unpredictable. The introduction of an aquatic organism will always have some impact on the recipient ecosystem and that the immediate effects on an ecosystem by an introduced species is not always indicative of the long term or permanent impact. In the early 1940s for example, the introduction of java tilapia (*Oreochromis mossambicus*) to Lake Toba had a negative impact on the declining and extinction of the population of an endemic species *Neolissochilus sumatranus* (Sarnita, 1999). Therefore, the introduction of fish into a water body must be carried out carefully and conducted with precautionary approach, especially to the lakes of Sulawesi and Papua where many endemic species inhabit (Kartamihardja *et al*., 2010).

Generally, the activities during this period may have not been based on scientific evidence so the activities had mostly failed. Nevertheless, some successful fish stock enhancement were recorded such as introduction of common carp (*Cyprinus carpio*) in Tondano Lake in North Sulawesi; java barb (*Barbonymus gonionotus*), snake skin gouramy (*Trichogaster pectoralis*) and kissing gouramy (*Helostoma temminckii*) in Tempe Lake in South Sulawesi, and snake skin gouramy in flood plain areas of South Sumatera and Kalimantan. These species were found to have adapted to the available habitat, grown well and spawn naturally contributing significantly to the fish catch of these water bodies (Sarnita, 1999).

In the second period since 1999, fish resources enhancement in Indonesian inland waters, especially in lakes and reservoirs started with experimental research and were therefore based on scientific evidences, such as productivity and ecological niche of the water bodies, structure of fish communities, life cycle and biology of the fish stocked (Kartamihardja, 2007). Some successful fish stock enhancement in some lakes and reservoirs are presented in **Table 1**. A significant result of restocking is transplantation of the bilih fish (*Mystacoleucus padangensis*), an endemic species of Singkarak Lake in West Sumatera to Toba Lake in North Sumatera, where fish productivity increased to 350 kg/ha/yr or 1400% five years after stocking (Kartamihardja & Purnomo, 2006; Kartamihardja & Sarnita, 2010; Kartamihardja, 2012). The bilih fish inhabits all over of the lake and reproduces naturally in the inlet river to the lake (Wijopriono *et al*., 2010). In 2000, the Siamese (stripped) catfish (*Pangasianodon hypophthalmus*) introduced into the Wonogiri Reservoir in Central Java was observed to grow well and spawn naturally in the deepest part of the Keduwang river mouth entering the Reservoir thereby contributing significantly to the fishers' catch (Adjie *et al*., 2010; Kartamihardja & Purnomo, 2004; Kartamihardja *et al*., 2011).

Milkfish (*Channos channos*) stocking into Djuanda (Jatiluhur) Reservoir was meant not only to promote the utilization of phytoplankton abundance as result of the enrichment from floating net cage activities but also to mitigate the improvement of water quality from micro-algae bloom (Maskur *et al*., 2010). Stocking of the giant freshwater prawn into the shallow reservoir, Darma in West Java resulted in rapid growth and significant catch, although the number of prawn juveniles stocked was below the optimum (Kartamihardja *et al*., 2004).

The reasons for fish stock enhancement into a new water body can vary. Some of the goals of stock enhancement which have been identified include: enhancing commercial or subsistence fisheries; restoring degraded fish communities including the recovery of rare, threatened or endangered fish species; enhancing food supply; creating new or diversified fisheries for associated social and economic benefits; establishing biological control agents for micro-algae and mitigating the water's quality.

Table 1. Productivity of lakes and reservoirs after stock enhancement

Lakes/ Reservoirs	Area (ha)	Species stocked	Productivity before stock enhancement (kg/ha/yr)	Productivity after stock enhancement (kg/ha/yr)	Increase in productivity	Economic value* (IDR/ha/yr)
Toba Lake	112,000	Bilih (*Mystacoleucus padangensis*)	22.0-28.0	340.0-400.0	350.0 (1400%)	5,250,000
Wonogori Reservoir	7,800	Siamese catfish	26.0-35.0	59.0-62.0	30.5 (102%)	457,500
Mahalayu Reservoir	275	Siamese catfish	60.0-75.0	102.0-129.0	49.5 (73%)	742,500
Darma Reservoir	400	giant freshwater prawn	75.0-123.0	99.0-128.0	14.5 (15%)	217,500
Jatiluhur Reservoir	8,300	milkfish	27.0-32.0	178.0-181.0	150.0 (508%)	2,250,000
Sempur Reservoir	255	milkfish	3.5-4.0	7.9-9.2	5.0 (133%)	na

***Note:** Economic values were analyzed 2-5 years after the start of stock enhancement activities
Source: Kartamihardja (2015)

Lessons Learned

Based on the successful implementation of the stock enhancement in Indonesian inland waters, lessons could be learned. In culture-based fisheries activities, stocking of fish was undertaken regularly, while in fish restocking conducted the fish stocked were those that spawn naturally. Fish seeds were stocked at an optimum level. In the management of fish stock enhancement, regulations on fishing, marketing system, and strengthening of management institutions were developed. In addition to enhancing the participation of communities around water bodies, a co-management system had also been developed. Co-management using Fishers' Group (as community institution) is a formal process of sharing the responsibility and authority between the government and organized groups in a decentralized approach to decision-making that can be replicated (Pomeroy *et al.*, 2001). Without co-management, decision making could lead to top-down management that involves fewer users in fisheries management, and often resulting in communication barrier. The success or failure of stock enhancement is also determined by the availability of data and information on the results of monitoring carried out continuously. Therefore, the monitoring activities should be carried out by fishers' groups and local communities as the main champion in the management and direct beneficiaries of the stock enhancement activities.

Recommendations and Way Forward

Indonesian inland waters bodies have different limnological characteristics, especially in terms of productivity (potential fish yield), fish species inhabiting, and their functions. These different characteristics resulted in varied levels of stock enhancement successes. Community participation around water bodies has determined the success and sustainability of the fish stock enhancement. Therefore, in the future fish stock enhancement should include the following strategies.

- Identification of water bodies suitable for stock enhancement, such as its productivity, niche ecology, structure of fish community and its trophic level
- Selection of fish species to be stocked based on biological, social as well as economic aspects
- Species to be introduced should be plankton feeder and/or herbivore (fish stocked mainly utilizing the natural food such as plankton or aquatic weeds)
- Introduction of fish species should be done with precautionary approach especially in lakes of Sulawesi and Papua inhabited by endemic species
- Development of local hatchery to provide seeds or fingerlings of fish species to be stocked, which the Government could facilitate and support local fish hatcheries
- Establishment of regulations on fishing and development of co-management regime and coordination among users
- Development of best practice guidelines on stock enhancement in Indonesian inland waters which should take into consideration certain characteristics of specific water bodies

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Current Status of Fish Stock Enhancement in Thailand

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Abstract

Aquatic animals from natural waters have long been exploited by rural poor as cheap protein food. Natural waters including rivers, canals, swamps, lakes, large reservoirs, and small water bodies are significantly exploited as fishing areas. Unfortunately, country development together with destructive fishing practices led to the deterioration of these aquatic habitats and fishery resources. Production from advance aquaculture technologies can support the steady increase demand for fishery resources to some extent. Natural fishery resources, however, still maintain its crucial role in providing cheap protein particularly for the rural poor in remote areas. The Department of Fisheries (DoF), the national fisheries competent authority of Thailand, manages to maintain/enhance fisheries production through number of strategies including law enforcement, habitat rehabilitation and stocking programs. Stocking has been widely implemented due to its simplicity and proven to be the most successful technique for fisheries management. Over thousand millions fingerlings of fishes, frogs and giant freshwater prawn have been stocked annually by DoF through a number of fisheries development projects, *i.e.* Village Fisheries Project, School Fisheries Project, Bamrung Phan Pla Pracha-arsa Project (Participatory Voluntary Fish Stock Enhancement Project), Small Water Bodies Rehabilitation for Fisheries Project, Large Water Bodies Fisheries Development Project, and Seed Production for Stocking. Post-stock assessment since 1985 revealed that the recapture rate of the giant freshwater prawn is around 3% with rate of investment return which is more than 6 folds. The recapture rate of fishes is in the range of 5-10% with total production of 20,000 metric tons and valued at about 30 million USD. Stock enhancement could be achieved through a number of strategies depending on the conditions of particular water bodies. Law enforcement on illegal fishing is an important lesson learnt at the Yom river basin, where stocking large numbers of giant freshwater prawn had been successful at Pak Mun reservoir while community-based fisheries management had been effective at Ubol Ratana reservoir. The rate of achievement of stock enhancement, however, depends on participation of local communities the most essential element for fisheries management. Inland capture production varies depending on the challenges including habitat alteration, overfishing, genetic alteration, fisheries regulations, and climate change. Alterations of inland capture fisheries production would definitely have adverse impacts on livelihoods of rural poor who entirely rely on the natural aquatic resource. Stock enhancement through the various strategies would be effective only when all challenges concerned are taken into account and properly managed.

Introduction

Thailand is overwhelming with water sources and abundance of fishery resources. People utilize water in their daily life activities and exploit fisheries resources for food since the ancient times. Human settlement is always associated with water sources. Aquatic animal is one of the natural resources closely related with people livelihood, tradition and culture. These Thai proverbs "ในน้ำมีปลาในนามีข้าว" means "in the waters are fish and in the field is rice" or "กินข้าวกินปลา" means "eat fish eat rice" just reflect the fact that rice and fish are staple food for Thais since long time ago. The abundance of fishery resources in the past adequately supported the demand of low population. However, country development has negatively impacted on natural habitats and resources. In addition, increased population from 25 million to 65 million during the last couple of decades inevitably resulted in increasing demand for fishery resources. Inland fisheries play a crucial role in providing food and nutrition particularly for the rural poor who has less or no opportunity for improving their living conditions.

Most rural poor rely on the fishery resources as cheap protein source. Inland fishery resources generally characterize the significance of food security, nutrition, livelihood, local knowledge, and income earnings. River basins of the country comprised 25 main basins and 254 sub-river basins. According to geomorphology and aquatic ecology, water sources within these river basins can be classified into 4 categories, namely: rivers and canals, swamps and lakes, large reservoirs, and small water bodies. These waters are fisheries productive areas. Unlike production from marine capture fisheries that steadily declines, inland capture fisheries production has been maintained well about 200,000 metric tons since 1994. Such stability of production reflects the achievement of effective fisheries management. Inland fisheries production comprises fish as the mainstay component coupled with very minute production of shrimps and other aquatic animals. The Department of Fisheries (DoF) is the national competent authority, responsible for maintaining/enhancing fisheries production for self sufficiency as well as to export the surplus for income earning.

Activities

Inland fisheries production is largely influenced by a complex interaction of physical, chemical and biological conditions and fishing practices. Therefore it needed proper management to sustain/enhance the production. Three approaches, however, are generally used for fisheries management; a) fisheries law is commonly applied to regulate fishing including gear and size restrictions, seasonal closures, limitation on entry, taxes levies and property rights; b) habitat rehabilitation aims to increase or recover available habitat and/or access to key habitat for at least some life stages of a target species. Such an approach may range from increased connectivity along a river e.g. fish passage, through reconstruction of the habitat to the installation of artificial habitats; and c) stock enhancement referred to as the manipulation of the fish stocks by addition of material, usually of a desired species to improve the fishery productivity or diversity conservation. Stocking is widely popular due to its perceived simplicity. Pawaphutanon (1988) reported that stocking has been proven to be the most successful technique for fisheries management. Aquatic animal stocking generally associated with traditional and religious ceremonies such as making merit on birthday, on new-year celebration and many other special occasions. Aquatic animal stocking is practiced more widely and intensively when fish hatcheries able to produce massive seed production of various species.

Aquatic animal stocking, fish stocking in particular has been practiced by many agencies with different purposes, but two commons are production enhancement and species conservation. Over thousand millions fingerlings of fishes, frog and freshwater giant prawn have been stocked annually by DoF through number of fisheries development projects; 1) Village Fisheries Project, 2) School Fisheries Project, 3) Bamrung Phan Pla Pracha-arsa Project (Participatory Voluntary Fish Stock Enhancement Project), 4) Small Water Bodies Rehabilitation for Fisheries Project, 5) Large Water Bodies Fisheries Development Project, and 6) Seed Production for Stocking. For example, DoF stocked more than 1,333 million fingerlings of 59 aquatic animal species in natural waters in 2013. Out of the total 59 stocking species, 53 species are freshwater fishes, 6 species of frogs and freshwater giant prawn. In addition to DoF, Tambon (Local) Administration Organization (TAO), Provincial Governors, Electricity Generating Authority of Thailand (EGAT), and other private and government organizations also involved in stocking.

Village fisheries project was initiated by DoF in 1983 with objective to alleviate shortage of fish protein of rural people. The projects functioned effectively and were expanded to implement throughout the country by emphasizing on remote areas. However, these projects were transferred to be overseen by Tambol Administration Organization (TAO) according to decentralization policy of the new constitution in 1997. Unfortunately, a survey by DoF in 2010 revealed that those projects transferred to be managed by TAO more than 50% was no longer function.

Alongside with stocking program, DoF has also been also conducting post stock assessment since 1985, where positive impact was apparently found with the stocking of the giant freshwater prawn. Success in stocking however depends on the number of factors including hydrology, fertility of the water, number and size of the stocked seeds, quality of seeds and growth period. Recapture of the giant freshwater prawn is observed to be about 3% with rate of investment return which is more than 6 folds. Meanwhile, recapture rate of stocked fish in general, is found to be 5-10%.

Stock Enhancement Lessons Learnt

Giant freshwater prawn stocking in Pak Mun

Pak Mun dam in Ubon Ratchathani Province was constructed to impound the Lower Mun River stretch in 1994. The dam is located about 4-5 km away from the confluence of the Mun and the Mekong Rivers. Apparent decrease in fish abundance was due to the obstruction of dam on fish migration from the Mekong River to the Mun River. Even if fish ladder was provided to facilitate fish migration, the design seems to be inefficiently functioning. For years, local fishers and the Poor Association encountering the negative impacts from dam post-impoundment demanded the then government to find solutions that would address the decreasing fishery resources. The Thai cabinet announced in 2003 a compromised resolution by regulating the dam operations, *i.e.* closing it for 8 months to generate electricity and opening for 4 months during fish migration period to allow the migratory entry fish from the Mekong River. In addition, the cabinet had assigned EGAT in collaboration with DoF to enhance fisheries production at the lower Mun River stretch by stocking 50 millions fingerlings or juveniles of aquatic species annually for 5 years during 2003-2007. DoF stocked 40 millions of giant freshwater prawn and other 10 million of economic freshwater fishes annually during the particular period. Post stock assessment revealed an apparent production increase, especially the production of giant freshwater prawn. Recapture rate was found at 2.4%. Prawn production accounted for 98 metric tons during the 8-month culture period, valued at 35 million Baht with rate of investment return of about 5.84 folds.

Control of illegal fishing Yom River Basin

Yom River originates from the mountain range in the north of the country and river flows through agriculture and communities' plain areas in the lower north. The Yom River is a main origin of the Chao Phraya River and is the only main river which has no dam impoundment. Flood is always happening at the lower part of the basin during the monsoonal season. The flood plain covers an area of 500,000-600,000 rai (80,000-96,000 hectare) and is a significant spawning and nursing ground for various aquatic animals. The number of illegal fishing gears such as large stationary bag net, small stationary bag net, push net and giant lift net has been increasing in the River, where destructive fishing gear operations result in alteration of fish abundance and unfair resources exploitation.

DoF has managed to reduce the number and effectiveness of these destructive fishing gears in the Lower Yom River Basin in 2009-2011. Stock enhancement project was initiated on the first year of the project which was operated by involving government agencies and enhancing the participation of local administration agencies, communities and fishers. The project aims to reduce fishing effort while research was conducted to assess stock of fishery resources and catch production of different types of fishing gear in the river basin. Results of the research activity indicated the operations of 248 units of illegal fishing gears. These included 123 units of large stationary bag net, small stationary bag net, 40 units of push net, 30 units of giant lift net and 25 pieces of bamboo fence, 22 units of small stationary bag net and 8 electro-fishing.

In 2008, the project operation focused on reduction of fishing effort based on agreement with fishers to reduce large stationary bag net use by 25% of during 3-12 December 2008. The results showed that the fisheries production increased by 84,000 kg or equivalent to 12.20 million individuals survived from 25% reduction of fishing effort of large stationary bag net. The value of the increment is about 2.55 million Baht at conservative level while the maximum value could reach up to 12 million Baht.

In 2009-2011, the project tried to reduce the number of illegal fishing gears by employing many strategies, such as: 1) training fishers to gain knowledge on participatory fisheries management, 2) development of collaborative fisheries management plan with participation of government agencies and fisheries communities, 3) strict law enforcement and punishment, 4) buy back of large stationary bag net, 5) support by providing fingerlings and cage culture facilities to those who volunteer to stop using large stationary bag net, 6) development of fish habitat for fish broodstock conservation.

Community-based fisheries management in Ubol Ratana Reservoir

Annual fish production in Ubol Ratana Reservoir showed a declining trend over the past 40 years. The annual catch production decreased after 12 years of impoundment. The CPUE (kg/boat/day) in the wet season is smaller than during the dry season. Closed season (16 May -15 September) and mesh size limitation (not less than 2.5 cm) are two measures employed for fisheries management. Trend of the catch, however, continuously keep on declining year by year. In 2009, the catch was about 21.4 kg/ha/yr but with very high fishing effort. It is estimated that there are more than 5,000 fishing households in 101 villages located around the Reservoir. The DoF introduced a Community Fisheries Based Management project in the Ubol Ratana Reservoir since 2009 to improve fish habitats with the involvement of local communities and government agencies.

The activity intended to encourage relevant stakeholders to participate in the fisheries management such as the Tambol Administration Organization (TAOs), resource users and government agencies and to co-manage the Reservoir's fishery resources. The 3 year-project (2009-2011) commenced by organizing a stakeholders' meeting for the development of the project management plan, with fisheries resources enhancement as the ultimate goal of the plan. During 2010–2011, DoF established 30 Fish Conservation Zones (1 habitat/village) in the reservoir to increase the fish sanctuary area for broodstock enhancement. Alongside with fish habitats building, stocking is another strategy introduced to enhance fish production. Since then, fish production had markedly increased in 2010 and 2011 as results of the new fisheries management strategies introduced.

Recommendations and Way Forward

Wild capture fisheries could tremendously impact on the livelihood of major population basin-wide especially the rural poor in remote areas. Basin-wide fisheries management strategies should take into account the issues on fisheries stock enhancement as the first priority. Basin-wide fisheries management is related to water management and many other related developmental sectors. Data and information together with knowledge on hydrology, aquatic ecology and fish biology associated with each type of water are crucial in undertaking appropriate planning and implementing such plans under the integrated water resources management (IWRM) approach and stock enhancement. Therefore, personal and institutional capacity building is necessary particularly the enhancing the capability of stakeholders in planning and implementing basin-wide fisheries management. Fisheries law and regulations to control illegal fishing is necessary but law enforcement alone does not function completely due to limitation of budget and number of officials. Therefore, fisheries co-management with participation of local communities in fishery resources management is a promising strategy, which has shown effectiveness in many pilot areas. Contemporary law for effective enforcement is essential for stock enhancement.

Both fish habitat and species diversity of aquatic animal, the essential basic elements for fisheries production have been deteriorated by a number of influential factors including basin development projects and natural phenomenon like climate change. Holistic approach of basin development or IWRM is a promising strategy for basin development to maintain the production of all water related activities and attain their maximum potentials. Aquatic animal stocking will continue its crucial role in stock enhancement but indigenous species are recommended.

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Session Papers
Session 5: Release Strategies and Ecological Interaction with Natural Stocks

With the Deputy Chief of SEAFDEC Aquaculture Department (AQD) *Dr. Takuro Shibuno* as Facilitator, the Session had three resource persons presenting their experiences on release strategies, namely: (1) *Dr. Ma. Junemie Hazel Lebata-Ramos* on SEAFDEC/AQD Stock Enhancement Initiatives: Release Strategies Established; (2) *Dr. Yasuhiro Obata* on Stock Enhancement of Portunid Crabs in Japan; and (3) *Dr. Marie Antonette J. Meñez* on Approaches in Rebuilding Sea Urchin and Sea Cucumber Populations in the Philippines.

In the paper of ***Dr. Ma. Junemie Hazel Lebata-Ramos***, the progress of implementation of AQD's stock enhancement initiatives was discussed. Dr. Lebata-Ramos recalled that stock enhancement activities of AQD were started in 2001 with the first stock enhancement of mud crab (*Scylla* spp.) funded by the European Commission, and followed by another stock enhancement activities for seahorses (*Hippocampus* spp.), giant clam (*Tridacna* spp.), abalone (*Haliotis asinina*), and sea cucumber (*Holothuris* spp.) as priority species with support from the Japanese Trust Fund. As a result, release strategies had been established for the giant clam, abalone, and mud crab. Citing some examples, she mentioned that giant clams should be released in ocean nurseries until they reach escape size of 20 cm shell length (SL) for better survival before transferring to seeds to shallow reefs with warm temperature for better growth. For abalone, seeds should be released at $\geq$ 3 ml SL and should be transported from the hatcheries using PVC transportation modules to minimize mortalities caused by transport stress, and for mud crab there is a need to check the conditions of release areas at least one month prior to release to increase the chances of survival in the wild.

Dr. Lebata-Ramos also mentioned the importance of monitoring the released stocks as they had observed in releasing the mud crab, where the crablets appeared lost in the wild. In addition, tagging the stocks is also necessary to separate the released stocks from wild conspecifics, and that appropriate tags should be chosen. For example, diet tags have been used in the case of abalone, umbered dymatapes for giant clams, and coded microwires for mud crabs.

The presentation of ***Dr. Yasuhiro Obata*** focused on the results of a case study on stock enhancement of Portunid crabs in Japan. He cited that Portunid crabs such as the swimming crab (*Portunus trituberculatus)*, blue swimming crab (*P. pelagicus)* and mud crab species (*Scylla paramamosain* and *S. serrata)* are among the most important fishery resources in the coastal waters of Japan. Since the annual catch of the Portunid crabs have fluctuated and in order to sustain and/or increase the Portunid crabs stock, about 30 million hatchery-produced juveniles have been released annually since the late 1980s.

Dr. Obata explained that estimating recapture rates of stocked crabs is indispensable to evaluate the effectiveness of stock enhancement programs, therefore it is necessary that marking methods be developed to distinguish between wild and hatchery-released individuals. Moreover, stocking effectiveness of Portunid crabs could be easily determined if appropriate methods to mark small body sized juveniles which frequently molt in their life cycle, are put in place.

In the discussion, Dr. Obata explained that a technique has recently been developed to mark crab juveniles which could eventually estimate the contribution rates of released crabs to the total catch of mud crabs and swimming crabs. The mixture rate of released juveniles in the total catch of mud crab could be estimated using the method of genetic stock identification, which in this case could be 5.0-19.7%, and the contribution of released juveniles to the total catch could be about 0.5-1.0 metric tons. The recapture rate of released juveniles of the swimming crabs is estimated through a marking technique by clipping the swimming leg (dactylus). The result indicated that the estimated contribution rate of marked crabs to the landings was about 3.0%.

The approaches developed by MSI in rebuilding sea urchin and sea cucumber populations in the Philippines were explained by ***Dr. Marie Antonette J. Meñez.*** She cited that sea urchins (*Tripneustes gratilla*) and sea cucumber (*Holothuria scabra*) are invertebrates that have important ecological functions in tropical near shore ecosystems. The culture and release of sea urchins and sea cucumber has been conducted to rebuild depleted populations and provide income to fishers. She added that an integrated socio-ecological approach was applied with active participation of local partners in site management and regular monitoring. From the results, it was noted that sea urchins and sea cucumber function as reproductive reserves and source of larval supply to adjacent suitable habitats.

During the discussion, Dr. Meñez explained that although culture-based resource management is imperative however, it should also take into consideration the investment and high associated risks, it should be science-based, regular monitoring and evaluation should be carried out, local stakeholders and decision makers should be involved. Moreover, culture-based resource management should be able to demonstrate the ecological and economic benefits, and identify where appropriate governance that is necessary as this is a critical consideration for sustainability.

As for the impacts of mass spawning of the invertebrates on ecology, Dr. Meñez added that this is positive to maintain the stocks and the distribution of larvae through hydrology and thus should be maintained, even in nature broadcast spawning of invertebrates happens all the time. She also cited that the study area used is a natural habitat for sea urchins with rich seagrass beds. However, the relationship between the survival rate of sea urchins and density of seagrass beds had not been determined. Moreover, based on the spatial patterns for genetic differentiation through genetic distance, it was found that there could be five (5) populations of *H. scabra* in the study area.

SEAFDEC/AQD Stock Enhancement Initiatives: Release Strategies Established

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Abstract

SEAFDEC/AQD's Stock Enhancement Program started in 2001 with the first stock enhancement initiative on mud crab *Scylla* spp. funded by the European Commission. This was followed by another stock enhancement program in 2005 supported by the Government of Japan Trust Fund with seahorses *Hippocampus* spp., giant clam *Tridacna gigas*, abalone *Haliotis asinina*, and sea cucumbers *Holothuria* spp. as priority species. This paper discusses the release strategies that have been established for giant clam, abalone and mud crab.

Introduction

The problem of reduced productivity from many of the world's coastal and marine wild fisheries is caused by overfishing in all its forms (Pauly, 1988) and the degradation of the ecosystems through coastal development and destructive fishing methods (Bell *et al.*, 2005). Declining fisheries production have been reported for plaice *Pleuronectes platessa* as early as 1880 in the North Sea (Gulland and Carroz, 1968); scallop *Patinopecten yessoensis* since 1920s in Mutsu Bay and 1930s in Hokkaido (Ventilla, 1982); red abalone *Haliotis rufescens* since 1968 in California (Gaffney *et al*., 1996); and blue crab *Callinectes sapidus*, since 1993 in Chesapeake Bay (Zmora *et al*., 2005), to name a few. To boost production, scientists and fisheries managers have been looking at ways of enhancing fish stocks for over a century (Blaxter, 2000). Replenishing depleted stocks may be done first, by regulating fishing effort; second, by restoring degraded nursery and spawning habitats; or third, through stock enhancement (Blankenship and Leber, 1995). Stock enhancement using individuals reared in aquaculture facilities is becoming a popular method of supplementing depleted stocks *(Bert et al*., 2003). However, according to Bell and Nash (2004), the capability to produce and release juveniles from these aquaculture facilities is not enough reason to conduct stock enhancement.

Stock enhancement is a multidisciplinary technique that takes into consideration many factors and needs the involvement of different experts. Stock enhancement success, according to Bell *et al*. (2005), depends on knowing enough about the ecology of the species, its nursery habitat, and the survival of cultured juveniles in the wild. This means gathering information about the population of the species concerned and its habitat prior to any attempts on stock enhancement. It has been stressed by Gulland and Carroz (1968) that the essential basis of any management is the proper biological understanding of the state of the stocks concerned and emphasised that proper management requires good scientific knowledge based on adequate data.

Blaxter (2000) further added appropriate size-at-release, season of release and area for release as keys to stock enhancement success. To ensure successful use of the stock enhancement concept and avoid repeating past mistakes, Blankenship and Leber (1995) proposed ten components of a so-called "responsible approach to marine stock enhancement" which embrace logical and conscientious strategies for applying aquaculture technology to help conserve and expand natural resources.

To summarize, any stock enhancement activity changes the status quo of an ecosystem or the habitat involved. However, given the substantial damage these ecosystems have suffered due to anthropogenic activities and the depletion of fisheries resources in these ecosystems due to overfishing, the impact of adding juveniles aiming at improving production of the target species should not be a cause of great concern provided that this activity is conducted responsibly and that this will not cause further degradation to the ecosystem and its diversity. This paper reports the stock enhancement and restocking initiatives of SEAFDEC Aquaculture Department on the giant clam *Tridacna gigas*, abalone *Haliotis asinina*, and mud crabs *Scylla* spp.

Activities/Results

***Giant Clam*, Tridacna gigas**

The study was conducted in 1) Carbin Reef in Sagay Marine Reserve, Sagay City, Negros Occidental; 2) Kawit Reef in Malalison Island, Culasi, Antique; and 3) Igang Marine Station of SEAFDEC/AQD in Igang, Nueva Valencia, Guimaras, all in central Philippines. *T. gigas* juveniles were purchased from the Bolinao Marine Laboratory of the University of the Philippines Marine Science Institute. These clams were spawned in October 2004 by parent stocks obtained from Solomon Islands and Australia ages 9 yr and 2 mo and 13 yr and 10 mo, respectively, during spawning (Mingoa-Licuanan, pers. comm.).

During transport, clams were wrapped in moist cheesecloth bags, placed in oxygen-filled transparent transport bags and into styroboxes provided with ice enough to cool the clams during the long trip. Upon arrival in the study sites, clams were first acclimatized then brought to the ocean nurseries for stocking (refer to Lebata-Ramos et al., 2010 for details). Clams were measured monthly for growth (shell length, SL) and survival (individual counting to account for mortalities). Clams were regularly brushed to remove epiphytic organisms growing on their shells. Fouling organisms on the net of the cages and on the concrete slab substrates were also removed by brushing. Upon reaching ≥20 cm SL, clams in ocean nurseries were tagged and transferred to the adjacent reefs. According to Mingoa-Licuanan and Gomez (2007), upon reaching 15-cm SL, clams become less vulnerable to predation and as they grow bigger, predation-related mortality becomes less and they are ready for grow-out. Hence, the target size-at-release should be ≥20 cm SL.

Table 1 shows the number and mean shell lengths of giant clams initially stocked in ocean nurseries in different restocking areas. At this nursery phase, clams reared in Igang Marine Station had the highest survival of 92%. Clams reared in Kawit Reef suffered the highest mortality caused by two strong typhoons that affected the area. Half of the stocks were lost in the first typhoon and most of the remaining ones were lost six months later when another typhoon hit. Monitoring of clams in Kawit Reef stopped because only 11 clams were left. Survival of the clams that were transferred from the ocean nurseries to the reefs upon reaching the escape size of 20 cm SL was high both in Carbin Reef (98.6%) and SEAFDEC Igang Marine Station (94.9%).

Table 1. Giant clams *Tridacna gigas* stocked in Carbin Reef, Kawit Reef and Igang Marine Station

PARAMETERS	Carbin Reef	Kawit Reef	Igang Marine Station
Initial stocks (n)	605	506	300
Mean shell length (cm SL) at stocking	9.05	10.14	12.18
Survival in the ocean nursery (%)	423 (69.9%)	11 (2.17%)*	276 (92%)
Survival in the reef one year after transfer from the ocean nursery (%)	417 (98.6%)		262 (94.9%)
Mean shell length one year after transfer from the ocean nursery (cm)	35.35		31.02

Of the water parameters monitored (**Table 2**), only temperature and depth significantly differ between sites. Igang Marine Station was the shallowest among the sites and had the warmest temperature. Clams had the highest survival and the best growth rate in this site.

Table 2. Mean±SE (range) of water parameters recorded from each site during the duration of the nursery phase

PARAMETERS	Carbin Reef	Kawit Reef	Igang Marine Station	Statistical Analysis
Temperature (°C)	29.26±0.20[ab] (26.8-31.5)	28.61±0.30[b] (25.0-30.5)	29.52±0.24[a] (26.3-31.0)	ANOVA, $p<0.05$
Salinity (ppt)	33.29±0.32 (27.3-36.7)	33.95±0.32 (30.9-36.2)	33.33±0.28 (29.5-36.4)	Not significant
TSS (mg/L)	84.01±7.04 (0.0-202.4)	79.60±6.68 (3.4-139.8)	84.43±5.21 (24.8-31.0)	Not significant
Chlorophyll a (mg/L)	0.0015±0.0002 (0-0.003)	0.0012±0.0004 (0-0.003)	0.0010±0.0002 (0-0.003)	Not significant
Light intensity (Klux)	7.78±1.52 (2.7-21.8)	--	10.04±1.17 (3.0-17.8)	Not significant
Mean depth (m)	2.43±0.16[b] (1.1-3.9)	6.34±0.12[a] (5.3-7.3)	1.89±0.10[c] (1.1-2.8)	ANOVA, $p<0.001$

Abalone, Haliotis asinina

The study site, Sagay Marine Reserve (SMR) in Sagay City, Negros Occidental, Philippines, has been described in earlier studies of Maliao *et al.* (2004), Okuzawa *et al.* (2008) and Lebata-Ramos *et al.* (2010). Carbin Reef, one of the four "no-take" zone reefs, was chosen as the site for stock enhancement of abalone. The reef flat, approx. 20 ha, is exposed during low tide when the water level goes beyond 0.3 m depth above chart datum (Lebata-Ramos *et al*., 2010). On the eastern side of Carbin Reef ten 50x2 m belt transects were permanently set up from the southernmost edge of the reef going up north at 100 m apart. Release and monitoring of wild and HR abalone were done inside these belt transects.

Trial Release (HR1) - Diet-tagged abalone (n=1,010) measuring 2.1-3.0 cm SL were obtained from the SEAFDEC/AQD Abalone Hatchery. Tagging was done following Gallardo et al. (2003).

Abalone were transported to the site following Buen-Ursua and Ludevese (2011). Upon arriving at Carbin Reef, abalone, still in transport modules, were transferred to cylindrical net containers and placed in the deeper portion of the reef for onsite acclimation. Every day, each module was checked for mortality and abalone fed with *Gracilariopsis heteroclada*. Abalone were released after an acclimation mortality of <0.5% was attained. Transport modules were placed on each of the pre-installed transects at one module every 5-m interval. This was done on a neap tide in the day to keep them away from predatory reef crabs, which usually emerge when the water is very low and the reef flat exposed. Movement of abalone from the modules to the reef was monitored daily until all of them have moved out. All empty modules were then removed from the release site.

Monitoring was carried out either at dawn or dusk, during the last hour of a major tide of spring tide when the water was ebbing until the onset of high tide. All abalone found inside the belt transect were collected and classified as wild or HR. Individual SL and body weight (g BW) were measured, and sex and sexual maturation determined following Singhagraiwan and Doi (1993). Wild stocks were then tagged with numbered dymotape to determine individual recaptures and both wild and HR abalone returned to their respective transects.

Final Release (HR2) - Abalone (n=2,625), measuring 1.5-2.5-cm SL, were obtained from the SEAFDEC/AQD Abalone Hatchery. This batch (HR2) was tagged with two bands to differentiate them from HR1 abalone released in July 2008. When most of the abalone attained at least 3 cm SL, diet tags were supplemented with individually numbered dymotapes for individual identification.

Transport, acclimation, release and monitoring followed the protocols employed during the release trial (HR1). Growth, total percent recapture, and duration between release and recapture were calculated from the number of recaptured individuals for wild, HR1, and HR2 abalone. Acclimation mortality in HR1 was 14.36%. In HR2, acclimation mortality was lower at 3.50%. The same trend was observed for both HR1 and HR2 where the highest mortality was recorded on day 1 and decreased until day 3 when mortality of <0.5% was attained (**Fig. 1**). Utilization of PVC pipe transport modules as temporary shelter during release was more pronounced in HR1, where almost 19% of the abalone did not move away from the modules on day 1. In HR2, only 4.67% of the released abalone remained in or on the modules during the first 24 hr (**Fig. 2**).

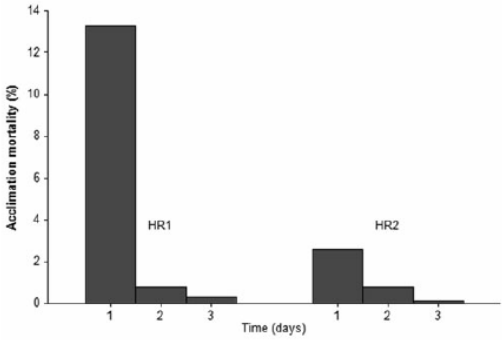

Fig. 1. Acclimation mortality from trial (HR1) and final (HR2) releases of hatchery-reared abalone *Haliotis asinina* in Carbin Reef, Sagay Marine Reserve, Negros Occidental, Philippines (lifted from Lebata-Ramos *et al*., 2013)

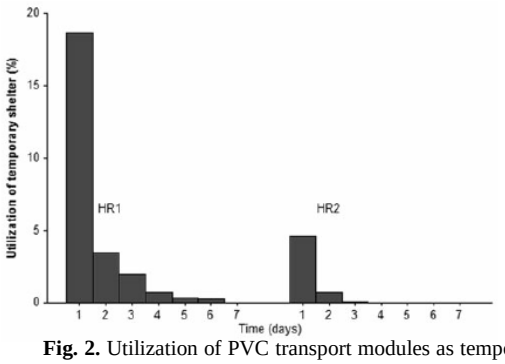

Fig. 2. Utilization of PVC transport modules as temporary shelter during trial (HR1) and final (HR2) releases of hatchery-reared abalone *Haliotis asinina* in Carbin Reef, Sagay Marine Reserve, Negros Occidental, Philippines (lifted from Lebata-Ramos *et al*., 2013)

Of the 239 wild abalone tagged and released from August 2008 to March 2011, a total of 19 individuals (ind) or 7.95% were recaptured. Recapture of abalone ranged 24-278 days after release. For the same period, of the 856 HR1 and 2396 HR2 abalone released, 14 (1.64%) and 155 (6.47%) ind have been recaptured, respectively. Recaptures for both HR1 and HR2 were obtained 26-513 days post-release. All wild abalone were recaptured in transects where they were previously captured and returned. Just like their wild conspecifics, most HR abalone were recaptured from transects where they were released.

Mean growth rates of wild abalone recaptured were 0.25±0.06 cm SL and 4.02±0.64 g BW mo^{-1} with maximum growth rates of 0.7 cm SL and 11.56 g BW mo^{-1}, respectively. Growth rates for HR1 were 0.27±0.04 cm SL mo^{-1} with a maximum of 0.52 cm and 4.6±1.37 g BW mo^{-1} with a maximum of 23.44 g. Growth rates for HR2 were 0.35±0.01 cm SL mo^{-1} with a maximum of 0.92 cm and 3.80±0.23 g BW mo^{-1} with a maximum of 12.46 g. Growth rates were comparable in both wild and hatchery-reared abalone released in the wild.

Mud crabs, Scylla *spp.*

The study was done in a 70.2-ha basin mangrove system located in Naisud and Bugtong Bato, Ibajay, Aklan, Philippines. Three release areas were chosen in the upper reaches of the three main branches of Naisud River. The mangrove area surrounding the river was divided into six fishery monitoring areas (refer to Lebata *et al*., 2009).

Wild *Scylla olivacea* crabs were obtained from the replanted mangroves in New Buswang, Kalibo, Aklan and described in detail in Walton *et al*. (2006). Batches of *S. olivacea*, measuring 30-79.9 mm carapace width (CW), were caught over a period of 4-5 days during spring tides within the duration of the release trials. Wild-caught crabs were tagged on the last day of each spring tide collection period. Hatchery-reared (HR) *S. olivacea* and *S. serrata* crabs were obtained from the Crustacean Hatchery of SEAFDEC/AQD. Hatchery-reared crabs were either released directly from the hatchery to the mangroves (HR-unconditioned) or first transferred to earthen ponds in Dumangas Brackishwater Station of SEAFDEC/AQD and reared for 1-1.5 mo before release (HR-conditioned). Except for the first batch of HR-unconditioned *S. serrata* (20-mm CW), both HR-unconditioned and HR-conditioned crabs measuring at least 30 mm CW were tagged for release. Tagging, release, and monitoring of recaptures were done following Lebata *et al*. (2009).

Release of hatchery-reared mud crabs in the wild has increased the overall yield by 46% from April 2002 to November 2005. An overall increase of 51% in CPUE number and 42% in CPUE biomass were recorded for the same period. The percentage of recaptured *Scylla* spp. in total monthly catches ranged from 11.9% (June 2004) to 62.3% (May 2005). Of the two *Scylla* spp. from different sources, wild-released *S. olivacea* had the highest recapture rates of 55.9% and HR-unconditioned *S. serrata* had the lowest at 12.5%. This supports the hypothesis that survival is higher in wild-released than in hatchery-reared crabs. Of the 12 size classes of *Scylla* spp., there was an increasing trend in percentage recapture observed from the smallest size class (20.0-24.9-mm CW; no recaptures) to 65.0-69.9-mm CW (54.2% recapture). This trend was observed in all batches of released crabs, regardless of species or source.

Lessons Learnt

Lessons learned from the different species released for stock enhancement:

Giant Clam, *Tridacna gigas*

1. Clams should be reared in ocean nurseries until the escape size of at least 20 cm SL
2. Clams should be reared in shallow reefs, 1.0-2.0 m deep during low tide
3. Among the sites where the clams were released, the site with warmer water gave better growth rates

Abalone, *Haliotis asinina*

1. Abalone may be batch tagged using the diet tagging techniques developed by Gallardo et al. (2003) or individually tagged using numbered dymotape before release to be able to differentiate them from their wild conspecifics
2. Abalone should be released at a minimum size of 3 cm SL
3. Abalone should be acclimated onsite before release for at least 3 days to eliminate mortalities caused by transport stress
4. Abalone should not be forcibly removed from the transport pipes during release; these pipes will serve as their temporary shelter in the wild and should be removed only from the site when all abalone have moved out voluntarily

Mud Crabs, *Scylla* spp.

1. Mangrove forest complexity affects mud crab density in the wild hence baseline assessment of stocks is very important before conducting release
2. Mangrove restoration enhances mud crab population in the wild and stock enhancement should only be considered only if habitat restoration doesn't work
3. Should there be a need for stock enhancement, translocation of wild crabs proved to be more effective than releasing hatchery-reared crabs
4. If hatchery-reared crabs will be released, they should be conditioned in ponds for at least 1 month before release
5. Crabs should be tagged internally because external tags won't work on animals that molt
6. Crabs should be released at a minimum size of 4.5 cm carapace width

Recommendations and Way Forward

As a general recommendation, baseline assessment of the population of the target species for release should be conducted first before considering any stock enhancement activity. This should include assessment of the habitat for presence of food and shelter for the stocks to be released. Possible predators that may prey on the released stocks should also be considered during site assessment. Animals for release should be tagged to differentiate them from their wild conspecifics. In areas where poaching is prevalent, secured areas such as marine protected areas, sanctuaries and the like are the recommended sites for release to provide stocks with some form of protection. Proper information dissemination should be employed before release for all stakeholders to be aware of the proposed activity which may, in one way or the other, affect their livelihood. Considering the many considerations before proper stock enhancement could be implemented, other options on increasing population or fisheries stocks should be considered before considering stock enhancement.

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Stock Enhancement of Portunid Crabs in Japan

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Abstract

Portunid crabs such as swimming crab *Portunus trituberculatus*, blue swimming crab *p. pelagicus* and mud crab species *Scylla paramamosain* and *S.serrata* are one of the most important fishery resources in Japanese coastal waters. The annual catch of the Portunid crabs have fluctuated between ~2,300 and 5,600 tons in Japan. In order to sustain and/or increase the Portunid crabs stock, a number of 30 million hatchery-produced juveniles have been released annually since the late 1980s. Estimating recapture rates of stocked crabs is indispensable to evaluate the effectiveness of stock enhancement programs, so that it is necessary to develop marking methods that distinguish between wild and hatchery-released individuals. The stocking effectiveness of Portunid crabs have been difficult to estimate because there have been no appropriate methods to mark small body sized juveniles which frequently molt. Therefore, recently, we developed a technique to mark juveniles and eventually estimated the contribution rates of released crabs to the total catch of the mud crab and swimming crab. The mixture rate of released juveniles in the total catch of the mud crab is estimated by the method of genetic stock identification, to be 5-19.7%. The contribution of released juveniles to the total catch was estimated to be about 0.5-1 metric ton. The recapture rate of released juveniles of the swimming crab is estimated by the marking technique of clipping swimming leg dactylus. Estimated contribution rate of marked crabs to the landings was about 3.0%. Effective marking methods and potential of stock enhancement programs for the Portunid crabs is discussed.

Keywords: juvenile release, marking, recapture rate, stocking effectiveness

Introduction

Portunid crabs such as swimming crab *Portunus trituberculatus*, blue swimming crab *P. pelagicus* and mud crab species *Scylla paramamosain* and *S. serrata* are among the most important fishery resources in Japan. The annual catch of the Portunid crabs in Japan have fluctuated between ~2,300 and 5,600 tons. In order to sustain and/or increase the Portunid crabs stock, about 30 million hatchery-produced juveniles have been released annually since the late 1980s.

Estimating the recapture rates of stocked crabs is indispensable to evaluate the effectiveness of stock enhancement programs. A technique was developed in Japan to mark the juveniles and eventually the contribution rates of released crabs to the total catch of the mud crab and swimming crab could be estimated.

The recapture rate of released juveniles of the swimming crab was estimated based on the marking technique of clipping the swimming leg dactylus. Thus, the estimated contribution rate of marked crabs to the landings was about 3.0%. Effective marking methods and potentials of stock enhancement programs for the Portunid crabs are discussed in this paper.

Mud crab (*Scylla paramamosain*)

In Japan, more than 1.0 MT of mud crab could be captured every year from three areas, namely: Lake Hamana, Urado Bay and Ryukyu Islands. In Lake Hamana and Urado Bay, the dominant species are *S. paramamosain* and in Ryukyu Islands is *S. serrata*. A study on stock enhancement of crabs was carried out in Urado Bay, Kochi Prefecture in Japan (**Fig. 1**).

Considering that estimating the recapture rates is indispensable in order to evaluate the effectiveness of stock enhancement programs, it has become necessary to develop marking methods in order to distinguish between wild and reared individuals. At the early stages of the program, the stocking effectiveness of mud crabs was difficult to estimate because of lack of effective marking methods.

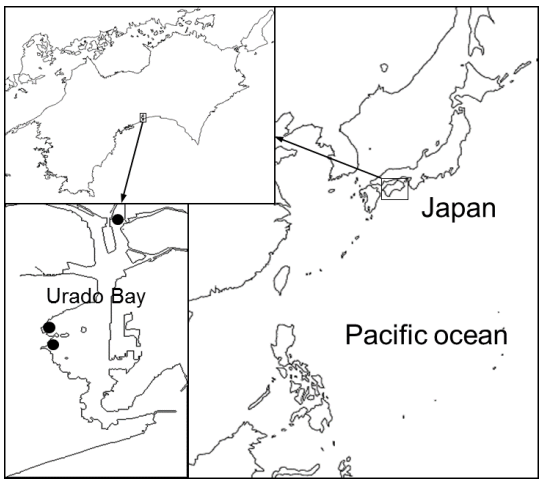

Fig. 1. Map showing the location of Urado Bay where marking surveys for *S. paramamosain* were conducted (black circles indicate the release points)

Due to their small size, the carapace width (CW) is about 10 mm, external tags could not be used on released juvenile mud crabs. Therefore, the use of genetic tags using mtDNA D-loop region was adopted. The haplotypes of mtDNA D-loop region were determined for a sample based on the methods detailed in Imai *et al.* (2002).The mtDNA D-loop region was amplified by PCR. The PCR product was digested by three restriction enzymes (Hinf Ⅰ, PshB Ⅰ and Pac Ⅰ). The RFLP profiles were visualized by agarose gel electrophoresis, where haplotypes were discriminated.

A total of 98-149 broodstock females (CW 143 mm) were collected using gill nets in Urado Bay around December each year. A minor haplotype was selected as the genetic tag for released juveniles. About 3-5 million larvae from selected crabs were reared in a 200-kg indoor tank at Tamano Station, out of which between 72 thousand and 149 thousand juveniles were released during mid-May to early-June of each year from 1997 to 2001. The mean carapace width was between 8.5 to 9.9 mm, and each year, haplotypes of the released crabs differed.

From 1997 to 2002, 145 to 567 live *S. paramamosain* were collected, with a carapace width exceeding the market-size of 11 cm, from fishers during the main fishing season from August to December. The mean carapace width of collected crabs was 13.6 cm. The percentage of released juveniles (mixed populations) in the total catch was estimated using the maximum likelihood method. The log likelihood function for the samples is given by this equation (Obata *et al*., 2006). In this case, the log likelihood function is maximized using the estimates of haplotype frequency.

$$\log L(\theta \mid n_i^{(0)}, n_i^{(1)}, n_i^{(2)}) =$$

$$\sum_{i=1}^{m} n_i^{(0)} \log\left(\theta p_i^{(1)} + (1-\theta) p_i^{(2)}\right) + \sum_{j=1}^{2}\left(n_1^{(j)} \log p_1^{(j)} + \cdots + n_m^{(j)} \log p_m^{(j)}\right)$$

θ : the mixing rate of stocked crabs

m : the frequency of haplotype i in baseline population j

$n_i^{(0)}$: the number of individuals that haplotype i in the sample drawn from the mixed population

$n_i^{(j)}$: the number of individuals that haplotype i in the samples drawn from baseline population j

$p_i^{(j)} = \dfrac{n_i^{(j)}}{n}$: the estimates of haplotype frequency

Optimization was performed to the quantity of released juveniles (mixed populations), using the solver of Microsoft Excel. The 95% confidence intervals were estimated by the bootstrap method, using 10 thousand times re-sampling of the sample with replacement. The life span of this crab is about 2 years and newly settled crabs were considered to reach market-size in October. Assuming that the crab's life span is two years, the mixed population was divided into 2 periods, where the period from October in the release year to September the following year was taken as the first year after release while the period from October the following year of release to June in the year after the next was considered as the second year after release. The frequency of haplotypes in the 1997 release group increased from 15.4% to 30.5% after release. While the 1998 release group also increased from 9.8% to 16.1%, but the 1999 release group did not increase after release. However, the 2000 release group increased from 2.7% to 4.4%, and likewise, the 2001 release group also increased from 0.9% to 7.5% (**Table 1**).

In the 1997 release group, the weight and number of catch were estimated at 915 kg and 2,226 individuals, respectively. The 1998 release group had 1145 individuals and weighed 471 kg, the 2000 release group, the weight was estimated at 77 kg with 188 individuals, and the 2001 release group had 588 individuals and weighed about 242 kg. The return rates of each release group were calculated as 2.26%, 1.53%, 0.23% and 0.39%, respectively. The unit cost of released juveniles was about five Japanese Yen. The mean market price of mud crabs was about 2,500 Yen/kg. The economic efficiency was therefore calculated as 4.7, 3.1, 0.5 and 0.8, respectively, for each release groups. As a result, the *S. paramamosain* stock enhancement program has been considered as economically viable in two cases.

Table 1. Changes in the haplotype frequency (%) which was selected as a genetic tag for each release group of *S. paramamosain*

Year of release	Haplotype used for the tag	Previous year of each release		First year after release[1]		Second year after release[2]	
		Haplotype (%)	*n*	Haplotype (%)	*n*	Haplotype (%)	*n*
1997	2	15.4	149	30.5	213	25.9	143
1998	3, 9	9.8 [3]	213	16.1	143	10.9	403
1999	4	7.7	143	3.7	403	6.1	521
2000	6	2.7	403	4.0	521	3.2	158
2001	18	0.8	521	7.0	158	2.0	247

[1] October in release year to September in the following year.

[2] October in the following year of release to June in the year after next.

[3] Haplotype 3 and 9 were combined.

Swimming crab (*Portunus trituberculatus*)

A marking method used for swimming crab juveniles was by clipping the dactylus of the swimming leg from the central tip, with small scissors. Three types of malformed dactylus were found and the frequency of crabs with malformed swimming leg dactyli reached about 70% with vertical slit of about 60% of the dactylus length. Further, the size of juveniles for clipping dactylus should be at fifth crab stage with 20 mm carapace width. Mark-recapture experiments were carried out at Tajiri, Hiroshima Prefecture in Seto Inland Sea (**Fig. 2**). A total of 11,900 and 13,000 hatchery-produced juveniles with clipped swimming leg dactyli were released at the artificial tideland in 2006 and 2007, with mean carapace widths of 28.4 mm and 29.9 mm, respectively. The juveniles were transported from the hatchery to the release site for 2 hours by truck. The swimming crabs were captured using a small set net and were landed at Tajiri Fish Market. Sampling surveys for estimating the mixed populations of marked crab to commercial catches were carried out at the said market. Total catch during the sampling survey was 2.7 metric tons in both years. The ratios of observed number of crabs in the total catches were 28% in 2006 and 21% in 2007. Numbers of crabs surveyed were 3874 individuals in 2006 and 2407 individuals in 2007. Numbers of marked crabs in the catches were estimated at 130 individuals in 2006 and 57 individuals in 2007. The quantity of marked crabs in the total catches was estimated at 3.36% in 2006 and 2.37% in 2007 (**Table 2**).

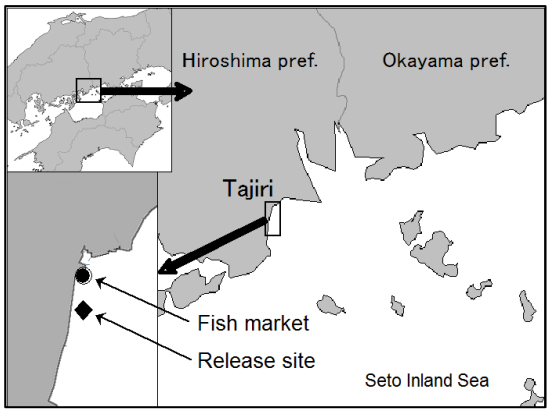

Fig. 2. Map showing the location of Tajiri in Seto Inland Sea, Hiroshima Prefecture, Japan

Table 2. Estimates of weight and number of recaptures, and recapture rate of released crabs

Year	Number of juveniles released (individual)	Total catch (kg)	Mixture rate (%)	Estimates for recaptures			
				Weight (kg)	Number (individual)	Ratio (%)	YPR (g/ individual)
2006	11,900	2,516	3.36	81	473	4.0	6.8
2007	13,000	2,722	2.37	59	288	2.2	4.5

In the 2006 releases, the weight and number of recaptures and recapture rate of released crabs were 81 kg, 473 individuals and 4.0%, respectively, and 59 kg, 288 individuals and 2.2%, respectively in the 2007 releases. Yields from released individuals (YPR) were estimated at 6.8 g in 2006 and 4.5 g in 2007. YPR was estimated at 33.6 g for *P. trituberculatus* using regression analysis between annual number of C2 juveniles released and annual catches in Seto Inland Sea. Results should that the YPR estimates of 4.5–6.8 g from marking surveys were lower than that value. This could be due to the estimations carried in marking surveys that depend on catches from small set nets. After recruitment, swimming crabs are also caught by gill nets and small trawls, so the YPR in the marking surveys could be underestimated. The manner of clipping the dactylus might have also affected the behavior of released juveniles resulting in low survival rate or the quality of seed juveniles might have reduced due to loss of legs during the nursery culture before release.

Recommendations

Marking method for swimming crab, using mtDNA control region sequence and microsatellite DNA markers had been developed. The stocking effectiveness of swimming crab in Ariake Bay has been investigated using this method together with release techniques such as size, time and site at release. However, it is also necessary to estimate not only the stocking effectiveness but also reproduction by the released crabs.

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Approaches in Rebuilding Sea Urchin and Sea Cucumber Populations in the Philippines

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Abstract

Sea urchins and sea cucumbers are among the most valuable and overexploited fishery resources. Culture and release of juvenile *Tripneustes gratilla* and *Holothuria scabra* have been undertaken to rebuild depleted populations and provide a supplemental source of income for fishers. In both cases an integrated socio-ecological approach was used. Studies on factors affecting growth and survival of released juveniles were conducted alongside active participation of local partners in site management and regular monitoring. For *T. gratilla*, community-based grow-out in sea cages complemented with restocking of protected areas helped in the recovery of a collapsed fishery. Gonad biomass and quality of sea urchins fed with *Sargassum* were high. These increased the value of the gonads and reproductive output of cultured sea urchins. In the case of *H. scabra*, release of juveniles in a communal sea ranch resulted in the build-up in density and biomass. Observations of regular mass spawning in the sea ranch established that a viable spawning population was maintained through selective harvesting. Both the sea urchin cage grow-out culture and sea cucumber sea ranch function as reproductive reserves and source of larval supply to adjacent suitable habitats. In addition, wild recruits in the sea ranch and in the vicinity of the sea urchin sea cages indicate that natural recruitment may be enhanced by the high density of conspecific adults. These models have demonstrated that both ecological and economic benefits can be realized through of responsible culture-based management interventions. The development of appropriate governance mechanisms is a critical consideration for sustainability.

Keywords: community-based grow-out, sea ranching, sea urchin, sea cucumber

Introduction

Marine invertebrates are harvested for livelihood and sustenance by coastal communities. Some species are among the most highly valued marine food commodities. It is estimated that about 34% of global invertebrate fisheries are overexploited or have collapsed (Anderson *et al*., 2010). This is the case for sea urchin and sea cucumber fisheries in many countries worldwide, including the Philippines (Andrew *et al*., 2002;Choo, 2008).In the tropical Indo-Pacific, the pin cushion sea urchin *Tripneustes gratilla* is highly valued for its roe (*uni*) (Juinio-Meñez *et al*., 1998) and *Holothuria scabra*, commonly known as sandfish, is one of the most expensive tropical sea cucumber species processed into "beche-de-mer" or *trepang* in the international market.It is currently the only tropical Indo-West Pacific species of sea cucumber that can be mass-produced and culture of this species is being undertaken in several countries at different scales (Purcell *et al*., 2012). Populations of both species are depleted in many areas due to overexploitation given the high demand in the luxury seafood industry. This has resulted in the loss of a source of income and livelihood of many small fisher families. Culture and release of juvenile *Tripneustes gratilla* and *Holothuria scabra* have been undertaken to rebuild depleted populations and provide a supplemental source of income for fishers. Culture production and management approaches for the two species were developed and implemented in Bolinao, Pangasinan, in northwestern Philippines (**Fig. 1**). In both cases, an integrated socio-ecological approach was used. Studies on factors affecting growth and survival of released juveniles were conducted alongside the active participation of local partners in site management and regular monitoring.

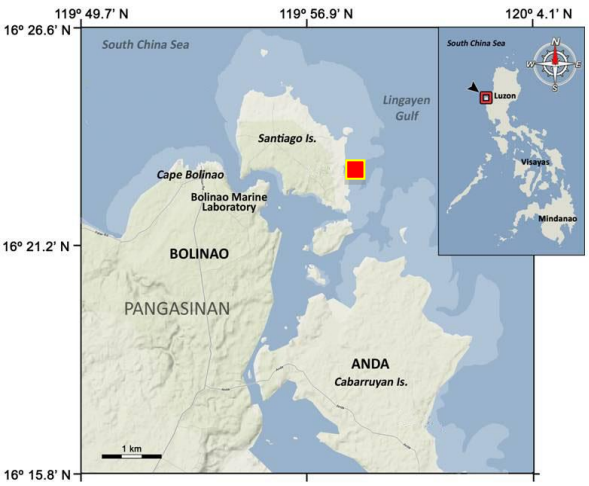

Fig. 1. Location of the U.P. Marine Science Institute' Bolinao Marine Laboratory where sea urchins and sea cucumbers are produced for culture-based resource management interventions on sea urchin grow-out culture and restocking, and sandfish sea ranching (indicated by square)

Activities and Results

Community-based Grow-out culture and Restocking of *T. gratilla*

T. gratilla was cultured in the hatchery and early juveniles (>1 cm) were used for community-based grow-out culture and restocking. To optimize survival to adulthood of the limited number of hatchery-reared seedstock, grow-out culture was developed to address ecological and socio-economic considerations while rebuilding the spawning populations (Juinio-Meñez *et al*., 1998). Feeding and stocking experiments in sea cages were undertaken to optimize gonad quality and yield.

Results showed that feeding sea urchins with *Sargassum* spp. resulted in better growth and gonad quality than when fed the seagrass Significant increases in catch per unit effort, as well as in the density of recruits were observed after restocking and sea cage culture interventions (Juinio-Meñez *et al*., 2008). The higher density of recruits in sites with grow-out culture further indicated that the high density of adult conspecifics in the cages enhanced local recruitment (Juinio-Meñez *et al*., 2009). *Thalassia hemprichii*. Histological analysis of gonads showed that gonadal development of sea urchins in the cages were highly synchronous and had lunar periodicity. Together with the high reproductive output due to gonad quality, synchrony in spawning will increase fertilization success and larval supply, which can contribute to natural recruitment. The sea cages served as de facto reproductive reserves prior to harvesting. Fishery dependent (*i.e*. landed catch) and fishery independent (*i.e*. regular field surveys) monitoring were undertaken to evaluate the impact of interventions and determine recruitment strength in the wild.

Population genetic studies showed that there is very high genetic exchange and connectivity among *T. gratilla* populations in the northwestern part of Luzon (Malay *et al*., 2002; Casilagan *et al*., 2013). This indicates that the sustainability of the fishery stock is dependent on maintaining viable spawning populations in various locations across the northwestern region of Luzon.

Communal *H. scabra* sea ranch

Sea ranching of sandfish *H. scabra* is being developed as a means to enhance natural stocks and provide sustainable supplemental livelihood for fishers. The management framework for communal sea ranching of sandfish ensures that benefits accrue to both the "rights holders" and other community members (Juinio-Meñez *et al*., 2013). Field surveys showed that sandfish, which used to be a major species collected in the area, was rare and very low in density in the landed catch.

A 5-hectare subtidal area on the southeastern coast of Santiago Is. in Bolinao (**Fig. 1**) was chosen for the establishment of the pilot sea ranch. Aside from habitat suitability, the presence of an active people's organization with experience in coastal resources management and support of the local government were primary considerations in the selection of the sea ranching site. Multiple releases totaling about 10,000 juveniles (>3 g) per year were undertaken in the sea ranch starting 2008.

Quarterly monitoring was conducted to estimate population growth rate based on size frequency analysis. The abundance of sandfish increased from 416 to 5,562 individuals with a corresponding increase in biomass from 7 to 221 kg ha^{-1} over the 19-month period. Apparent survival was estimated at 20-30%. The estimated density of adults in the sea ranch reached up to 500 individuals ha^{-1} (Juinio-Meñez *et al*., 2013).

While sandfish attain sexual maturity at around 180 g, only sandfish > 320 g are harvested since prices are dependent on size. As such, a viable spawning population has been maintained at the sea ranch for over seven years. Mass spawnings of sandfish have been regularly observed in the sea ranch and wild recruits were found during most monitoring periods.

Landed catch monitoring showed a significant increase in the volume of sandfish harvested in adjacent areas. Local collectors attribute the increase in the catch to the sea ranch, which is the source of larvae and recruits in their fishing areas.

Recent population genetic studies showed high genetic variability in *H. scabra* populations throughout the Philippine archipelago (Ravago-Gotanco *et al*., manuscript in prep). Thus restocking of cultured juveniles produced from broodstock obtained from a different genetic stock should be avoided.

Lessons Learned

For *T. gratilla*, community-based grow-out in sea cages complemented with restocking of protected areas helped in the recovery of a collapsed fishery. Gonad biomass and quality of sea urchins fed with *Sargassum* were high. These increased the value of the gonads and reproductive output of cultured sea urchins. In the case of *H. scabra*, the release of juveniles in a communal sea ranch resulted in the build-up of density and biomass.

Observations of regular mass spawning in the sea ranch established that a viable spawning population can be maintained through selective harvesting. Both the sea urchin cage grow-out culture and sea cucumber sea ranch function as reproductive reserves and sources of larval supply to adjacent suitable habitats while providing additional sources of income to small fishers. The cooperators gain direct benefits from exclusive harvest rights and the spill-over benefits of the spawning populations benefit many other fishers. The presence of wild recruits in the sea ranch and in the vicinity of the sea urchin sea cages indicates that natural recruitment may be enhanced by the high density of conspecific adults in these managed areas. These models have demonstrated that both ecological and economic benefits can be realized through responsible culture-based management interventions. The development of appropriate local governance mechanisms is a critical consideration for the sustainability of the initiatives. Active engagement with local stakeholders facilitated awareness raising and development of local capabilities in coastal resources management. Local cooperators who participated in these efforts were very effective in fishery management information and education campaigns and supported the passage of local regulations on harvest size limits.

Way Forward

Culture-based resource management interventions have become imperative due to widespread depletion of fishery stocks. However, these involve considerable investment and high associated risks, and in order to be effective, these should be science-based; there should be regular monitoring, evaluation and feedback to stakeholders and resource managers; and adherence to responsible sustainability practices. To scale up both ecological and economic impacts, these interventions should be incorporated within an integrated capture fishery management program.

Management should be undertaken at the level of local municipalities, as well as at broader management systems to maintain the natural bio-physical and genetic connectivities of the fishery stocks.

The long term goal is to rebuild a productive and sustainable capture fishery independent of the release of hatchery-cultured juveniles. To conserve genetic diversity and ensure the resilience of local stocks to environmental changes, cultured juveniles should be released only in areas with similar genetic stock.

Given the high genetic diversity in the Philippines, the development of hatcheries to increase production using discrete stocks in different regions is important. Scaling up through involvement of different stakeholders (*e.g.* commercial hatcheries, fisher organizations, government agencies) could be facilitated through the development of low-cost ocean nursery and grow-out systems accessible to many small fishers, and enhanced management of marine invertebrate resources.

Acknowledgements

The studies summarized in this article were undertaken through the efforts of various research personnel and local collaborators particularly the people's organization in Victory (*Samahan ng Maliliit na Mangingisda ng Victory, Inc.)* with funding from the Philippines' Department of Agriculture- Bureau of Agricultural Research and the Department of Science and Technology – Philippine Council for Marine and Aquatic Resources Management. Funding for sandfish sea ranching was also provided by the Australian Center for International and Agricultural Research (ACIAR FIS/2003/059 and FIS/2010/042), with counterpart support from the University of the Philippines Marine Science Institute and the hatchery facilities at the Bolinao Marine Laboratory. Travel support for the presentation of this paper was provided by SEAFDEC/AQD.

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Session Papers
Session 6: Aquaculture-based Enhancement and Restoration

With the Head of AQD's Research Division *Dr. Evelyn Grace de Jesus-Ayson* as Facilitator, the Session had three speakers presenting the results of their activities focusing on aquaculture-based enhancement and restoration. The speakers were: (1) *Dr. Jon P. Altamirano* on Aquaculture-based Restoration and Stock Enhancement of Tiger Shrimps in the Philippines; (2) *Dr. Jintana Nugranad* on Aquaculture-based Enhancement and Restoration of Giant Clam in Thailand; and (3) *Dr. Hoang Dinh Chieu* on Aquaculture-based Enhancement and Restoration of Many-colored Abalone Resources (*Haliotis diversicolor*) in Bach Long Vi National Marine Protected Area in Viet Nam.

In the presentation of ***Dr. Jon P. Altamirano***, he shared the results of a study on stock enhancement of tiger shrimp (*Penaeus monodon*) in New Washington Estuary (NWE) in the Province of Aklan in central Philippines with the collaboration of and support from the Research Institute for Humanity and Nature (RIHN) of Japan. While providing the background, he also gave the reasons why tiger shrimp stock in that area should be restored. He cited the impacts of the tiger shrimp stock enhancement which included increased income of fishers, reduced number of fishing gear, mangroves rehabilitation promoted, and methods for implementation the tiger shrimps stock enhancement established considering the biological, technical and socio-economic aspects. Although the impact of shrimp stock enhancement in NWE is site-specific, the results after implementing the stock enhancement activity, where fishers used conservative simulators for capturing the release stocks, indicated that their incomes had increased by 300%. During discussion, Dr. Altamirano explained that in the stock enhancement study, intermediate rearing was necessary especially because stocking was done in abandoned ponds and distant rearing could lead to high mortality. Nevertheless, he also mentioned that mixed technique could be adopted prior to releasing the seeds to the waters for increased survival rate. With regard to tagging, he suggested that the seeds to be tagged should weigh 1.0 g based on cohort analysis. Dr. Altamirano added that the community has been engaged as part of the project and helps in monitoring the stocks twice a month, and encouraged fishers to report the tagged stocks that have been captured. As for rehabilitation of the mangroves, he provided the information that the Philippines has a law for the protection of mangrove areas but in this area, the mangroves have not been rehabilitated when aquaculture operations in the area were not very productive and some ponds had been abandoned.

The paper of ***Dr. Jintana Nugranad*** focused on the giant clam species in Thailand which is a protected species under Thailand's Wildlife Conservation and Protection Act of B.E. 235. Considering that the natural stock of giant clams has been declining to scarcity in their natural distribution area, hatchery breeding and seed production of the giant clam species *Tridacna squamosa* had been carried out in Thai waters by DOF Thailand since 1993. However, such seed production and restocking of giant clam in Thailand is undertaken mainly for conservation purposes. In the discussion, Dr. Jintana explained that results of the trial restoration of giant clam attained a survival rate of 40% although this could have been influenced by various factors that affect the environment. The restoration of giant clam made use of metal netted cages to protect the stocks from predators. Dr. Jintana also mentioned that as reported, high survival has been attained in giant clams stocked in national parks although such trend is still being established by the Department of Marine and Coastal Resources of Thailand.

The paper of ***Dr. Hoang Dinh Chieu*** discussed the experience of Viet Nam in artificial breeding of abalone (*Haliotis diversicolor*) in Bach Long Vi (2012-2015). Dr. Hoang specified that the many-colored species of abalone (*Haliotis diversicolor*) is of high commercial value in Viet Nam, but the abalone stocks in the natural habitat had decreased due to over-exploitation. In order to restore the natural abalone resources, artificial breeding had been carried out resulting in production of 1,250,000-2,000,000 larvae and 137,960 juveniles (6.4-17.3 mm length) with survival rate of 6.9-11.0%. About 6,000 juveniles (1 cm length) were then released in Bach Long Vi National Marine Protected Area in 2014 for conservation. After one year, the abalones were found to have attained an average shell length of 3.4 cm.

Aquaculture-based Restoration and Stock Enhancement of Tiger Shrimps in the Philippines

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Abstract

In central Philippines, the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD), with strong collaboration and support from the Research Institute for Humanity and Nature (RIHN) of Kyoto, Japan, has been looking into the stock enhancement of tiger shrimp *Penaeus monodon* in the New Washington Estuary (NWE), province of Aklan, central Philippines. The NWE was a productive fishing ground that has been suffering from degenerating brackishwater fisheries and estuarine environment. Average daily catch declined from 24 kg in 1970s to only 0.7 kg at present. Shrimp fisheries, the most important livelihood, declined in quality and quantity. Tiger shrimps were abundant in catch until the early 1990s when these were observed to decline in volume, replaced by smaller and cheaper species. This was coincidental with the rapid decline in mangrove cover for ponds and huge increase in fishing pressure. It is clear that crucial interventions are required to restore the tiger shrimp fisheries in the NWE in order to increase income of local fishers, while promoting reduction of fishing gears and restoration of mangroves. Stock enhancement of tiger shrimps shows good potential in answering these needs. Site-specific assessments were conducted to evaluate prospects of shrimp stock enhancement in NWE. Conservative simulations of capture of released stocks showed that fishers can increase income by 300%. To decrease fishing pressure in the area, number of gears per fisher may have to be reduced but shrimp catches will be relatively high-priced. Comparative experiments using aquaculture techniques were done to identify strategies especially in the delicate intermediate acclimation rearing. Aquaculture protocols like those for pond preparation were also adapted to be used in a mangrove pen nursery rearing system for shrimps. Supplemental feeding with formulated feeds increased carrying capacity of the culture area, while enhancing growth and survival of stocks. Culture experiments showed that shrimps grow to 0.5 g within 1 mo and >1g in 2 mo. High stocking density of 40-60 shrimps m^{-2} can be used for <2 mo rearing in a mangrove pen. Release experiments showed that 60-d old shrimps have higher chances of survival when released in the estuaries. With strong support from local communities, government and other sectors, together with effective management and law enforcement, aquaculture-based stock enhancement of tiger shrimps can be a viable intervention to restore livelihood and promote estuarine rehabilitation in the NWE.

Introduction

The Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) with strong collaboration and support from the Research Institute for Humanity and Nature (RIHN) of Kyoto, Japan has been looking into the stock enhancement of tiger shrimp *Penaeus monodon* in the New Washington-Batan (NW-B) Estuary, Province of Aklan, central Philippines (**Fig. 1**). The NW-B Estuary used to be a productive fishing ground but has suffered from degenerating brackishwater fisheries and estuarine environment. Catch per unit effort (CPUE kg $gear^{-1}$ d^{-1}) declined by almost half in every decade since 1970 (**Table 1**). Specifically, shrimp fisheries which is the most important livelihood, declined in quality and quantity. Tiger shrimps were dominant in catch until the early 90s when these were observed to decline in volume, replaced by smaller and cheaper species like the greasy-back shrimp *Metapenaeus ensis* (Ingles *et al*., 1992).

This was coincidental with the rapid decline of mangrove cover where 76% has been converted to ponds by late 1990s (Altamirano *et al*., 2010). A great number of stationary fishing gears also proliferated increasing by 400% from two decades ago (Altamirano and Kurokura, 2010).

It is clear that crucial interventions are required to restore the tiger shrimp fisheries in the NW-B Estuary to increase the income of local fishers, and promote reduction of fishing gears and restoration of mangroves. Shrimp stock enhancement shows good prospects in answering these needs where fishers can potentially increase income by 400% and reduce fishing gears by 60% (Altamirano *et al*., 2015). Mangrove rehabilitation programs can then be conducted through education and information campaigns, emphasizing on the roles and functions of mangroves as nursery for fish and shrimps.

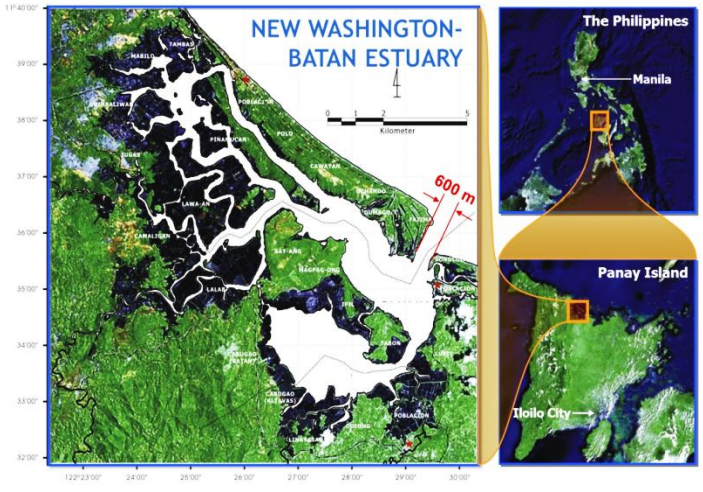

Fig. 1. Located at the northern coast of Panay Island, New Washington-Batan Estuary is a semi-enclosed lagoon and river system receiving seawater from a 600-m opening, while freshwater drains through various creeks and streams around the estuary

Activities Conducted

Baseline assessment

The project started during the last quarter of 2012 mainly focusing on preparation and networking with concerned partners like the local government units (LGUs) of the Municipality of New Washington, Aklan State University (ASU), and the resident fishing community, represented by the local people's organizations called the Pinamucan Small Fisherfolk Association (PSFA). Secondary data for both environmental and socio-economic aspects have been collected from literatures and government records. Collection of baseline information on the socio-economic status of fishers and actual catch was done since January 2013.

Preparation

Local fishers, who are members of the local PSFA, participated in the stock enhancement activities and were successful in the construction and preparation of the intermediate nursery culture site using an abandoned pond in a mangrove area in the middle of the NW-B Estuary (**Fig. 2**). The fishers are also involved in monitoring of the shrimps during intermediate rearing, as well as maintenance of the nursery site. Additionally, other fishers and local traders are responsible in recording actual catch to aid in the assessment of impacts of the project.

Table 1. CPUE from fish corral or stake nets in NW-B Estuary from 1970 to 2013 (updated from Altamirano and Kurokura, 2010)

Year	CPUE (kg gear^{-1} d^{-1})	REFERENCE
1970	24.00	Altamirano & Kurokura (2010)
1980	10.00	Altamirano & Kurokura (2010)
1990	7.66	Ingles *et al*. (1992)
2000	5.00	Altamirano & Kurokura (2010)
2000	3.44	Babaran *et al*. (2000)
2006	1.65	Altamirano & Kurokura (2010)
2013	0.73	Current study

Site and Species-specific Experiments

Site-specific assessments were conducted to optimize the success in rearing and release of tiger shrimps for stock enhancement in NW-B Estuary. Comparative experiments using aquaculture techniques were done to identify the strategies especially in the delicate intermediate acclimation rearing. Aquaculture protocols like those used in pond preparation were also adapted in a mangrove pen nursery rearing site for shrimps. Supplemental feeding with formulated feeds especially at initial stage of rearing increased survival and growth of juvenile shrimps, while optimizing carrying capacity of the rearing area.

Intermediate Nursery Rearing

Intermediate rearing of shrimps for stock enhancement adapted various aquaculture techniques for rearing tiger shrimps in ponds. Four intermediate culture trials were conducted in 2014 to test site-specific requirements for rearing juvenile tiger shrimps in a mangrove pen. Parameters like stocking density and optimal time for release were tested experimentally. Based on best results from these four trials, another intermediate rearing run was conducted in April 2015 that was successful in releasing an estimated 250,000 shrimps (51% survival) of desired size (>0.5 g) after 30 days of rearing.

Release and Monitoring

Actual catch monitoring is being done since January 2013 with data on catch volume, and species composition forming part of the baseline data. As a representative, 20 fixed fishing stations are monitored regularly twice a month to detect impacts of release activities.

Lessons Learned

Species selection

In 1970s, tiger shrimps *P. monodon* composed the majority of shrimp catch of fishers (Ingles *et al*., 1992), indicating their natural historical abundance in the NW-B Estuary. The restoration and enhancement of tiger shrimps in the area augments the limitation of natural recruitment of the species, while environmental rehabilitation is in preparation. The selection of tiger shrimps as the target species is not only based on historical ecology of NW-B Estuary but is socially-driven as well. Based on validation interviews with local fishers, tiger shrimps turned out to be the top species of choice – being preferred by 82 out of 200 interviewees – for stock enhancement in the area because of its rarity and value; while white shrimp *Penaeus ensis* and grouper *Epinephelus* sp. were only preferred by 26 out of 200 fishers.

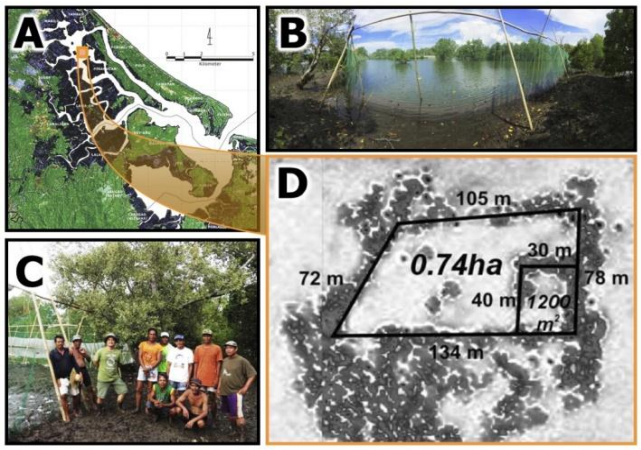

Fig. 2. The intermediate nursery area is in the upper estuary (A) where salinity and water temperature are conducive for young shrimp juveniles. Nets supported by bamboos (B) constructed by local PSFA members (C) were placed around an abandoned pond, surrounded by naturally regenerating mangroves, dominated by *Sonneratia alba* (D)

Source and Health of Stocks

In a stock enhancement program, it is crucial to maintain local genetic diversity. Therefore, it is important to refrain from the translocation of non-native populations. Fortunately in NW-B Estuary, at least four local shrimp hatcheries are operating within 20 km of the area, making use of only wild-caught local shrimp spawners collected from nearby seas. This assures that shrimp post-larvae and juveniles used in release activities at NW-B Estuary carry local genes. Similarly important is making sure that stocks are clean. So, screening and testing for bacterial and viral diseases were conducted periodically to ensure the health of stocks.

Intermediate Acclimation Rearing

Specifically for shrimps, an intermediate nursery phase is necessary to increase the chances of survival when released, considering that postlarvae from the hatcheries are too small (<1.0 cm total length) and predation could be very high when released directly to estuaries. Moreover, these hatchery-bred individuals are accustomed to feed on artificial diets and clean environment in tanks. A transitional or intermediate nursery culture phase is therefore needed to condition and acclimate the postlarvae in a natural estuarine environment. Experiments conducted for this study was able to establish some optimal conditions for intermediate rearing. Location of the rearing site must be at the upper river areas with optimal salinity of 15-25 ppt for young shrimp juveniles. Age of shrimps to be released is optimal at 60 days old, so 20-30 day-old postlarvae from hatcheries need to be reared in intermediate acclimation nurseries for about 30 more days. At this age, body weight postlarvae should ideally be ~0.5 g with ~20 mm carapace length. At this particular site in NW-B Estuary, optimal stocking density is 40-60 juvenile shrimps per m^2 for ~30 days culture duration. In addition, considering that the site is affected by seasonal storms, the best time for rearing and release at the NW-B Estuary is from April to June when typhoons are expected to be minimal.

Initial Impacts of Stock Enhancement

Immediate increase in catch after rearing and release activities can clearly be seen even with the small-scale monitoring of 20 fixed gears (**Fig. 2**). In 2013, average catch from all 20 stations was only 1 tiger shrimp per month. The first rearing trial in Jul 2013 suffered very high mortality but possible escapees caused a slight catch increase of 3-4 pcs per month in August and September.

Super Typhoon Haiyan in November 2013 caused an immediate decline in catch in December because most gears were destroyed. Another corresponding increase in catch (6 pcs mo^{-1}) was recorded in January and February 2014 when fishing gears where repaired and fishing operations resumed. Successful rearing and releases in April and Jul 2014 caused a steady increase in tiger shrimp catch from May (2 pcs mo^{-1}) to Aug 2014 (20 pcs mo^{-1}). Typhoons in November and early December 2014 caused another unsuccessful rearing and stocks to escape, thereby increasing catch in December (13 pcs mo^{-1}). Incorporating all best practices and optimal protocols from previous 4 trials resulted in the most successful rearing and release run in April and May 2015. This also resulted in the highest *P. monodon* catch (28 pcs mo^{-1}) recorded in June 2015; while another failed rearing with escapees in July still reflected some increased catch in August 2015.

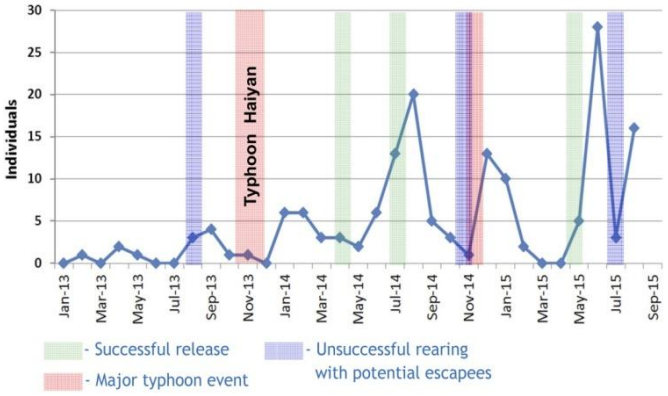

Fig. 3. Monthly total catch of tiger shrimps from 20 fixed gears from Jan 2013 to Aug 2015. Months of rearing and release activities (green and blue), as well as major typhoon events (red) are highlighted

Conclusion and Recommendations

Fisheries Management

The stock enhancement activities in the NW-B Estuary showed a clear impact in shrimp fisheries (**Fig. 3**). However, increased catch immediately after release activities indicated very active and strong fishing pressure in the area. In all of these cases, good catch were not sustained and steep decline in tiger shrimp harvest were clearly evident afterwards. This result suggests that some fisheries management intervention in terms of catch regulations must be considered and implemented in the area. With strong support from local communities, government and other sectors, together with effective management and law enforcement, aquaculture-based stock enhancement of tiger shrimps could be a viable intervention to restore livelihood and promote estuarine rehabilitation in the NW-B Estuary.

Key ingredients for success

The following are recommended key points to consider for best chance of success for a stock enhancement program:

- ❑ Partnership with a local community with strong leadership
- ❑ Sufficient social preparation and capacity building
- ❑ Active community participation from planning to implementation
- ❑ Diversification of activities and livelihood for community
- ❑ Accurate, reliable and science-based baseline information
- ❑ Site-specific and species-specific assessments and studies
- ❑ Multi-institutional/sectoral collaboration
- ❑ Establishment of legal framework and agreements among collaborators

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Aquaculture-based Enhancement and Restoration of Giant Clam in Thailand

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Abstract

Giant clams are protected species under Thailand's Wildlife Conservation and Protection Act of B.E. 2535. Natural stock of giant clams has been declining to scarcity in almost every natural distribution area. Among three living giant clam species in Thai waters, *Tridacna squamosa* was considered the most endangered with less than 1% in existing number. Successful hatchery breeding and seed production of this species has been achieved by Thailand Department of Fisheries since 1993. After that, the giant clam restocking programs have been carried out at several sites both in the Gulf of Thailand and the Andaman Sea with various levels of success. Unlike other fisheries resources, the giant clam seed production and restocking in Thailand have been targeted mainly for conservation purposes. The restocking programs were cooperated by Department of Fisheries and Department of Marine and Coastal Resources. The activities have been conducted in collaboration with local communities, private sectors, as well as conservationists. Details on methodology, constraints, and results will be presented and discussed.

Introduction

In Thailand, giant clams (*Tridacna* spp.) are protected species under the Wildlife Conservation and Protection Act of B.E. 2535. These species are known to have potentials for commercial culture, especially for the aquarium trade. There are three existing giant clam species in Thailand (**Fig. 1**): *Tridacna crocea*, *T. maxima* and *T. squamosa*. These species are distributed in the waters of Thailand (**Fig. 2**), such as the Gulf of Thailand (25%) and the Andaman Sea (75%). Recent reports have indicated that in Thai waters, *T. crocea* is still abundant and *T. maxima* relatively abundant. However, *T. squamosa* is already endangered (**Fig. 3**). It is for such reason that efforts are being made to breed and enhance the stock of *T. squamosa* in Thai waters.

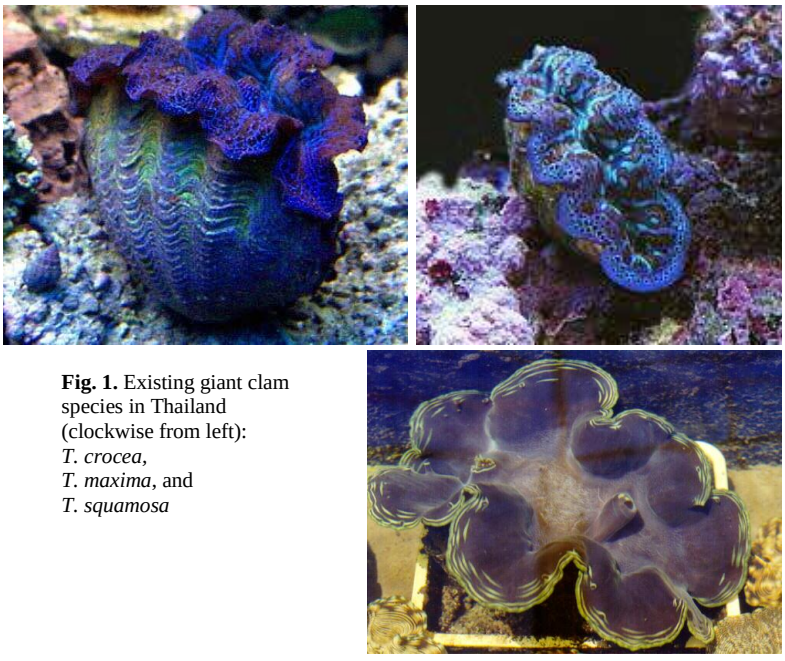

Fig. 1. Existing giant clam species in Thailand (clockwise from left): *T. crocea*, *T. maxima*, and *T. squamosa*

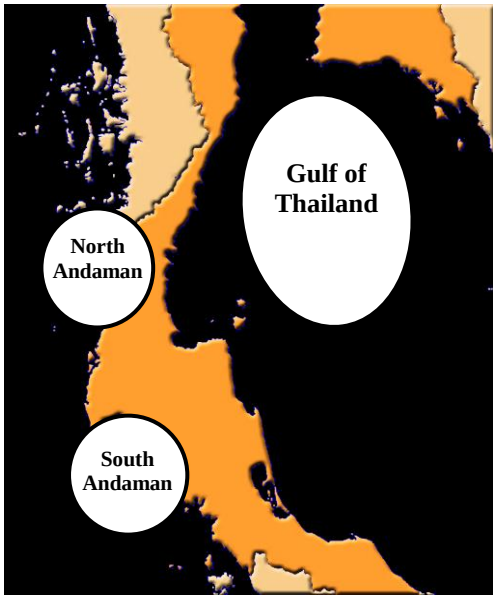

Fig. 2. Distribution of giant clams in Thai waters

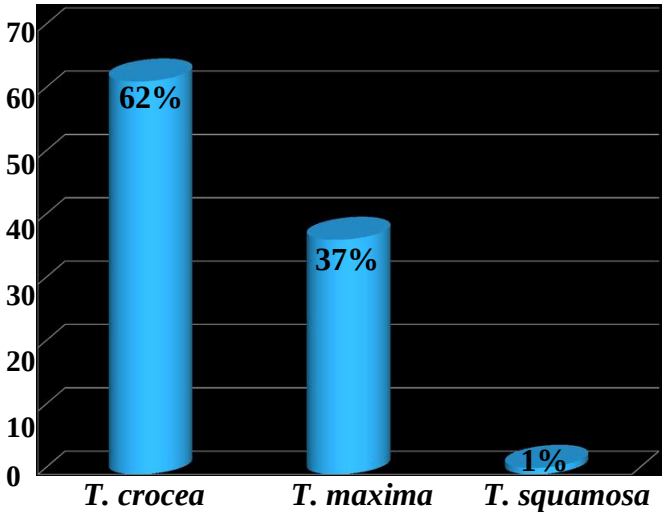

Fig. 3. Level of abundance of giant clams in Thai waters

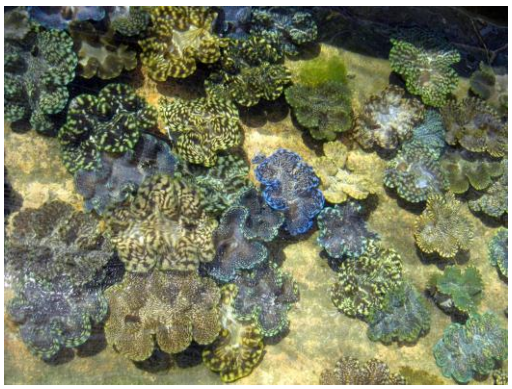

Fig. 4. Successful breeding of *T. squamosa* in Thailand

Activities Conducted

Tridacna squamosa has been successfully bred since 1993 (**Fig. 4**). This was achieved through cooperative works on enhancement and restoration by the Department of Fisheries of Thailand under the Ministry of Agriculture and Cooperatives and the Department of Marine and Coastal Resources under the Ministry of Natural Resources and Environment. The specific activities included broodstock management; hatchery, breeding and larval rearing; land-based nursery; and transportation of juveniles.

Ocean nursery and releasing/transportation had also been carried out since 1994 by restocking juveniles into natural reefs. Bottom cages were fabricated to serve as ocean nursery, in the waters of Koh Tao in Surat Thani Province; Koh Maithon in Phuket Povince; and in Islands at the Chumphon Natural Marine Park (**Fig. 5**). Various stakeholders join the restocking activities, such as local communities, SCUBA diver-volunteers, members of diving clubs/operators, conservationists, etc.

Fig. 5. Map of Thailand showing the locations of ocean nurseries for the giant clam *T. squamosa*

Results and Lessons Learnt

During the installation and monitoring of the ocean nurseries, it was noted that natural predators were common in the ocean beds preying on the stocked juvenile clams. The predators include the yellow-margin triggerfish *Pseudobalistes flavomarginatus*, giant triggerfish *Balistoides viridescens*, tripletail wrasse *Cheilinus trilobatus*, sea turtles, and others. It is therefore necessary that the ocean nurseries (**Fig. 6**) should be regularly maintained and monitored.

Fig. 6. Ocean nursery for the giant clam *T. squamosa*

Conclusion

From 1994 to 2015, about 16 sites in Thai waters had been restocked with the giant clam *T. squamosa*. Different populations were stocked in the Gulf of Thailand and the Andaman Sea. So far, more than 6,000 clams were stocked in the Andaman Sea and more than 250,000 in the Gulf of Thailand. During the restocking important considerations were always kept in view. These include the genetic diversity of broodstock populations and hatchery-produced juveniles. Monitoring of the restocked clams indicated survival rate of 5-65% one month after release. The activity was however confronted with various problems and constraints. These included natural environmental factors such as storms, wave surge and sea turbulence, increasing seawater temperature that could lead to bleaching, habitats destruction, and predation by other marine animals; and human interferences. The activity has provided juvenile clams for the Giant Clam Garden Project under the Royal Patronage of H.M. the Queen of Thailand since 1997. Moreover, special conservation activities had been promoted including the so-called Giant Clam Adoption scheme. This way, the concerned stakeholders monitor and make sure that their adopted giant clams are growing well.

Aquaculture-Based Enhancement and Restoration of Many-colored Abalone Resources (*Haliotis diversicolor* Reeve, 1846) in Bach Long Vi National Marine Protected Area, Vietnam

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Abstract

Many-colored abalone (*Haliotis diversicolor*) is high commercial species in Vietnam. Meanwhile, these resources have been over-exploited, thus, artificial breeding was implemented to restore natural abalone resources. After sourcing the broodstock, many-colored abalones were stimulated to reproduce during October – December 2013 at the Abalone Seed Center in Bach Long Vi, Hai Phong City. The results showed that veliger larvae developed from 11h – 36h after breeding. Abalone juveniles reached to 4.5 mm (shell length) at the age of 42 days. Survival rate of abalone juveniles 1-2 mm (28 days old) was 0.92%, 3.80%, and 24.00% at larvae densities 7.5, 6.8, and 1.6 larvae/cm^2 algae board, respectively. After 2 months (October – November), 30,000 juveniles of 4.5 mm shell length; 33,800 juveniles of 3 mm shell length; 45,500 juveniles of 2 mm shell length; and many small larvae were collected at the Bach Long Vi Abalone Seed Center. More than 6,000 juveniles of 4.5 mm shell length were released to Bach Long Vi National Marine Protected Areas for conservation in April 2014. The restoration assessment was briefly carried out in June 2015, and found that almost all individuals were found to have average shell length of 3.4 cm in Bach Long Vi National Marine Protected Area. This is an initial achievement of aquaculture and juvenile rearing to release and protect the many-colored abalone resources in Viet Nam.

Keywords:abalone, enhancement, *Haliotis diversicolor*, nursery rearing

Introduction

Many-colored abalone (*Haliotis diversicolor*) is the valuable seafood in Viet Nam and all over the world, and considered as one of the greatest foods in the diet of ancient kings. Abalone meat has high nutritional value and is widely favored. Simultaneously, abalone contains valuable medicines useful for people's health and believed to cure many human diseases. In addition, the inner shell of abalone is beautiful nacre used in fine arts technology. Therefore, the many-colored abalone is now highly commercial in the market in Viet Nam. Nevertheless, in view of its high commercial value, the abalone resource has been over-exploited not only for domestic demand but also for export. According to the statistical data, 37.0 tons of dried abalones were produced in Bach Long Vi Island before 1987. Since then, the quantity decreased to only 1.0 ton in 1992. The main cause of such decrease was excessive exploitation, use of destruction-explosives, use of chemicals - anesthesia, as well as potential pulse and high-pressure lamp. Once depleted, the recovery of abalone populations is very slow, taking 2 to 3 years to grow from juveniles to adult and reproduce for the first time. Thus, this resource is now in danger of exhaustion and restoration could be difficult. In order to protect the abalone resource, the People's Committee of Bach Long Vi Island divided the water column and tidal area square to the fishermen for management. Therefore, the abalone resources have been improved partly. However, that was just natural abalone farming, and still could not meet the demand of growing market. Nowadays, one of the effective conservation measures of natural resources is artificial reproduction for producing seeds that are released to the sea. At the same time, seeds are also supplied to fishers for commercial farming thus, reducing the fishing pressure on the natural abalone resources. Thus, the Research Institute for Marine Fisheries has been taking charge of implementing the project on "*Improvement of the technology models of artificial breeding and conservation of many-colored abalone resources in Bach Long Vi Island"*. The project which has been implemented from 2012 to 2015 in the Bach Long Vi Seed Center, aims to restore and conserve abalone resources, increase income and alternative livelihoods for local communities. After the project, it is expected that technical model for artificial breeding of the many-colored abalone would be improved and stabilized. As a result, huge amount of abalone seeds have been produced for restocking and restoration of the natural abalone populations in Viet Nam.

Activities and Results

In order to attain the above goal, the following activities have been implemented:

- From July to October, 2013: collecting and conditioning of abalone broodstock
- From October to December, 2013: induced spawning and larvae rearing
- From December, 2013 to March, 2014: rearing of abalone juveniles
- In April, 2014: releasing abalone seeds to tidal areas and coral reefs for stock enhancement
- From May, 2014 to 2015: monitoring and assessing the survival and growth of abalone juveniles

Conditioning and induced spawning

Healthy many-colored abalones were collected from natural waters then kept in the concrete tanks in the hatchery, separating the males from the females. The main food of given was seaweeds (*Gracilaria* sp., *Sargassum* sp., and *Hypnea* sp.*)*. The broodstocks were provided dried seaweeds (*Laminaria* sp.) in winter. The amount of seaweeds given was about 15–20% of broodstock weight, and put in broodstock tanks 2-3 times a week (**Fig. 1**). Gonads were checked weekly for maturity, and if the gonads were at stage IV (developed stage), male and female individuals were put together in one tank with the ratio of 3 females to 1 male for induced spawning.

In the Bach Long Vi hatchery, four methods of induced spawning were adopted: UV-sterilizing, drying exposure, increasing water-flow and pH. All these induced spawning methods were found effective in the hatchery. The male individuals responded positively with all these methods with 100% ejaculation, but the female individuals responded differently with such methods. The spawning rate fluctuated from 52.8% (pH method) to 72.2% (drying exposure and water-flow). After 2 months (October – November, 2013), 2 million larvae were produced in Bach Long Vi Abalone Seed Center.

Fig. 1. Abalone juveniles rearing in Bach Long Vi Seed Centre

Larvae and early juveniles rearing

Rearing density played an important part in larvae growth and survival rate of abalone juveniles. Specifically, rearing density impacted strongly to the abalone juveniles at 1-2 mm and 28 days old. Results showed that the survival rate was obviously different, at averages of 7.50 larvae/cm^2; 6.80 larvae/cm^2; 1.60 larvae/cm^2 algae board. Survival rate of abalone juveniles with 1-2 mm (28 days old) was 0.92%; 3.80%; 24.00% at larval densities of 7.5; 6.8; and 1.6 larvae/cm^2 algae board, respectively. Therefore, abalone juveniles of with 1-2 mm shell length are recommended for rearing at densities of 2-5 larvae/cm^2 algae board.

Husbandry of juveniles

In this project, the juveniles 5-7 mm and 7-10 mm were tested in two different temperatures, at 16° and 25°C. The results showed that smaller juveniles ate more seaweeds in 25°C than in 16°C and the average food consumption was 60 g seaweeds/3 days. Similarly, food consumption average was 80 g seaweeds/3 days at 25°C in abalone with 7-10 mm shell length. After 2 months (October – November, 2013), 30,000 juveniles of 4.5 mm shell length; 33,800 juveniles of 3 mm shell length; 45,500 juveniles of 2 mm shell length; and many small larvae were collected in Bach Long Vi Abalone Seed Center (**Fig. 2**). Finally, the total abalone juveniles harvested was 137.96 individuals as result of abalone rearing from October 2013 to April 2014. The average growth rate was more than 1.0 mm/month. The growth rate was very high from December 2013 to April 2014, especially in March and April. The size average was 8.7 mm shell length (fluctuating from 6.4 mm to 17.3 mm) in April 2015. The average survival rate was 6.64%.

Fig. 2. Growth rates of abalone juveniles from 10/2013 to 04/2014

Fig. 3. Releasing of abalone juveniles to the sea for conservation in Bach Long Vi National Marine Protected Area, Viet Nam

Restock and stock enhancement

More than 6,000 juveniles of 4.5 mm shell length were released to Bach Long Vi National Marine Protected Areas for conservation in April 2014. The restoration assessment was briefly implemented in June 2015, and almost all individuals were found to have average shell length of 3.4 cm. This is an initial achievement of aquaculture and juvenile rearing to release and protect many-colored abalone resources in Viet Nam.

Conclusion

- Broodstock conditioning and artificial breeding of abalone was successful. About 1,250,000 – 2,000,000 larvae and 137,960 juveniles (6.4-17.3 mm length) were collected with survival rate of 6.90-11.00%.
- Fishers have been trained and breeding techniques transferred to fisheries communities and study trips conducted to the hatchery for visitors.
- Released 6,000 juveniles (1cm length) to Bach Long Vi National Marine Protected Area on 15th April 2014 for conservation.
- Almost all released individuals were found with average shell length of 3.4 cm 1 year after restoration assessment. This is an important scientific basis for restocking and stock enhancement of abalone in Viet Nam.

Recommendations and Way Forward

- The seabed structure, environment and seed size need to be taken into account in detail before restocking. After releasing abalone seeds to tidal areas and coral reefs, monitoring and assessment should be carried out regularly.
- Aquaculture-based enhancement and restoration of many-colored abalone resources is potential and important for recruitment of abalone. These factors play important role in reducing the fishing pressure on natural abalone resources and increasing incomes of fishers, and creating alternative livelihoods for local communities. The participation of local communities is therefore necessary in aquaculture-based enhancement for abalone resources.
- The technical model of artificial breeding and aquaculture-based enhancement of many-colored abalone resources need to be generated and expanded for large-scale operation in the near future in Viet Nam.

ANNEX

OPENING STATEMENT

Dr. Chumnarn Pongsri
SEAFDEC Secretary-General and Chief of SEAFDEC Training Department

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Representatives from SEAFDEC Members Countries,
Distinguished Resource Persons, My Colleagues from SEAFDEC,
Ladies and Gentlemen, Good Morning!

It is indeed a great pleasure for me to welcome you all to this Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region. I am very happy and grateful that you, especially our distinguished guests, have come a long way to take part in this Symposium to share your knowledge and experiences on good practices for enhancing the fisheries resources. Let me tell you beforehand that we are also here to develop Regional Policy Recommendations and strategies on fisheries resources enhancement for the Southeast Asian region.

As you are already aware of, the coastal waters of Southeast Asia are blessed with highly productive fisheries resources because of the rich ecosystems such as dense mangrove forests and vast sea grass beds sustained by rich effluents of nutrients from land, as well as extensive coral reefs with clean tropical sea environment. These areas are critical to a broad range of aquatic organisms during their life cycle from breeding, spawning, nursing and growing. These areas also host the feeding zones of aquatic species that are economically important, and serve as important sources of recruitment of a wide diversity of fisheries resources. It is widely recognized that healthy marine environment is a prerequisite for sustainable marine fisheries production. Therefore, as fishery managers it is our most important responsibility to work for the realization of a good balance and relationship between human activity and coastal environment utilization so that we can utilize the marine fisheries resources in a sustainable manner. However, we are also aware that most of the commercially important fisheries resources in the region have declined due to many factors that include overfishing, illegal fishing, rampant use of destructive fishing practices, and environmental degradation. Although massive clearance of mangrove forests for aquaculture, urbanization, wood fuel, timber and the like, could bring about large temporary economic benefits to certain groups of people or governments, in the process, the breeding, nursery and feeding areas of many aquatic species such as fishes, crustaceans, and mollusks could also be destroyed and finally lost.

The Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region that we are commencing today would provide the forum for SEAFDEC Member Countries to discuss and share experiences on good practices in enhancing the fisheries resources. In addition, as I mentioned earlier, we are here to develop Regional Policy Recommendations and Strategies that could be used as guide for the Southeast Asian countries in promoting fisheries resources enhancement. Finally, I would like to express my deepest appreciation to those who have supported this Symposium including the SEAFDEC Member Countries, for the unceasing and tremendous efforts to make this Symposium even more significant. Your best experiences in your home countries, expertise and readiness to share your knowledge and ideas are highly valuable and necessary to sustain the discussions during the Symposium. I therefore wish that we will have fruitful discussions, and that interesting findings and observations could be obtained from the Symposium. I sincerely believe that this Symposium will serve as a valuable opportunity for establishing solutions to the problems that confront the sustainability of the fisheries resources for the future generations, not only to the SEAFDEC Member Countries but also the entire world.

Last but not least, I hope that you will enjoy the beautiful beaches and the night's life in this coastal City of Pattaya. The coastal environment here could be different from those in your home countries.

Ladies and Gentlemen, with those insights, let me welcome you again to the Symposium, and I now declare this Symposium open. Thank you and have a very good day.

ANNEX

CLOSING STATEMENT

Mr. Hajime Kawamura

SEAFDEC Deputy Secretary-General and Deputy Chief of SEAFDEC Training Department
Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region
27-30 July 2015, Pattaya, Thailand

Prof. Dr. Hiroshi Fushimi of the Faculty of Life Science and Engineering Fukuyama University,
Dr. Tetsuo Yanagi, Principal Investigator International EMECS Center, Professor Emeritus of Kyushu University; Other Resource Persons, Speakers and Representatives from SEAFDEC Member Countries;
My Colleagues from SEAFDEC Secretariat, TD, AQD, MFRDMD and IFRDMD;
Ladies and Gentlemen, Good Evening!

On behalf of SEAFDEC, I would like to extend my sincere gratitude and appreciation to all of the participants for making this symposium a great success. I would also wish to thank all those who have worked hard for the smooth arrangements of this symposium.

Ladies and Gentlemen, we are all aware of the productivity of nature is great. On the other hand, we are also all aware of human activities, not only fisheries activities but also those of other industries. Together with increasing population, all these factors affect the ecosystem on earth.

In Southeast Asia, there is clear evidence of habitat degradation and fishery resources are at the verge of collapse. Many efforts have been done to mitigate and manage such situation. We all know that, and there had been many successes as well as failures.

Through this 4-day Symposium, we tried to summarize and share our knowledge and experiences, from which we were able to foresee the way forward. We have discussed the aspects not only from scientific and technical points of view but also the social side of such aspects. We have also discussed many key elements such as the need for baseline information and the need to come up with good strategies, collaborative work by all stakeholders, among others. Through our deliberations, we were able to compile with "Policy Recommendation and Strategies Plan of Action for Fishery Resources Enhancement in the Southeast Asian Countries".

I am strongly certain that the outputs of our discussion during this Symposium as well as the shared experiences would contribute the efforts to develop and establish habitat rehabilitation practices and management plans in our respective countries.

Finally, once again, I would like to express our gratitude for your active participation in sharing and exchanging experiences for this symposium. We are looking forward to collaborate and pursue this mission with you again in the future, especially for the development of appropriate Plans of Action which could lead to the effective implementation of resource enhancement strategies in the region.

Ladies and Gentlemen, I now declare this Symposium closed. I wish to thank you once again for the good cooperation that we all had during the Symposium. Good luck and I do wish that you would have a very safe journey back home. Have a good day.

ANNEX

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During the Symposium




During the field trip