FISH for the PEOPLE

A Special Publication for the Promotion of Sustainable Fisheries for Food Security in the ASEAN Region

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Capacity Building for Sustainable Management of Fisheries in Southeast Asia

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Editorial

The deteriorated natural fishery resources and degraded habitats take root from irresponsible fisheries and non-fishery activities that continue to threaten and endanger the resources in the Southeast Asian waters to the brink of collapse. Meanwhile, human population in the Southeast Asian region continues to increase exponentially leading to the soaring demand for food fish. Given these two regional scenarios, there is an emergent need for fisheries managers and other stakeholders, to take a very close look at the current critical state of fisheries in the region considering that this situation has contributed to the severity of the challenges for the sustainability of fisheries in the region. With the intention of catching more fish for increased production and incomes without thinking of the impacts of their actions, many small-scale fishers in the region continue to fall victims of the vicious cycle in fisheries. Many fishers are tempted to catch more fish by all means to the extent of destroying the fishery resources, and still continue to extract fish from the already degraded resources even if it means harvesting and demolishing the natural stocks especially those that are being conserved and restored. However, such phenomenon could still be countered by turning the cycle around while asserting the will to change.

Sustainability cannot be attained without increasing the awareness of stakeholders, especially the fishers, and one of the processes that could address this concern is through capacity building especially on sustainable fisheries management. Firstly, fishers should be made to understand the impacts of irresponsible fishing operations on the fishery resources and on the need to conserve the resources for future generations. Secondly, enhance the awareness of fishers on the significance of resource enhancement and restoration of the resources and for them to adhere to fishing limitations and restrictions such as closed season and closed areas, as examples. Lastly, introduce and promote the adoption of responsible fishing methods and practices in fishing communities, with due consideration to the impacts of illegal fishing operations. This whole process is not difficult to promote because the region through various R&D institutions and the academe, has already amassed technologies and technical advances in responsible fisheries and aquaculture as well as on sustainable management of the fishery resources. What the region needs is intensified dissemination of information and technologies in more effective and efficient way with the objective of building the capacity of stakeholders, especially the fishers.

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Capacity building has been defined by many authors and in several books as a process of creating an enabling environment for stakeholders to strengthen the capability in effectively implementing changes in development. Capacity building is more than training as it encompasses not only human resource development but also institutional development based on appropriate policy and legal frameworks. The needs and beneficiaries of capacity building are constantly changing based on the situation however, fishers' associations, local government units, and community groups including women's groups could be the target clients for capacity building. Nevertheless, central government offices and the private sector may also need to build their capacities in terms of organization, management, and in creating the environment for carrying out effective capacity building activities.

The ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 adopted in 2011, stipulates the need to strengthen human capacity as well as that of fishing communities and institutional capability for the sustainable development of fisheries in the region. In accordance with such provisions, SEAFDEC through its four Technical Departments had been exerting efforts to ensure that building the capacity of stakeholders especially in responsible fisheries management is incorporated and strengthened in the overall plans and programs of SEAFDEC.

Within SEAFDEC, capacity building includes various strategies such as packaging the various technologies that it has accumulated through R&D and disseminating the information through training (on-site and in SEAFDEC premises), trainers' training, and extension activities; providing discussion fora for the exchange of information and experiences on fisheries management as well as for developing common positions on emerging issues through workshops, seminars, and conferences; and conducting actual demonstrations of technological advances on-site to provide first-hand information to stakeholders such as those on co-management and ecosystem approach to fisheries management. In all these aspects, SEAFDEC adheres to the age-old Chinese proverb "***give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime***". Therefore, SEAFDEC is committed to ensure that transfer of knowledge on its developed technologies through capacity building is done with full attention and guidance, and whole-heartedly conducted to attain lifetime achievement in sustainable fisheries management.

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C O N T E N T S

FISH for the PEOPLE is a special publication produced by the Southeast Asian Fisheries Development Center (SEAFDEC) to promote sustainable fisheries for food security in the ASEAN region.

Advances in Fishing Technology: Mitigating the Impacts of Fishing Operations on Coastal and Marine Environments

Bundit Chokesanguan and *Petri Suuronen*

Recently, a strong movement has taken place worldwide to minimize the impacts of fishing activities on coastal and marine environments, and put an end to the over-exploitation of the fishery resources. Many factors are held responsible for the current dismal state of the world's fisheries including excessive fishing effort and the exploitation of immature fishes that seek food and protection in shallow coastal areas. Likewise, the continued capture of unwanted fish (by-catch) is contributing to acute reduction of fish stocks. FAO has been working closely with SEAFDEC through its Training Department (TD) in promoting responsible fishing technologies and practices in the Southeast Asian region, specifically towards reducing by-catch and discards from fishing operations. Through such cooperation, TD has served as collaborating partner in the implementation of projects such as the Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of By-catch Reduction Technologies and Change of Management (REBYC-I), and the subsequent project that focuses on the Coral Triangle region of Southeast Asia (REBYC-II CTI). The successful implementation of the REBYC projects prompted FAO to organize in 2013 the annual ICES-FAO WGFTFB Meeting for the first time in Southeast Asia instead of convening it in the temperate regions. This article displays the advances in fishing technology that were presented and discussed during the meeting of WGFTFB which was organized on 6-10 May 2013 at the TD premises in Samut Prakan, Thailand.

In order to pave the way for addressing issues that impede the promotion of sustainable and responsible utilization of fishery resources, and minimizing the impacts of fishing activities on the environment, the Food and Agriculture Organization of the United Nations (FAO) and the International Council for the Exploration of the Sea (ICES) established in 2002 the Working Group on Fishing Technology and Fish Behavior (WGFTFB). Specifically, the Working Group aims to foster dialogue and collaboration among member states in addressing issues on fishing technology and fish capture for the sustainable utilization of the world's fishery resources. The WGFTFB Meeting convened by FAO and ICES in May 2013 in Thailand served as a forum for global synthesis of scientific knowledge on fishing technology and its effective use. The meeting explored the means of evaluating the role and potential for capture technologies and practices to reduce fishing impacts on the environment and energy use, and served as a medium to review and discuss advances in technology and analytical methods used to study these effects. Furthermore, the meeting provided a forum for discussion on how perceptions and decisions of fishers and resource managers affect the success of achieving sustainable use and successful management of fishery resources, and means of fostering new partnerships between scientists and technology from developed and developing economies to minimize the impacts of fishing on the environment.

Advocating the Recent Advances and Future Direction of Fishing Technology

The ICES-FAO WGFTFB Meeting in May 2013 in Thailand was a significant event in SEAFDEC in view of its relevance to the sustainable development of small-scale fisheries in its Member Countries, and considering that SEAFDEC has been implementing various projects including "*Optimizing Energy Use and Improving Safety at Sea in Fishing Activities*" and "*Mitigating the Impacts of Fishing on the Environment: Fishing in Harmony with Nature*" with funding support from the Trust Fund of the Government of Japan. The Meeting provided information that enhanced the expertise of SEAFDEC in addressing various constraints that impede the sustainability of small-scale fisheries in the Southeast Asian region. The partnerships developed between countries in the region and with various stakeholders from other parts of the globe that was forged during the 2013 WGFTFB Meeting will help to build synergies for addressing regional and global challenges that hamper the Southeast Asian region. Development of sustainable fisheries for poverty alleviation and food security is the mandate for SEAFDEC and the ASEAN as provided for in the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 adopted in June 2011.

The May 2013 Meeting was attended by more than 150 fishing technologists, scientists, and other stakeholders representing 25 countries. It included a mini-symposia to discuss the effects of fishing on the environment which have been addressed through various initiatives and research studies undertaken not only in the temperate countries but also in the tropics, grouped into three main topics: (1) Low Impact and Fuel Efficient (LIFE) Fishing; (2) Use

Participants of the 2013 Annual Meeting of the Working Group on Fishing Technology and Fish Behavior

of Artificial Light as Behavioral Stimulus in Fish Capture (LIGHT Fisheries); and (3) Selectivity of Trawl in Multi-species and Crustacean Fisheries (SHRIMP Fisheries). These initiatives and research activities have recently led to significant advances in fishing technology, more particularly on sustainable fishing operations that minimize the impacts of fishing on coastal and marine environments.

Low Impact and Fuel Efficient (LIFE) Fishing

LIFE fishing means cost-effective next generation fishing technology through modifications and/or replacement of high-impact and fuel hungry fishing techniques and practices. As widely recognized, fishing activities can impact the environments not only due to over-exploitation of valuable aquatic species but also from direct physical contacts with critical habitats. LIFE fishing addresses these impacts and the heavy dependence of many capture fishing methods on fossil fuels. High consumption of fuel comprises a major constraint to the economic viability of capture fisheries and contributes to greenhouse gas emissions. Fishing gears can be designed and operated to cause less impact on the environment and to consume less fuel. Some pot, trap-net, hook-and-line fisheries are good examples. Currently, research in LIFE fishing has been focused on the creation of energy-efficient fishing vessel design and fishing operations that takes into consideration the associated policy and socio-economic aspects.

Once sustainably managed, the fishery sector could substantially decrease the negative impacts to aquatic ecosystems, reduce greenhouse gas emissions, and lower fuel costs by adapting technological improvements and adopting behavioral changes. LIFE fishing addresses the complex dynamic of energy consumption and environmental impacts while promoting economic viability and environmental sustainability of fishing operations, and enhancing the sector's contribution to food security.

Box 1. Papers presented during the Mini-symposium on LIFE Fishing

John Willy Valdemarsen and Petri Suuronen. 2013. **Low-Impact and Fuel-Efficient (LIFE) Fishing - Challenges, Opportunities and Some Technical Solutions**

Mobile Fishing Gear

Emilio Notti and Antonello Sala. 2013. **Propulsion System Organizations for Fuel Savings in Trawlers**

Shigeru Fuwa, Saeko Kude, Keigo Ebata, Hiroyasu Mizoguchi. 2013. **A Comparison of the Fishing Gear Efficiency on the Trawl with Knotted and Knotless Net Webbings**

Bob van Marlen. 2013. **The Development of Pulse Trawling in the Netherlands**

Keigo Ebata and Shinpei Teraji. 2013. **Reduction of Hydrodynamic Force Acting on Bottom Trawl Net**

Ulrik J. Hansen, Johan W. Nielsen and Jacob L. Rønfeldt. 2013. **Using Best Available Technology Drastically Improve Fuel Efficiency in Trawl Fisheries**

Leela Edwin and T.K. Srinivasa Gopal. 2013. **Initiatives Towards Development of Green Fishing Systems for Indian Waters**

Stationary Fishing Gear

Liming Song, Weiyun Xu, Daomei Cao, and Jie Li. 2013. **A Comparison of Two Catch Rate Calculation Methods: Application to a Longline Tuna Fishery**

Philip Walsh and Rennie Sullivan. 2013. **Comparative Baited Pots Trials to Harvest Northern Stone Crab (*Lithodes maja*) and White Hake (*Urophycis tenuis*)**

T. Arimoto, T. Kudoh, Y. Takashima, K. Ebata, A. Munprasit, T. Amornpiyakurit, N. Manajit, W. Yingyuad, A. Boutson, Yap Minlee, and S. Ishikawa. 2013. **Operation System Analysis of Set Net in Rayong, Thailand from the View Point of Cost-profit Simulation with Fuel Consumption Assessment**

Keigo Ebata, Anukorn Boutson, Isara Chanrachkij, Nakaret Yasook, Tanut Srikum, Takafumi Arimoto, Takatsugu Kudoh, Minlee Yap, and Satoshi Ishikawa. 2013. **Seasonal Variation in Fishing Operations and Fuel Consumption of Small-scale Fisheries in Rayong, Thailand**

Tools for LIFE Fishing

Chun-Woo Lee and Jihoon Lee. 2013. **Energy Saving Fishing Gears Design Using a Numerical Simulation**

Michael Pol, Steve Eayrs, Pingguo He. 2013. **GEARNET: A Bottom-up Approach to Gear Testing and Uptake**

Steve Eayrs and Christopher Glass. 2013. **Developing Fishing Gear to Reduce Environmental Impact and Increase the Profitability of Fishermen in the New England Groundfish Fishery: So Why are They so Reluctant to Use This New Gear?**

Box 2. Findings from LIFE Fishing session

Employing various fishing techniques and types of fishing gear and practices has advantages and disadvantages, but the suitability of each gear type depends considerably on the operational conditions and on the species targeted. Moreover, the impacts of fishing gear on the ecosystems depend largely on the physical characteristics of the gear; the mechanics of its operation; where, when and how the gear is used; and the extent of its use. Nevertheless, there is still no single solution to increase the interest of fishers in new fishing gears and practices, as this depends on the fishery and individual circumstances. Suggestions, however, were offered such as providing incentives for participating fishers and encouraging them to take part in finding solutions to the problems that confront the fisheries sector. Considerations should also be given on how motivation and incentives, *i.e.* economic, regulatory, peer pressure, societal expectations, public perception and markets can drive fishers' uptake of such innovations and changes in fisheries development. Furthermore, there is also a need to make fishers understand the issues such as high-energy consumption and greenhouse gas (GHG) emissions that could occur after the catch is taken onboard fishing vessels as well as after landing (*i.e.* fish processing, cooling, packaging and transport).

Minimizing the impacts and energy consumption throughout the whole product chain is needed to reduce the overall environmental costs of fishing. For such reason, it is crucial that the fishing sector should lower its fuel consumption and decrease ecosystem impacts. Through technological improvements, gear modifications and behavioral change, the fishing sector can substantially decrease the damages that it inflicts to aquatic ecosystems, reduce GHG emissions, and lower operational costs without creating excessively negative impacts on fishing efficiency.

Box 3. Possible solutions that could address problems impeding the promotion of LIFE Fishing

Demersal trawl can be operated on many types of areas and grounds, in shallow and deep waters, by small and large vessels for a wide range of target species. Bottom trawling conducted in high-biodiversity environments is difficult to manage in terms of by-catch and habitat impacts although techniques and operational adaptations are available to reduce the drag and weight of the bottom trawl gear and reduce significantly fuel consumption and impacts on sea bed without marked decrease in the catch of the target species. Further work, however, is needed to improve the construction of the different components of the gear to minimize friction on the bottom and reduce the overall gear drag. For beam trawls, alternative gear designs are being developed to reduce the amount of tickler chains and to avoid excess weight in the beams, while the use of other stimuli (*e.g.* electric pulses) as alternative to chains is being tested to scare the target fish off the bottom and into the net. The use of acoustics, light or other additional stimuli to enhance encounters by target species within the catching zone of trawl nets has been explored. Electronic sea bed mapping tools and integrated global navigation satellite systems have been used to estimate the location of targeted fish and help in avoiding sensitive bottom habitats as well as minimize fishing effort and fuel consumption. The so-called smart trawling should be promoted to ensure that sea bed damages by bottom trawling are reduced.

Bottom seining such as Danish, Scottish and pair seining is generally considered a more environment-friendly and fuel-efficient fishing method than bottom otter trawling since the gear is lighter and the area swept is smaller. The absence of trawl doors or heavy ground gear implies that there is less force on the sea bed. Therefore, the light gear used and low hauling speed could lead to significantly lower fuel usage than trawling operations. Although bottom seine nets have been regarded as having low impact on benthic invertebrates, the high by-catch of both undersized individuals of the target species and individuals of non-target species can be a problem in some seine fisheries.

Trap-nets are passive fishing gear usually set along the path of migrating fish in relatively shallow coastal waters. The leader-net herds and guides fish into a holding chamber. Modern trap-net fisheries can be energy efficient, flexible, selective and habitat-friendly, providing high quality catch still alive when brought onboard the vessels and allowing the operators with a greater number of options to add value to the catch. A recent innovation, the pontoon trap, offers various advantages compared with traditional trap nets because it is easy to transport, handle and haul, and adjustable in terms of size, target species and capture depth, as well as being predator-safe. Future developments may include large-scale, ocean-based fish traps with provisions to attract the fish. Designs and practices need to be improved to prevent the entangling of non-fish species in the netting and mooring ropes of the trap.

Pots are small transportable cages or baskets with one or more entrances designed to allow the entry of fish, crustaceans or cephalopods, but prevent their escape. Pots are usually set on the bottom with or without bait, and are extensively used in the capture of crustaceans such as lobster and crabs, and successfully used in fisheries targeting coral-reef species inhabiting areas where the use of active gear is banned or not practical. Compared with many other types of fishing gear, pots, like trap-nets, possess several appealing characteristics such as low energy use, minimal habitat impact, high quality, and delivery of live catch. However, lost or abandoned pots may continue to catch target and non-target species, known as ghost fishing, thus, contributing to marine debris with associated effects. Design features such as biodegradable materials may reduce ghost fishing, while the use of delayed surface marker buoys and location could promote the recovery of lost gear. Understanding fish behavior in relation to pots is essential in order to increase efficiency for those species that are currently not captured by pots in commercially viable quantities.

Hook and line refers to a gear to which fish, squid or other species are attracted and caught through the use of natural or artificial baits or lures placed on a hook. In view of its wide variations in term of configuration and their mode of operation, hook and line is an effective gear type for a wide variety of species. It is a versatile fishing method which is employed by a wide range of vessels from artisanal boats to large mechanized long-liners. Hook and line fishing is generally considered an environment-friendly but labor-intensive fishing method, with catches of high quality. Fuel consumption is comparatively low although it can increase significantly depending on the distance the vessels have to travel to and from fishing grounds (*e.g.* coastal hook and line fisheries versus high seas tuna long-lining). Long-line fishing may cause incidental mortality of seabirds, sea turtles and sharks, many of which are either protected or endangered. Bottom-set long-lines may also snag and damage benthic epifauna and irregular objects on the bottom. Nevertheless, long-line fisheries offer the potential of fishing without causing severe habitat damage provided it is done in a relatively energy-conscious manner.

Gillnetting using bottom-set gillnets, entangling nets and trammel nets have undergone improvements in materials and techniques, allowing the expansion of using these gears in deeper and rougher grounds (including wrecks and reefs). Gillnetting is a very versatile and flexible fishing method but can be labor-intensive. Except with trammel nets, size selectivity for fish is generally good, but species selectivity can be poor. Nevertheless, since fish are often injured and die during capture, catch quality is typically not as good as with pots, traps and long-lines, although gillnets may also give catch of good quality when the time the net is left in the water to fish is short. Gillnet fishing operations in general can damage benthic epifauna during gear retrieval at which time the nets and lead-lines are more likely to snag bottom structures. Abandoned, lost or otherwise discarded gillnets could continue to fish for long periods depending on their construction, the depth, and prevailing environmental conditions (ghost fishing). This can be addressed by increasing efforts to avoid losing gillnets and facilitating the quick recovery of lost nets.

During the Mini-symposium on LIFE Fishing, the scope of the presentations were broad and varied, *i.e.* on mobile gear fishing, stationary gear fishing, and tools for LIFE fishing, exhibiting a wide range of R&D on LIFE fishing conducted around the world. The papers presented and the findings noted during the Mini-symposium on LIFE Fishing are shown in **Box 1** and **Box 2**, respectively.

Furthermore, several activities were suggested that could address the issues that impede the promotion of LIFE fishing operations (**Box 3**). These include the practice of smart trawling and seining that reduce seabed damages, promotion of responsible passive gears, improvement of the use and recovery of gill nets, and conduct of R&D activities on energy-saving technologies. Changes from high-energy high-impact fishing methods or practices to practices with lower energy consumption and lower ecosystem impacts could offer opportunities for conserving fuel, preserving the ecosystems and improving food security.

However, it was noted that there are also barriers to the transition towards the use of LIFE fishing practices and gear. These include: lack of familiarity with cost-effective and practical alternatives; limited availability of suitable technologies especially in developing countries; incompatibility of vessels with alternative gear; risk of losing marketable catch; additional work at sea; concerns with safety at sea related to using unfamiliar gear or strategies; high investment costs; lack of capital or restricted access to capital; ineffective technology infrastructure support; inflexible fisheries management systems that include too rigid regulatory regimes. In inflexible management systems, regulatory regimes could be too rigid creating a new set of problems and denying fishers the flexibility to innovate and adopt new technologies. Making stakeholders an integral part of the management process could address these concerns, especially when amendments to legislations are under consideration. Changes from high-energy high-impact fishing methods or practices to practices with lower energy consumption and lower ecosystem impacts could offer opportunities for conserving fuel, preserving the ecosystems and improving food security.

The transition from using one gear type to another is not always easy or practical because there are often limited possibilities for changing the size and design of existing fishing vessel including machinery and equipment. Secondly, fishing gear, fishing vessels, operations, and practices have been adapted to specific fishing grounds and the behavior of target fish species over a considerable period of time. Accordingly, the evolved fishing gear and practices are "*tailor-made*" to catch specific target species or species groups in a manner that is often perceived to be optimized to the best technical and economic scenarios that will be encountered during fishing. Moreover, where fishing practices are rooted in tradition there is a strong resistance to change. Nevertheless, fuel consumption and ecosystem impacts can often be reduced through simple modifications in operational techniques and gear design without drastic changes in the gear and operational practices. This approach has shown promising results in many cases and is often preferred by the fishing industry over transitioning to a completely new gear type and fishing practice, an alternative that has many uncertainties with high economic risks. R&D on energy-saving technologies carried out by designers of machinery and fishing vessels and gear, point towards the signs that the fishing industry has begun to improve its fuel efficiency. However, refinements to fuel quality, *i.e.* lowering the content of sulfur oxide and particulate matter, could lead to even higher fuel and lubricating-oil costs. This would have greater impact on the fishing industry in developing countries where mechanization continues to increase since fuel continues to be the major cost of operation in capture fisheries, although it will also strengthen the advocacy for fuel efficiency.

Use of Artificial Light as Stimulus on Fish Behavior in Fish Capture (LIGHT Fisheries)

Fishing attractor makes use of lights attached to structures above water or suspended underwater to attract fish to specific areas and facilitate harvesting. While fishers seek conditions where the chance of catching fish is optimized, fish seek the areas where the chance of finding their food is optimal. Most fish seek waters that are rich in food such as smaller fish, insects or shrimps, and congregate where their food is most concentrated. Scientific research shows that fish and some of their food animals have eyes sensitive to blue and green color because the water where these aquatic animals live in is bluish or greenish in color. Water, containing little particulate matter, scatters light in the blue

region of the spectrum. Meanwhile, water which is rich in nutrients and contains photosynthetic micro-organisms and plants preferentially absorb red light. The remaining, unabsorbed light is transmitted and scattered, thus giving the water a greenish appearance. If water contains a lot of organic materials from decaying plants or suspended sediments, it may take on a yellowish brown color.

Fish and some of their food animals have color receptors in their eyes that could optimize the light of their "space", see a single space color, and detect changes in light intensity, equivalent to a world in black, white and shades of gray. In its simplest level of visual information processing, an aquatic animal can recognize that something is different in its space, *i.e.*, there is food or predator "over there". Most animals living in a lighted world have an additional visual resource: color vision, which means that they have color receptors containing at least two different visual pigments. To efficiently perform this function in water illuminated with light, an aquatic animal would have visual pigments sensitive to the background "space" color and one or more visual pigments offset from this blue-green region, especially in the red or ultraviolet region of the spectrum. This produces a clear survival advantage for these aquatic animals because they can detect not only changes in light intensity but also contrasts in color. Many fish, for example, have two color receptors, one in the blue region of the spectra (425-490 nm) and the other in the near UV (320-380 nm). Insects and shrimps which are members of the fish food chain, have blue, green (530 nm) and near UV receptors. Some aquatic animals have up to ten different classes of visual pigments in their eyes. By comparison, humans have three with maximum sensitivities in the blue (442 nm), green (543 nm) and yellow (570 nm). It is the differential responses of these receptor cells that enable the color vision.

The best color for a light attractor is still an open question, but based on the biology of visual receptors, the light should be blue or green — the space colors of fish and members of their food chain. However, while blue or green light is desirable it is not essential. Even if the eyes of fish or members of its food chain have color receptors most sensitive to the blue or green, these same receptors have a broad but decreased sensitivity to other colors. So, if a fishing light source is intense enough, other light colors will also attract fish. For example, a sodium vapor light with its characteristic yellow color will attract fish — if intense enough. A fishing light attractor can also be white light because a portion of its total energy is in the blue to green region. Nevertheless, the perfect fishing light could have the following properties: (1) high intensity, (2) emit light in a color similar to the fishes' space (blue

Box 4. Papers presented during the Mini-symposium on LIGHT Fisheries

Mike Breen and Amit Lerner. 2013. **An Introduction to Light and Its Measurement when Investigating Fish Behavior**

T. Arimoto. 2013. **Fish Behavior and Visual Physiology in Capture Process of Light Fishing**

Physics & Engineering

Yoshiki Matsushita and Hisayuki Arakawa. 2013. **Marine Optics - Essential Elements for Fishing Technology and Fish Behavior**

Ja Soon Jang. 2013. **Review of Technological Design: LED Packaging and Lighting**

Heui Chun An. 2013. **Research on Artificial Light Sources for Light Fishing**

Sugeng Wisudo. 2013. **Light Output Arrangement in Light Fishing Through the Use of Simulation Model of Underwater Illuminance Distribution**

Dan Watson. 2013. **Novel Power Supply Technologies for Artificial Lights on Fishing Gears/Energy Harvesting in the Trawling Environment**

Biology & Behavior

Ronald Kröger. 2013. **The Biology of Underwater Vision**

Amit Lerner. 2013. **Polarization Vision in the Sea**

Kyounghoon Lee. 2013. **Attracting Effects on Swimming Behavior Patterns of the Chub Mackerel (*Scomber japonicus*) and Common Squid (*Todarodes pacificus*) by LED Luring Lamp**

Daniel Aquilar-Ramerez, S. Hoyt Peckham, Jesse Senko, John Wang, Luis V. González-Ania and Santa L. Ganelón-Leon. 2013. **Effects of LED Illuminated Gillnets on By-catch of Loggerhead Turtles in Coastal Mesh Net Fisheries at Baja California Sur, Mexico**

Hyeon-Ok Shin and Jin-Wook Jung. 2013. **Visual Threshold of Rockfish (*Sebastes inermis*) Response to Different Wavelength of LED Lamp**

Kazuhiko Anraku and Tatsuro Matsuoka. 2013. **Development of the Evaluation Method on the Effect of Artificial Fishing Light**

Light Fishing

Weiguo Qian and Yingqi Zhou. 2013. **Review on Squid Jigging with Lights of Chinese Fishing Fleets**

Young-Il An and T. Arimoto. 2013. **Fishing Efficiency of LED Fishing Lamp for Squid Jigging and Hair Tail Angling in Korean Waters**

Daisaku Masuda, Shuya Kai, Taisei Kumazawa and Yoshiki Matsushita. 2013. **Application of the Low-power Underwater Light to a Large Scale Fish-trap Fishery**

Grant Murphy and R. Sullivan. 2013. **Modifying Baited Cod Pots to Capture Flatfish Species While Excluding Snow Crab**

Box 5. Findings from the Mini-symposium on LIGHT Fisheries

The discussions centered on the physics, properties, and characteristics of light including the tools to measure light and clarification of the myriad of units used in light measurement. The use and development of artificial light in squid jigging operations and the importance of understanding fish vision, its influence on fish response to visual stimuli, and research methods and techniques to investigate fish vision and functions such as visual acuity, maximum sighting distance, and spectral sensitivity were also examined. Likewise, the development and engineering of LED lights, and harvesting renewable energy sources from the fishing processes and ocean environment using innovative technologies and techniques to develop self-powered underwater lights. Measurements of the underwater light field and the behavior of squid and fish in response to artificial illumination onboard fishing vessels or underwater, and the importance of polarized light to some fish and invertebrates particularly in prey detection were also described. Finally the benefits of LED lights compared to other sources of illumination including their effect on catch rates and fuel consumption, as well as the relative performance of LED lights of different color were also discussed. The question on why light fisheries have been popular in the east and less so in the west, was explained in terms of the abundance and schooling behavior of fishes in the eastern hemisphere. However, the aspect of why fish are positively phototactic is still not well understood and remains an area for future research. Although Light Fisheries could be less harmful to the environment and overfishing is seemingly lessened than in using other gear, in some fisheries light can create conflict between the fishery and fishers which is difficult of control and regulate.

Lights used in fishing could be classified into two groups: portable and permanently mounted. Portable lights which are powered by batteries, sets practical limits to the kind of light used in fishing. Most portable light sources are relatively low in light intensity and have short operating times. A 12 volt automobile incandescent headlight mounted on a styrofoam float ring is probably the least expensive and lasts for a few hours before the battery is discharged. Battery-operated fluorescent lamps are three times more efficient in converting electricity to light. Therefore, comparing lamps of similar brightness, these lamps can be operated about three times longer before the battery is discharged. Also, the operating lifetime of fluorescent lights are about ten times longer than incandescent lights. Commercial portable fishing lights based on fluorescent lamps vary widely in intensity. The best use 25-40 watt lamps that emit about 1000–3000 lumens per tube cost $160–$200. Lights made up of LED lights are an up-and-comer but to date are 10 to 100 times less brighter than a fishing light using a standard 25-40 watt fluorescent lamp. LEDs are extremely efficient in converting electrical energy to light, and as the cost of LEDs decrease and their brightness increases, functional fishing lights consisting of large arrays of LEDs could be promising. Permanent lights are typically powered with 115 volt house current, placed on poles at the end of a dock or pier, and are the least expensive lights for outdoor use for security purposes. Flood lights that make use of mercury vapor, high pressure sodium vapor, metal-halide discharge or fluorescent bulb cost US$25-100. While the lower cost 115 V AC outdoor flood lights using standard tungsten (incandescent) or tungsten-halogen (quartz) bulbs can also be effective as fish attractors and are energy inefficient. While it takes about five 100 watt tungsten lamps to deliver the light equivalent of one security lamp, the fixture includes a photocell controller for automatic dusk-to-dawn operation and comes complete with an appropriate bulb. These lights are very bright (6-8 thousand lumens), efficient in converting electricity to light (operated daily for 8 hours, electrical supply costs US$40–100 per year), have long bulb lifetimes (24,000 hours) and stand up well to outside weather conditions. When used as fishing light, its light output can be redirected towards the water by installing a 5”x10” piece of aluminum flashing or heavy foil bent into a half circle and placed next to the lamp’s circular acrylic lens. Stadium spot lights are energy efficient and their superior brightness illuminates a large area of water. Sorted in 250, 400, 1000 and 1500 watts, the high intensity discharge lamp, parabola-shaped reflector and light ballast are each sold separately, so that a complete light fixture and lamp would cost about $400–$500. The cost of lamps with different wattage ratings is similar, so one can choose higher wattage lamps. The bulbs in these lamps can emit white, blue-green, green or yellow light. For most fishing waters, the lamp color of choice is green but it would take two people to install these big lamps and the installation may also include a switch, timer, heavy gauge wiring and circuit breaker, thus adding to the cost. However, a significant fraction of the light shining on the surface of the water is lost by reflection and, thus, will not be available to attract fish and members of their food chain. Security lights can be modified to operate when submerged in water, because positioning the bulb underwater delivers approximately twice as much light to attract fish. Modification must be done professionally as high voltage that powers these lamps can be lethal. Therefore, the power ballast and lamp housing should be mounted on a pole in a dry location while the lamp, potted in a waterproof housing, is connected to the ballast through a waterproof cable. Floating like a fishing line bob, the lamp is positioned underwater by weights on its submerged power supply cord. The bulb is fragile so some manufacturers offer protective covers and hard lenses. One unique feature of the submerged, unprotected bulb is that its outer glass envelope could get hot enough to prevent establishment of marine growth. When the bulb has a protective cover or is not operated daily occasional cleaning is required. A permanently fixed fishing light attractor is most effective if it is operated every night. It takes a week or two for larger fish to discover the increasing concentration of bait fish attracted to the light. Once discovered, the fish return regularly, often arriving at predictable times of the evening.

or green), (3) powered by a portable electrical supply, and (4) submersible. The last attribute is desirable because significant amounts of light energy from land- or boat-mounted lights are lost through the reflection off the surface of the water.

However, no commercial light has so far satisfied all four of the abovementioned criteria. For example, high intensity lights such as tungsten-halogen (incandescent), medium pressure mercury or metal-halide discharge lights are so power hungry that they can only be operated for very short periods of time with a battery, thus compromising convenience and portability. While LEDs and fluorescent lights use much less electrical energy, these are mostly not very bright. Furthermore, many of the abovementioned lights cannot be submerged in water without risks of electrical shock or damage to the lighting system. The Mini-symposium on LIGHT Fisheries therefore, focused on the physics and engineering aspects of artificial light in water; biology of vision and behavioral responses of fish to artificial light; and novel and innovative approaches in LIGHT fisheries

More specifically, the papers presented have pointed towards significant technological advances in LIGHT Fisheries such as the adoption of LED lights in favor of incandescent, halogen, and metal halide illumination. These technological advances have shown to be similarly effective compared to many of the older sources of illumination with the added benefit of requiring considerably less energy, hence, consumption of fuel and greenhouse gas emission are significantly reduced. The papers presented and additional findings from the Mini-symposium on LIGHT Fishing are shown in **Box 4** and **Box 5**, respectively.

Selectivity of Trawl in Multi-species and Crustacean Fisheries (SHRIMP Fisheries)

A range of tools to manage by-catch and reduce discards, including technological measures to improve the selectivity of fishing gear, has recently been promoted worldwide. As a result, decline in by-catch and discards have been attained in many fisheries through the introduction of effective gear modifications and by-catch reduction devices. Species selectivity is aimed at reducing unwanted species while size selectivity aims to reduce the catch of undersized fish. The coastal shrimp trawl fisheries in the Southeast Asian region can be characterized as highly multi-species fishery. Thus, it might not be possible to catch all species in an optimal way. Tropical shrimp trawl fisheries should be allowed some by-catch taking into consideration social and market implications, although "shrimp" trawling with no retention of any other species may not be a practical objective, because selective fishing may not necessarily equate to better conservation.

More specifically, the papers presented during the Mini-symposium on SHRIMP Fisheries emphasized on the challenges associated with the development, testing, uptake, and regulatory compliance associated with turtle excluder devices (TEDs) and by-catch reduction devices (BRDs). The high ratio of shrimp to discards and the ongoing practice of landing significant numbers of undersized fish for commercial purposes were also reported. Another issue raised was the loss of shrimp and other commercial species from both TEDs and BRDs, often described as the result of poor TED or BRD design or clogging of the TED by sawfish, tree limbs, and other debris. The papers presented and main findings from the Mini-symposium on SHRIMP Fisheries are shown in **Box 6** and **Box 7**, respectively.

Box 6. Papers presented during the Mini-symposium on SHRIMP Fisheries

David Brewer and S. Griffiths, S. Zhou, S. Eayrs, I. Stobutzkic, R. Bustamante & C. Dichmont. 2013. **Understanding and Managing Impacts on By-catch in Australia's Northern Prawn Fishery**

Petri Suuronen and Daniela Kalikosk. 2013. **Incorporating Human Dimension in the By-catch Management of Shrimp/Bottom Trawl Fisheries**

Ari Purbayanto, Ronny I. Wahyu, and Joko Santoso. 2013. **Research on By-catch of Shrimp Trawl Fishery in Arafura Sea: Volume, Reduction Devices, and Utilization of Discarded By-catch**

Adna Tokaç, Hüseyin Özbilgin and Hakan Kaykaç. 2013. **Selectivity of Five Different Codend Designs to Improve Size Selectivity for Deep Water Rose Shrimp (*Parapenaeus longirostris*) in the Aegean Sea**

Gökhan Gökçe, Ahmet Eryaşar, Yeliz Özbilgin, Adem Bozaoğlu, Ebrucan Kalecik and Hüseyin Özbilgin. 2013. **Discard Ratios of Fish and Shrimp Trawls in the North Eastern Mediterranean**

Pingguo He. 2013. **A Decade of Systematic Research to Minimize Discards in Northern Shrimp Trawls**

Truong Nguyen, Paul Winger, George Legge, Earl Dawe and Darrell Mullowney. 2013. **When Shrimp Trawling Collides with Crab Fisheries: A Case Study from Newfoundland, Canada**

Eduardo Gramaldo, Jørgen Vollstad and Roger B. Larse. 2013. **Trawling for Shrimps and Simultaneously Retaining Cod**

Suppachai Ananpongsuk. 2013. **The Promotion of Responsible Trawl Fishing Practices in Southeast Asia Through the Introduction of Juvenile and Trash Excluder Devices (JTEDs)**

F.G. O'Neill, R.J. Kynoch, J. Drewery, A. Edridge, and J. Mair. 2013. **Netting Grids in *Nephrops* Trawls to Reduce the Capture of Cod in the North Sea**

Niels Madsen, Rikke Frandsen, Jordan Feekings, and Ludvig A. Krag. 2013. **Development of Sorting Grids for Norway Lobster Fisheries**

Petri Suuronen and Isara Chanrachkij. 2013. **Trawl Fisheries Management in Southeast Asia and Coral Triangle Region**

Minlee Yap. 2013. **Introducing RIHN Project: Coastal Area Capability Enhancement in Southeast Asia**

Other Issues

Papers were also presented during the Open Session (**Box 8**) that discussed other relevant issues. Understanding size selectivity in diamond mesh codends and fish morphology was discussed, where the codend mesh geometry could be measured in 5 locations in a flume tank over three simulated catch weights. Morphological data based on the cross section of the cod, could be used to calculate the L_{50} values at these and other selected locations along the codend, and a curve presenting L_{50} values over a range of catch weights could be compared against the data collected in the field. When the calculated data fitted poorly to field data, this could mean that catch weight has significant implications for size selectivity, particularly when catches are low. Efforts to use underwater video cameras were

Box 7. Findings from the Mini-symposium on SHRIMP Fisheries

During the discussion, the issue on blocker of clogged grids was raised and options were discussed to overcome the issue which often negatively impact the level of enthusiasm by fishers to use these devices because of associated shrimp loss. Reducing this effect includes the use of a well designed and maintained grid operated at correct angle. The use of large grid could increase the filtering area and also the likelihood that the shrimp could pass around the blockage and through the grid into the codend. A large grid also comes with a large escape opening so that large animals can quickly pass unimpeded through the opening while the distortion of the codend by a large grid helps ensure that the escape cover is held over the escape opening by water pressure. However, ensuring that the escape cover can be readily pushed aside by escaping large animals and thus promoting readily acceptance by fishers to use grids, such as the large ones, could be difficult given fishers' concerns for shrimp loss and the impacts of cumbersome grids on fishing operations. Regarding the notion that a successful trial of fishery could be quickly replicated in another location, it was argued that this is not always the case as time and patience are required to tune and optimize the devices, which could take several weeks longer. Utilization of by-catch was seen as an attractive option which could provide additional income to fishers. However, the sustainability of this activity has always been questioned and thus, should not be seen as quick response to the issues and concerns. Alternative tools to managing by-catch should therefore be considered, with the possibility of getting producers and supplies involved in developing incentives for adopting change.

Box 8. Papers presented during the Open Session to discuss other relevant issues

Juanita D. Karlsen, Ludvig Ahm Krag, Bent Herrmann, and Kurt Hansen. 2013. **Understanding the Size Selectivity in Diamond Mesh Codends Based on Flume Tank Experiments and Fish Morphology: Effect of catch size and fish escape behavior**

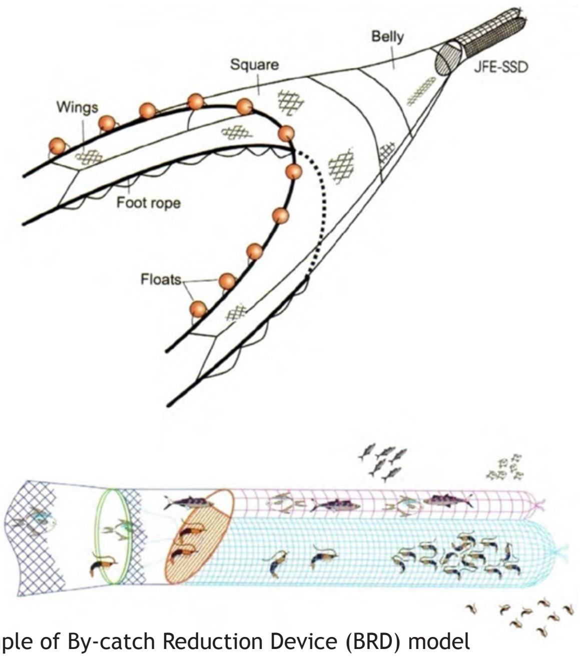
Yeliz D. Özbilgin, Ebrucan Kalecik, Adem S. Bozaoğlu, Ahmet R. Eryaşar, Gökhan Gökçe, and Hüseyin Özbilgin. 2013. **Observation of Fish Behavior during Demersal Trawling Operations in the North Eastern Mediterranean**

Mochammad Riyanto and Takafumi Arimoto. 2013. **Swimming Performance of Fish in Capture Process Simulation Examined by EMG/ECG Monitoring and Muscle Twitch Experiment**

Hüseyin Özbilgin, Ahmet Raif Eryaşar, Gökhan Gökçe, Yeliz Doğanyilmaz Özbilgin, Adem Sezai Bozaoğlu, and Ebdrucan Kalecik. 2013. **Improvement of Size Selectivity and Short Term Commercial Loss in the Eastern Mediterranean Demersal Trawl Fishery**

Limin Song. 2013. **A Comparison of Two Catch Rate Calculation Methods: Applicaion to a Longline Tuna Fishery**

Chris Rillihan. 2013. **Test of Rope Separator Haddock Trawl on Georges Bank**



Example of By-catch Reduction Device (BRD) model

also presented as means of evaluating qualitatively fish behavior during the capture process, especially in TEDs and BRDs. The footages presented useful observation and improved the understanding of trawl performance, TED and BRD performance, as well as the sources of blockage and loss of catch, and also demonstrated the fact that these trawl gear could cause mortality associated with using such gear. Moreover, efforts to evaluate the physiological condition of fish over a range of towing speeds were also reported, which involved the use of electrocardiograms and electromyograms in jack mackerel to evaluate the changes in heart rates and muscle power output over a range of swimming speeds. For example, while the peak swimming performance of jack mackerel was found to be around 5.0 fish lengths per second and the maximum sustained swimming speed was 4.0 fish lengths per second, the recovery time was found to be 300 minutes.

Results of a codend selectivity study were also described, where four different codends were tested in a covered codend experiment, while the selectivity of 5 common fish species and 2 species of shrimps was described. An evaluation of the impact of each codend on the income of fishers was also discussed, considering that several attempts to promote various codends had met resistance as these had reduced incomes of and uptake by fishers. Furthermore, efforts to develop and test a rope separator trawl to reduce catch of cod were also presented. Following a model tested in a flume tank, sea trials with a full sized separator trawl showed promise with significant reductions in cod, flounders, and skates compared to a control trawl. The impact of this trawl on catch of haddock was difficult to evaluate due to low and variable catch rates at the time of the experiments, although catch rates were only slightly less when the experimental trawl was used.

Conclusion and Way Forward

While fishing operations are exposed to the rising fuel prices with little or no significant price increases at the first sale of catch, capture fisheries will probably continue to suffer declining profitability in case necessary actions are not taken. If resource abundance remains static and operation costs are increasing, some bottom trawl and dredge fisheries may no longer be economically viable although passive gear and seine net fisheries may be less affected. Demersal trawl fishing, however, accounts for a significant part of the total catch for direct human consumption. Dramatically reduced trawling activity could adversely affect global fish supply and food security, at least in the short term. With medium-term forecasts indicating high likelihood of further increases in fuel prices (**Fig. 1**), sustainability of the fishing industry in the future becomes very challenging.

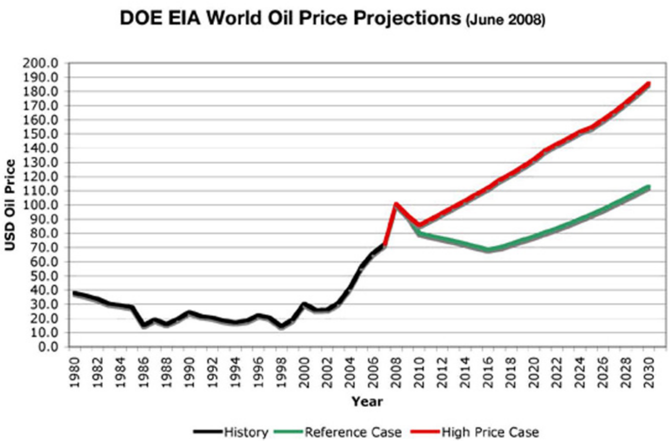


Fig. 1. Oil price projections until 2030

Thus, the fishing sector should strive to lower its fuel consumption, reduce carbon footprints, and decrease ecosystem impacts. Although the implementation or expansion of fuel subsidies as the case may be, would reduce immediate operating costs, this is often less accepted in many developing countries. Therefore, in order to help the fisheries sector achieve significant and permanent cost reductions, governments should strengthen their fisheries sector energy policy and create an enabling environment for fishing industries to rapidly and comprehensively adopt low-impact and fuel-efficient (LIFE) fishing technologies and practices. The development and adoption of such fishing techniques offer a range of aspects for maintaining the long-term profitability and sustainability of capture fisheries worldwide.

With fossil fuels remaining as the dominant energy source, pursuing energy efficiency in capture fisheries could generate benefits by reducing operating costs, controlling GHG emissions, and minimizing environmental impacts of fishing on the aquatic environments. Success of this transition will depend heavily on the response of governments to the implementation of international conventions together with positive reactions from the engine manufacturing sector, fuel-oil and lubricating-oil producers, and the fishing industry including the manufacturers of fishing gear. This could lead to the development and application of suitable and acceptable measures to conventional fisheries and create an appropriate catalyst for change in behavior of fishers. Furthermore, developing initiatives such as pursuing the modification of existing gear types and the development of low-resistance towed fishing gear with minimal impact in the aquatic environment is also equally important. In some cases, it may be necessary to switch to completely new gear types or practices in order to adopt LIFE fishing practices, thus, close cooperation between the fishing industry, scientists, fisheries managers, and other stakeholders will be fundamental to the development, introduction and acceptance of LIFE fishing technologies.

In general, in order to be effective, global R&D priorities should be established and pursued in support of the development and adoption of LIFE Fishing. The R&D priorities could include: promotion and funding of studies of cost-effective gear designs and fishing operations, including the establishment of technology incubators and other public-private sector initiatives to commercialize economically viable, practical and safe alternatives to conventional fishing methods; analysis and review of best practice operations across fisheries; improvement of technical ability among fishers; establishment of appropriate incentives; industry compliance with international conventions; and execution of robust but flexible fishery policies that support the transition to alternative technologies.

About the Authors

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Regional Fishing Vessels Record: Option to Mitigate IUU Fishing in Southeast Asia

Chumnarn Pongsri, Hajime Kawamura, Somboon Siriraksophon, and *Bundit Chokesanguan*

The project on the Promotion of Sustainable Fisheries and IUU Fishing-related Countermeasures in Southeast Asia which is being implemented by SEAFDEC with funding support from the Japanese Trust Fund (JTF), includes the Promotion of Fishing License, Boats Registration, and Port State Measures in Southeast Asia to pave the way for the development of a regional record of fishing vessels starting with vessels measuring 24 meters in length and over during its first phase, and to be expanded later with the recording of vessels measuring less than 24 meters. Through this project, SEAFDEC has been extending assistance to the countries in the region in their endeavors of improving their respective fishing licensing systems to conform to regional and international requirements, and in combating IUU fishing in their respective waters. SEAFDEC envisions that the establishment of regional fishing vessels record together with the refined fishing licensing systems could be effectively used as fisheries management tools in combating IUU fishing in the Southeast Asian region. Based on a paper presented by SEAFDEC during the Regional Workshop on Public Information Campaign organized by the ASEAN in Manila, Philippines on 28 June 2013, this article focuses on the progress of the establishment of the RFVR starting with vessels measuring 24 m in length and over, as one of the IUU fishing-related countermeasures, and updates the previous information contained in Matsumoto *et al*. (2012).

The FAO Code of Conduct for Responsible Fisheries with its overall objective of achieving sustainable fisheries puts serious concern on the issue of illegal, unreported and unregulated (IUU) fishing worldwide considering that IUU fishing undermines all efforts to conserve and manage fish stocks in capture fisheries. When confronted with IUU fishing, national and regional fisheries management organizations can fail to achieve management goals, leading to the loss of both short- and long-term social and economic opportunities and to negative effects on food security and environmental protection. IUU fishing can also lead to the collapse of a fishery or seriously impair efforts to rebuild stocks that have already been depleted.

In the Southeast Asian region, issues on IUU fishing have been seriously discussed by SEAFDEC in many events and occasions with concerned stakeholders (Matsumoto *et al*., 2012), especially with the Indonesian-based "Regional Plan of Action to Promote Responsible Fishing Practices including Combating IUU Fishing in the Southeast Asian Region" of RPOA-IUU which plays an important role in addressing issues on IUU fishing. As one of the advisory bodies of RPOA-IUU, SEAFDEC has been collaborating closely with the ASEAN and RPOA-IUU since their respective mandates are almost parallel, *i.e.* to promote responsible fisheries for sustainability and food security, as well as support regional and international approaches to prevent, deter and eliminate IUU fishing in the Southeast Asian region. Moreover, SEAFDEC also implements collaborative activities under the Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic Partnership (FCG/ASSP) that put priority on the direct and indirect impacts of IUU fishing on small-scale fisheries, including the development of a Regional Fishing Vessels Record (RFVR) as an option in coping with IUU fishing in the Southeast Asian region.

Occurrence of IUU Fishing in the Southeast Asian Region

Rapid growth of the fisheries industry in the Southeast Asian region had been noted especially in terms of increasing fishing capacity with higher efficiency of fishing gear such as trawlers and later purse seiners as well as the increasing number of processing plants since late 1970s. At the same time, fishing areas have also largely expanded covering the international waters of the South China Sea, and offshore areas within the Southeast Asian region when EEZs were only 12 nm. The adoption of 200 nm EEZ after 1982 made significant impacts to many countries in the region especially in terms of enhancing the capability to supply increased quantities of raw fish materials for the processing industries. However, without effective monitoring, control and surveillance (MCS) and fisheries management schemes (Yleaña and Velasco, 2012), the expansion of EEZ to 200 nm could drive the fishing industry to do illegal fishing, later known as IUU fishing. There are many types of IUU fishing, but the most common types include unlicensed fishing, landing of catch in neighboring states, double flagging of vessels, and conduct of illegal fishing methods and practices. The occurrence of IUU fishing activities in the Southeast Asian region is illustrated in **Fig. 1**. It should be noted that although Indonesia, the world's largest archipelago, has been monitoring its waters, illegal fishing

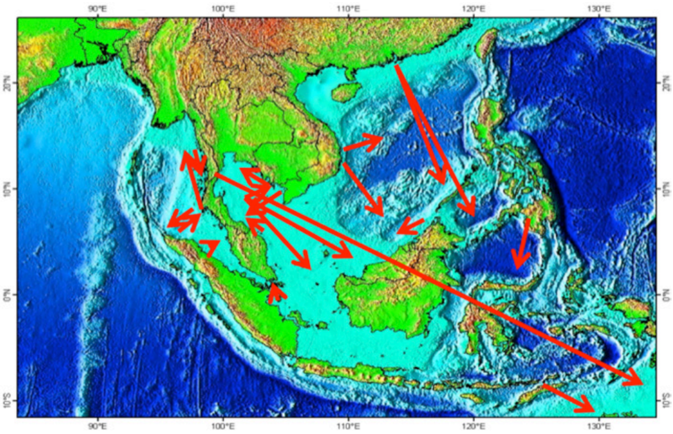

Fig. 1. Map of Southeast Asia showing the possible occurrence of IUU fishing

in its territory is still happening (Poernomo, *et al*., 2011). For instance, in 2008-2012 most of the illegal fishing boats were reported to have come from Vietnam, Thailand, and Malaysia, while a large vessel from China was apprehended for illegally fishing in Natuna Sea that spreads to the Strait of Karimata and Java Sea.

Impacts of IUU Fishing

Reports have indicated that the annual fisheries production from IUU fishing activities could be from 11 million to 26 million MT accounting for about 10 to 22% of the world's total fisheries production, and valued at about US$ 9 to 24 billion per year (MRAG, 2009). Nonetheless, some studies estimated that the value of IUU fishing in the Asia-Pacific region (including South Asian countries) could be around US$ 5.8 billion annually (Lungren *et al*., 2006). The impacts of IUU fishing is not only in terms of losses in revenues and resources, but also in the economic, social and environmental aspects.

For example, decreases in the contribution of EEZ fisheries to national economies could lead to reduced potential employment opportunities that local and locally-based fleets usually create, decreased local landings and potential export earnings, more budget needed for MCS/fisheries management, limited accuracy of stock assessment models, and reduced species richness and their diversity. In the case of Indonesia, it has been reported that its traditional fisherfolks are often left to deal with illegal fishers, especially in border areas such as in East Kalimantan and North Sumatra where Indonesian fisherfolks often encounter fish trawlers owned by foreigners, including those from the Philippines and Malaysia (Heriyanto, 2012).

Regional Approach to Prevent IUU Fishing/Illegal Fishing

Implementation of MCS has been considered as a catalyst in preventing IUU fishing particularly illegal fishing (Yleaña and Velasco, 2012). Under this circumstance, the implementation MCS could include such aspects as: joint marine patrol between navy, police and department of fisheries and marine departments, while vessels should be equipped with new engine technology and fast; increasing awareness on the use of advance technology such as coastal radar that can be installed in the vicinity of tracking illegal vessels; installation of vessel monitoring system (VMS) on fishing vessels that already have license whether local or foreign ships; and enhancing human resources to enable officers to carry out their duties, properly and professionally in their fields to avoid a breach or things that deviate from existing laws. In support of the implementation of MCS, SEAFDEC through a series of technical/expert consultations with the ASEAN Member States agreed in principle to establish a Regional Fishing Vessels Record as a tool to combat the IUU fishing in the Southeast Asian region.

Establishment of Regional Fishing Vessels Record

As SEAFDEC sustains its role in promoting sustainable fisheries in the region, its Training Department (TD) organized in October 2011 the Regional Core Experts Meeting in Fishing License, Boats Registration and Information on Export of Fisheries Products in Southeast Asia where information on the procedures for fishing licensing and boats registration in Southeast Asian countries

as well as the corresponding minimum requirements for obtaining fishing license and boats registration certificates were shared. It was during such Regional Core Experts Meeting that the development of regional guidelines on fishing licensing and boats registration was endorsed while the ways and means of preventing the trading of IUU fishing products from the region were initially identified (Matsumoto *et al*., 2012). In order to strengthen the regional networking and enhance the collaboration among the countries in the development of such guidelines as well as in future relevant activities, an electronic email group (*combat_iuu@seafdec.org*) was established which has since then, been actively used to exchange and update the necessary information. Subsequently, the Experts Group Meeting on Fishing Licensing and Boats Registration in Southeast Asia was convened by TD in June 2012 arrived at an agreement that the RFVR should be compiled focusing first on the information of larger fishing vessels with length from 24 meters and over. The proposed establishment of the RFVR was approved by the SEAFDEC Council during its 45th Meeting in April 2013 in the Philippines as well as by the ASEAN Sectoral Working Group on Fisheries (ASWGFi) during its meeting also in 2013.

Basic Requirements for Vessel Registration in Southeast Asian Countries

In launching the Establishment of Regional Fishing Vessels Record (Matsumoto *et al*., 2012), TD prepared a questionnaire which was sent to eight SEAFDEC Member Countries, *i.e.* Brunei Darussalam, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam, to explore the possibility of sharing data and identify the agreed basic information requirements for the compilation of information relevant to RFVR. From the responses, the concerned countries agreed on the basic requirements for vessel registration and the basic information that could be shared by the countries, as shown in **Box 1** and **Box 2**, respectively.

Moreover, the initial information on the respective number of national fishing vessels that measure 24 meters in length and over was also compiled (**Table 1**). Results of the analysis of the concerned countries' responses would be used as inputs during the proposed regional workshop to finalize the development and management of RFVR. In addition, obstacles with respect to the integration of the items in the basic requirements into the RFVR will also be considered during the finalization of the RFVR in 2014.

Box 1. Agreed basic requirements for compiling vessel registration in the Southeast Asian countries

- Name of vessel
- Type of fishing method/gear
- Port of registry
- Gross tonnage (G.T.)
- Length (L)
- Breadth (B)
- Depth (D)
- Engine Power
- Shipyard
- Date of launching
- International Radio Call Sign
- Engine Brand
- Serial number of engine
- Hull material
- Date of registration
- Area (country) of fishing operation
- Nationality of vessel (flag)
- Previous name (if any)
- Previous flag (if any)
- Name of captain/master
- Nationality of captain/master
- Number of crew (maximum/minimum)
- Nationality of crew

Table 1. Updated number of fishing vessels 24 meters in length and over (as of 2013)

Country	Total	less than 24 m in length	24 m and over in length
Brunei Darussalam	2,427	2,421	6
Cambodia	7,034	7,034	0
Indonesia	570,827	569,105	1,722
Malaysia	54,235	54,169	66
Myanmar	30,349	Powered 14,222 Non Powered 15,463	664
Philippines	473,400	472,804	596
Singapore	36	36	Nil
Thailand	40,742	39,995	747
Vietnam	123,124	122,812	312

Way Forward

The establishment of RFVR is being pursued at the regional level to ensure that relevant information could be shared between SEAFDEC, thus facilitating information sharing in the future.

Box 2. Agreed possible data that could be shared among the SEAFDEC Member Countries				
Information on fishing vessels	Accessible by			
	General public	SEAFDEC Member Countries	Exclusively for SEAFDEC database	Others (specify)
Name of vessel	BN, ID, MY, PH	TH, VN, SG	MM	MY (vessel number, not vessel name)
Type of fishing method/gear	BN, ID, MY, PH	TH, VN, SG	MM	
Port of registry	BN, MY, PH	TH, VN, SG	MM	ID (location of registry)
Gross tonnage (G.T.)(International gross tonnage/ registered gross tonnage)	BN, ID, MY	PH, TH, VN, SG	MM	MY (using GRT)
Length (L)	BN, ID, MY	PH, TH, VN, SG	MM	
Breadth (B)	BN, ID, MY	PH, TH, VN, SG	MM	
Depth (D)	BN, ID, MY	PH, TH, VN, SG	MM	
Engine Power	BN, ID, MY	PH, TH, VN, SG	MM	
Shipyard	BN, MY	PH, VN		ID (location of builder) MM (-) SG (not compiled) TH (data compiled by Marine Department)
Date of launching	ID, MY	PH, VN, SG		BN (no answer) MY (Same with date registered) MM (-) TH (data compiled by Marine Department)
International Radio Call Sign	BN	PH, TH, VN, SG		ID (-) MY (No answer) MM (-) TH (if data is available)
Engine Brand	BN, ID, MY	PH, TH, VN, SG	MM	
Hull material	BN, ID	PH, TH, VN, SG	MM	MY (optional)
Date of registration	BN, ID, MY	PH, TH, VN, SG	MM	
Serial number of engine	BN, ID, MY	PH, VN, SG	MM	TH (data compiled by Marine Department)
Area (country) of fishing operation	BN, ID, MY	TH, VN, SG	MM, PH	
Nationality of vessel (flag)	BN, MY, PH,	TH, VN	MM	ID (-)
Previous name (if any)	BN, ID, MY	PH, VN	MM	SG (not collected), TH (data compiled by Marine Department)
Previous flag (if any)	BN, MY	PH, VN	MM	ID (-) SG (not collected) TH (data compiled by Marine Department)
Name of captain/master	BN	PH, VN, SG	MM	ID (-), MY (optional) TH (data compiled by Marine Department)
Nationality of captain/master	BN	PH, VN, SG	MM	ID (-) MY (optional) TH (data compiled by Marine Department)
Number of crew (maximum/minimum)	BN, MY	PH, VN, SG	MM	ID (-) TH (data compiled by Marine Department)
Nationality of crew	BN, MY	PH, VN, SG	MM	ID (-) TH (data compiled by Marine Department)

Countries: Brunei Darussalam (BN), Indonesia (ID), Malaysia (MY), Myanmar (MM), Philippines (PH), Singapore (SG), Thailand (TH), Vietnam (VN)

In order to finalize the establishment of RFVR, SEAFDEC proposed to organize a regional workshop on RFVR database development and management in 2014, to enhance information sharing and integration of information on the basic requirements for the RFVR with the Member Countries concerned. Visit to the Member Countries concerned will also be organized to provide technical support and assistance during the introduction and implementation of the RFVR database.

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Big Artificial Reefs for Improved Enhancement of Fishery Resources: Experience of Malaysia

Ahmad Ali and *Virgilia T. Sulit*

In the development of its Artificial Reefs (ARs) Program for fishery use (resources conservation and fishing) and non-fishery use (marine resources enhancement), Malaysia had allocated about 155 million Malaysian Ringgit (RM) from 1976 to 2010. About 36% of the allocated budget was channelled through the Department of Fisheries Malaysia (DoFM) while more than 63% was allocated through the Fisheries Development Authority of Malaysia (FDAM) and less than 1% through other agencies. Many agencies in Malaysia have been involved in the construction, deployment and management of the ARs also known as ***tukun tiruan*** in Bahasa Melayu. In the early part of the country's ARs Program, the use of small and medium sized ***tukun tiruan*** had been promoted, while in the latter part and for various reasons, FDAM (2001-2010) and DoFM (2006-2010) focused on big-sized ***tukun tiruan***.

The Artificial Reefs (ARs) Program of Malaysia has two-pronged objectives, *i.e.* for fishery use (conservation and fishing) and for non-fishery use (enhancement). For conservation purposes, the ARs have enhanced coastal fishery resources by providing firm substrate for marine fauna and flora to grow. In addition, Malaysia had been using ARs to deter the encroachment of prohibited inshore areas by trawlers notwithstanding a regulation of the Department of Fisheries Malaysia (DoFM) that prohibits fishing activities within 0.5 nm from AR sites. The country's ARs that are intended for conservation are being collectively managed by various agencies, *e.g.* DoFM, Department of Fisheries Sabah (DoFS), Department of Marine Park (DMP), Sarawak Forestry Corporation (SFC), Fisheries Development Authority of Malaysia (FDAM), Malaysian Maritime Enforcement Agency, fishermen's associations, and recreational anglers. Fishing activities are not allowed within 0.5 nm from AR sites. However, for some ARs that serve as aggregating structures for scattered schools of fish, fishing activities are allowed near these ARs.

For non-fishery use, ARs have provided firm substrates for marine fauna and flora to grow, thus, enhancing the marine resources for recreational and eco-tourism activities (*e.g.* SCUBA, snorkelling activities). Fishing activities are allowed only near ARs that have been installed outside Marine Protected Areas. Construction and management of these ARs is conducted by various agencies, *e.g.* DMP, National Hydraulic Research Institute of Malaysia (NAHRIM), academic institutions, chalet operators, Malaysian Nature Society (MNS), Reef Check Malaysia, and other private companies. Construction and deployment of ARs or *tukun tiruan* in Bahasa Melayu have been carried out under the various phases of the Malaysian Plan (**Table 1**). The overall ARs Program of Malaysia from 1976 to 2010 entailed a total budget of more than 155 million RM, of which about 63% was provided through FDAM, about 36% through DoFM, and the remaining less than 1% through other agencies.

Table 1. Budget allocations to DoFM and LKIM for construction and deployment of ARs (1976-2010)

Malaysian Plan	Duration	Budgetary Allocations (in Malaysian Ringgit (RM)*	
		DoFM	FDAM
3rd Malaysian Plan	1976-1980	116,000	-
4th Malaysian Plan	1981-1985	524,000	199,657
5th Malaysian Plan	1986-1990	8,240,000	2,123,880
6th Malaysian Plan	1991-1995	9,400,000	3,831,275
7th Malaysian Plan	1996-2000	2,751,953	11,435,632
8th Malaysian Plan	2001-2005	2,524,344	60,377,893
9th Malaysian Plan	2006-2010	32,004,162	21,224,385
Total Budget Received		55,560,459	99,192,722
Years of operation		34 years	27 years
Ave Budget Received		1,600,000/ year	3,600,000/ year

**Exchange rate: 1USD=RM3.3*

Construction and management of the deployed ARs in Malaysia is being carried out through collective efforts of various agencies, namely: Fisheries Development Authority of Malaysia (FDAM), Department of Fisheries Malaysia (DoFM), Department of Marine Park (DMP), Malaysian Maritime Enforcement Agency (MMEA), Standards and Industrial Research Institute of Malaysia (SIRIM Bhd.), National Hydraulic Research Institute of Malaysia (NAHRIM), Universiti Sains Malaysia (USM), Income Revenue Board of Malaysia (IRBM), Department of Fisheries Sabah (DoFS), Sarawak Forestry Cooperation (SFC), among others. The contribution of these agencies to the development of ARs in Malaysia is shown in **Table 2**.

Table 2. Malaysian agencies involved in construction and deployment of ARs (1976-2013)

Agencies	Duration	Materials used for ARs
Department of Fisheries Malaysia (DoFM)	1976-2010	reinforced concrete, tires, polyvinyl chloride (PVC), old fishing vessels, ceramics, others
Sarawak Forestry Cooperation (SFC)	1977-2013	reef ball
Department of Fisheries Sabah (DoFS)	1980s	tires, old vehicles, old fishing vessels, others
Fisheries Development Authority of Malaysia (FDAM)	1983-2010	reinforced concrete, tires, ceramics, fiberglass reinforced concrete (FRC), fiberglass, others
Department of Marine Park (DMP)	1994-2012	reinforced concrete, bio-rocks, decommissioned war ships, old fishing vessels, PVC, fiberglass, others
Malaysian Maritime Enforcement Agency (MMEA)	2005-2012	confiscated fishing vessels
National Hydraulic Research Institute of Malaysia (NAHRIM)	2009	reinforced concrete
Standards and Industrial Research Institute of Malaysia (SIRIM Bhd)	2010-2012	ceramics
Universiti Sains Malaysia (USM)	2011	reinforced concrete (for sea cucumber)
Income Revenue Board of Malaysia (IRBM)	2013	steel

Big versus Small-Medium Size ARs

DoFM classifies the fabricated concrete ARs based on size, weight, materials and design, *i.e.* big size ARs should have a minimum size of 2m x 2m x 2m and weigh more than 10 metric tons (MT). Examples of big size ARs are shown in **Fig. 1**, **Fig. 2**, **Fig. 3**. DoFM had installed 68 big size ARs in the waters of Malaysia with 10-72 AR modules per site (**Fig. 4**, **Fig.5**).

During the initial stage of ARs development in Malaysia, DoFM constructed and deployed ARs mainly for conservation purposes, but starting in 1983 FDAM was seriously involved in the construction of ARs for the main purpose of aggregating fish to help traditional fishers in catching more fish and increase their incomes. The AR structures then were of small-medium sizes, *i.e.* cuboids, cylindrical, ceramics, piles, FRC, and others. The Department of Marine Parks was also involved in the development of ARs which were deployed for the purpose of rehabilitating the coral reefs in the country's marine park areas, which are not more than 2 nm from the islands. MMEA also did its share of AR deployment using fishing vessels that were confiscated for conducting illegal fishing in Malaysian waters (Ali *et al.*, 2011).

Fig. 1. Soft-bottom anti-trawler AR (size: 3.75m x 3.75m 3.85m; weight: 32 MT)

Fig. 2. Soft-bottom juvenile enhancement AR (size: 3.75m x3.75m x 3.85m; weight: 32 MT)

Fig. 3. Soft-bottom cuboid AR (size:3.0 m x 3.0 m x 3.85 m; weight: 22 MT)

Fig. 4. Map of Malaysia showing the sites where big size ARs had been installed (Number of sites: 68; No of modules/site: 10-72)

Fig. 5. Installing a cube anti-trawler AR by DoFM

Under the Artificial Reefs Program of Malaysia, installation of ARs was meant to increase productivity of the marine environment through the development of fish sanctuaries in sea beds, and promote the recovery of fishery resources that had been seriously depleted due to irresponsible fishing activities. In the early phase of the Program, only discarded tires were used until 1990s when reports indicated that tires could leach toxic matters into the marine environment, and since then Malaysia prohibited the use of tires as ARs.

Later, PVC materials were used to construct ARs but this was also found to be not suitable especially in open waters where many PVC ARs were lost or destroyed. The first pre-fabricated ARs using reinforced concrete were developed by Malaysia in mid 1990s, comprising two types: concrete drainage culvert and concrete pipes.

Other types of ARs were also developed, *e.g.* concrete lobster ARs, squid ARs, reef-ball ARs. However, due to severe weather conditions and fishing operations of illegal trawlers, most of these small-medium size ARs were abandoned. This led to the design and construction of big size reinforced concrete ARs for installation in hard and soft bottom sea beds (Ali *et al*., 2010).

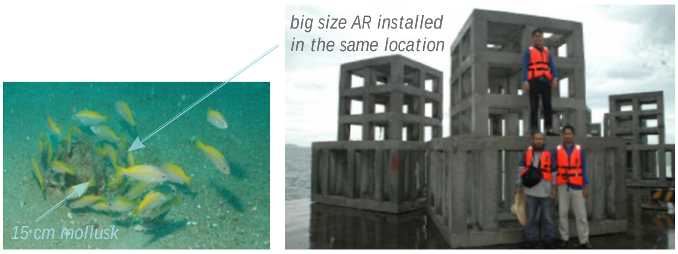

Fig. 6. Big size AR installed in location where schools of fish were known to aggregate

Fig. 7. Deployment of big size AR resulted in the aggregation of more fishes of high commercial value

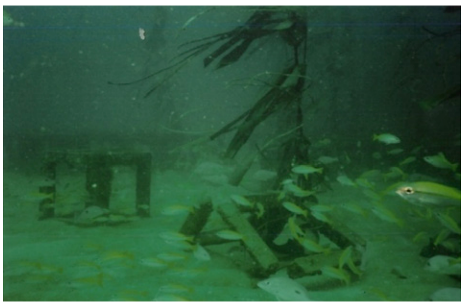

Fig. 8. Small-medium size ARs almost disintegrating while less schools of fish aggregate

Fig. 9. Encroaching trawlers often lose their trawl nets and codends when these become entangled with big AR structures

At the onset, researchers from DoFM observed that schools of big-eye snappers (more than 30 tails) were swimming close to a 15 cm mollusk (**Fig. 6**), thus, came the thought of installing a big size AR in that same location, and as a result, about 2,000 tails of *Lutjanus* spp. were observed to aggregate outside and within the big size AR (**Fig. 7**). While before, when small-medium size ARs were used, the structures could not last long while aggregation of fish was observed to be less (**Fig. 8**) compared to the situation with big size ARs. Nevertheless, one of the most critical advantages of deploying big size ARs is the deterrence of encroaching trawlers from getting close to inshore areas as their trawl nets and especially the codends could be entangled with the ARs (**Fig. 9**) leading to big losses in their fishing operations (Ali *et al*., 2011).

Deployment and Monitoring of Big Size ARs

Construction of ARs by DoFM follows the British Standard 8110 (column and beam rebar – Y12x4, link – R8@ 200 mm c/c, slab reinforcement – BRCA10/Y10). The concrete cover is 50 mm using ready-mixed concrete from batching plant, *i.e.* concrete grade 50 for soft bottom ARs and grade 40 for other types of ARs. Cube test is done 7-28 days after construction. The types of big size fabricated reinforced concrete ARs developed by DoFM from 2006 to 2013 are shown in **Table 3**.

To ensure adherence to specifications, AR construction works were supervised and monitored by officers from DoFM (Engineering Division, Licensing and Resource Management Division) together with researchers from MFRDMD and officers from state fisheries offices. After testing for sturdiness and before deployment of the ARs, site selection is conducted, *i.e.* using side scan sonar to create a visual profile of the sea bed of the possible area, using Phleger corer to obtain ocean bottom cores (1.2 m in length), using Smith Mc Intyre Grab to collect samples

Table 3. Big size ARs fabricated by DoFM using reinforced concrete (2006-2013)

AR types	Concrete grade used	Year produced	Specifications (m x m x m)	Weight (MT)
Soft-bottom 1	40	2006	3.0 x 3.0 x 3.6	14
Soft-bottom 2	50	2007, 2008	3.0 x 3.0 x 3.6	19
Soft-bottom 3	50	2009, 2010	3.75 x 3.75 x 3.85	23
Soft-bottom anti-trawler	50	2010	3.75 x 3.75 x 3.85	32
Soft-bottom juvenile enhancement 1	50	2010	3.75 x 3.75 x 3.85	42
Cube	40	2009	2.5 x 2.5 x 2.5	16
Cube juvenile enhancement	40	2010	2.5 x 2.5 x 2.5	20
Cube anti-trawler	40	2012	3.5 x 3.5 x 3.5	22.5
Cuboid	40	2007	2.0 x 2.0 x 3.0	10
Cuboid juvenile enhancement	40	2010	2.0 x 2.0 x 3.0	12
Cuboid bio-active	40	2010	2.0 x 2.0 x 3.0	14
Soft-bottom juvenile enhancement 2	40	2013	3.85 x 3.85 x 3.85	42
Soft-bottom cuboid	40	2013	3.0 x 3.0 x 3.85	22
Soft-bottom recreational	40	2013	3.5 x 3.5 x 3.85	25

of ocean sediments, using sub-bottom profiler to measure height of any objects on the sea floor, and using echo-sounder to detect schools of fish.

A pontoon or barge is used to transport the ARs from jetty to deployment sites. During the installation processes, free fall deployment method is applied using 50-80 metric tons crane equipped with special mechanical release device. At each site in Malaysian waters, 14-128 modules were placed 2-5 m apart from each other. For the purpose of deterring illegal trawlers, some modules were placed randomly over a larger area and spaced at about 100-200 m from each other. Location of every module is recorded using Global Positioning System (GPS). Soon after deployment is completed at each site, divers are dispatched to inspect and record the condition and position of the modules on the sea bed. The exact coordinates are submitted to the National Hydrography Center of Malaysia for national reference and future usage.

Success Story: Malaysian Big Size ARs

Visual observation was conducted using close-up and wide angle video and camera images to record physical stability of the reef modules, biofouling and encrustation of sessile organisms, fish behavior especially with regard to their interaction with the ARs as well as fish species. Big size ARs have been observed to be superior to small-medium size ARs in terms of their ability to attract more marine fauna and flora. Four years after deployment of big size ARs in Malaysia, recreational activities have increased near AR locations, with ARs fully covered by various species of soft corals and teeming with colorful small and large fishes as well as other crustaceans and invertebrates (**Fig. 10**, **Fig. 11**, **Fig. 12**, **Fig. 13**). In the socio-economic survey conducted, more than 97% of the respondents agreed that deployment of big ARs had decreased incidence of trawlers encroaching nearshore areas while more species of marine flora and fauna have settled outside and within big ARs. More than 78% of respondents reported that their incomes had increased considerably after the deployment of big ARs (Ali *et al*.,2013).

Conclusion and Way Forward

Based on the successful ARs Program of Malaysia, it can be deduced that larger size ARs are superior to small and medium size ARs especially in attracting more flora and fauna to settle within, on and outside the ARs. Moreover, big ARs have played excellent dual roles in resource

Fig. 10. Various species of soft corals covering big ARs

Fig. 11. Situation of big tetrapod ARs, four years after deployment

Fig. 12. Species of sea cucumbers settling near big ARs

enhancement and management, not only in terms of creating new habitats and recovering threatened stocks but also in deterring encroachment of trawlers in inshore areas thereby mitigating the conflicts between large-scale and small-scale fishers, with the latter increasing their incomes from fishing operations. Most modules placed on coarse sand sea beds were found to be stable while no scouring had occurred. The AR design allows the free flow of water current above the base of the modules facilitating water current flow with little resistance at the bottom of the modules. Good ARs design has therefore, contributed to making the AR structures attractive to more flora and fauna.

Fig. 13. Commercially-important fishes settling in big ARs

Considering that waters in various areas of Malaysia could be deep, DoFM is looking for new technology on ARs, especially the use of steel for the construction of big size ARs. Based on the study visits conducted by the first author from MFRDMD to the National Research Institute of Fisheries Engineering in Choshi Japan in 2013, he observed that the highest steel AR of Japan as of 2010 was 40 m and weighing 92 MT which could be deployed in water depths of 63 m targeting sea bream, horse mackerel, as well as yellow tail. DoFM is therefore exploring the possibility of adapting such technology in Malaysia. In order to facilitate discussions and exchange of information on new AR technology, DoFM plans to organize the second workshop on Artificial Reefs for Enhancement of Fisheries Resources in the Southeast Asian Region in 2015 with the collaboration of SEAFDEC and the Fisheries Research Agency (FRA) of Japan. Technologies developed through the ARs Program of Malaysia could be disseminated to the other countries in the Southeast Asian region. It is for this reason that the proposed workshop in 2015 will consider inviting more participants from the Southeast Asian countries.

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Milkfish and Tilapia as Biofactories: Potentials and Opportunities

Mudjekeewis Santos, Irma Destura and *June Feliciano Ordoñez*

Living organisms used in commercial-scale production of compounds such as recombinant proteins for agricultural, biomedical, and pharmaceutical applications are referred to as biofactories. This article assesses the role of two most important aquaculture species in the Philippines, *i.e.* milkfish and tilapia, as prospective biofactories from their production to semi-processing chain, considering the economic importance of these resources in the country. Based on a paper presented by the authors during the Round Table Discussion on Marine/Aquatic Biofactories in the Philippines organized by the Philippine National Academy of Science and Technology on 13 March 2013, this article focuses on the status of production and utilization of these species, especially on how these are utilized and processed into value-added products, as well as points out the underlying issues and concerns that impede the sustained role of these species as biofactories.

The rise of human population parallels with the growing need of the essential necessities of everyday life, which might not be limited only to food, shelter, and clothing, but also novel products that are made available through the integration of science and new technology-based systems. In our society today, many products are produced using raw materials generally coming from and already existing in the natural resources which are known to be free but their quantities may be continually declining. In order to maintain and enhance the availability of such resources, their production is always being intensified while their availability as raw materials for creating novel products should be assured. Two most economically-important fisheries commodities in the Philippines, *i.e.* milkfish and tilapia, have been found to have the potentials as biofactories.

Plant, algal, and bacterial cells have been the most successful biofactories, and are utilized in the production of many important metabolites in both wild type form or as recombinant cells (Sarmidi and El Enshasy, 2012). Sweeteners, essential oils, agar, carrageenan, biodiesel, antibiotics, and recombinant proteins are among the compounds produced from various biofactories and are now used for different purposes in various industries. Interestingly, several types of commercially-valuable compounds can also be extracted from fish especially from fish processing by-products using biotechnology. This opportunity could drive the Philippine tilapia and milkfish industry from being limited to fish meat production, as these aquatic species had been considered for decades, towards becoming biofactories. Certainly, the future progress of both industries will not only come from increased production volume and current value-added products but also by generating alternative products which are mainly offered through biotechnology techniques.

Current Milkfish and Tilapia Industry Statistics in the Philippines

Milkfish

Although not fully determined, the earliest account of the development of milkfish industry in the Philippines pointed to its existence even before the arrival of the European colonizers in the 1500s. The early milkfish farming then was more of a trap-and-grow operation based on the natural stock of milkfish fry that comes inland with the tidal waters. In 1900s, milkfish farming was purely a private sector effort in many areas of the country, namely: Central Luzon, Pangasinan and Iloilo Provinces. Milkfish culture from the early days of American rule (Radcliffe, 1912; Day 1915; Herre and Mendoza, 1929) until post independence in 1946 was mainly described based on such existing traditional practices.

The reorganization of the former Bureau of Fisheries in 1947, led to the conduct of research on milkfish culture focusing on fertilization and *lablab* production (Rabanal, 1949). In 1968, a hatchery project in Naujan, Mindoro was developed in order to minimize total dependence on natural supply of fry. In the early 1970s, milkfish culture in pens began in Laguna Lake (Delmendo and Gedney, 1974), and was found to be successful and commercially viable. In late 1970s, the Philippine Bureau of Fisheries and Aquatic Resources (BFAR) under a UNDP-funded project developed a production calendar to guide milkfish farmers in different climatic zones of the country. In 1981, the National Bangus Breeding Program (NBBP) by BFAR and SEAFDEC was established to jumpstart the mass production of milkfish fry and demonstrate its technical and commercial viability.

Status and trend of milkfish production in the Philippines

About 98% of milkfish production in the Philippines comes from aquaculture with only a very small amount from capture fisheries. Production from milkfish culture continued to increase contributing about 15% to the total aquaculture fish production of the country. An increase of about 4% production in 2012 from 2011 was a result of milkfish good farm management, availability of quality fry/fingerlings, and proper feeding practices (BAS, 2012). From 2002 to 2011, production of milkfish in aquaculture (**Fig. 1**) grew at an average rate of about 3% (PCAARRD, 2012), where production from brackishwater fishponds was known to be the highest among the various production systems.

The country's top five milkfish producing provinces are Pangasinan, Capiz, Iloilo, Negros Occidental, and Bulacan (**Fig. 2**). While Pangasinan had the biggest share of the production at 39%, Capiz, Iloilo and Negros Occidental come next contributing about 30%, and then Bulacan accounting for about 11%. In 2010, milkfish export amounted to 4,626 MT valued at PHP 715.05 million, where 60% of total exports were in frozen form and 25% were in whole or in pieces, and fillet and frozen forms in minimal quantities (BAS, 2012). A number of private and government milkfish hatcheries are operating in the Philippines, but despite their existence, some farmers continue to import milkfish fry from Indonesia and Taiwan. (PCAARRD, 2012). Recently, there has been an increasing trend in the utilization of milkfish in the country because of its availability in local markets.

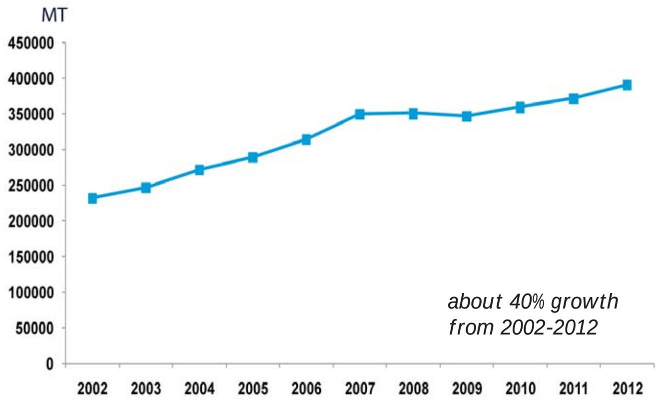

Fig. 1. Total annual milkfish production of the Philippines from 2002-2012 (BAS, 2012)

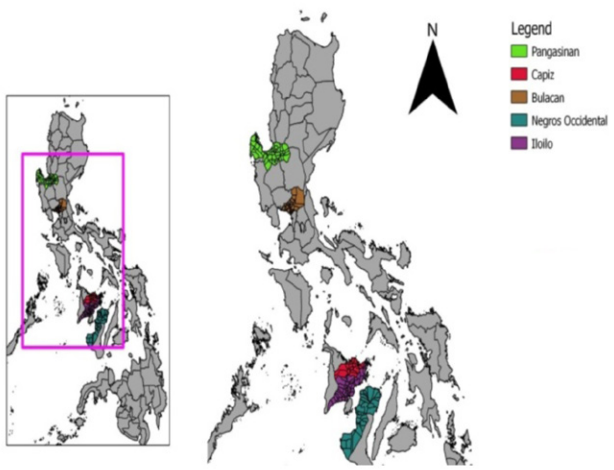

Fig. 2. Five top milkfish producing provinces of the Philippines

The performance of the milkfish industry has been affected by the limited supply of quality fry, especially considering the notable decline in the fry supply from the wild (Ahmed *et al*., 2001; Bagarinao, 1999) recorded during the previous years. Nevertheless, the demand for fry has been growing due to culture intensification and shift in production towards milkfish farming in reaction to the dwindling prawn industry (Israel, 2000). According to Israel (2000), if milkfish production is to keep pace with the average annual national population growth of about 2.5%, the country will have to produce about 356 million more fry in 2005 and 617 million more in 2010. The required volumes of fry will increase if there would be a decline in the available wild fry from the 1997 level or if other objectives beyond just meeting the needs of the growing population are targeted as well. To achieve this, there is a need to: (a) seed the open water bodies, (b) lower the nutritional deficiency rates of the population, and (c) enhance exports.

Israel (2000) also noted that if the growth rate in milkfish production is aimed at 5% annually, the additional fry requirement will go up to 1,443 million by 2010. Nonetheless, he also offered options to address the problem of limited supply of milkfish fry, *i.e.* either through importation or development of a home grown industry that will produce hatchery-bred fry in sufficient quantity and quality. While he considered the first option as undesirable since it can lead to transporting into the country certain milkfish diseases that are not locally endemic and will also cost the country its much-needed foreign exchange, it will forfeit the chance of exploiting the country's natural comparative advantage in aquaculture.

The development of an industry that produces hatchery-bred milkfish fry could address the problem of limited fry supply over the long term, and also helps in avoiding the undesirable effects of importation as well as decrease the price of fry and milkfish products in the long run. The effect

of these two options will be essential since it can promote the competitiveness of local milkfish-based products in the domestic and international markets.

The increasing demand for milkfish fry in mid 1990s when fish pens and cages in brackish and marine waters started to appear had nevertheless, prompted investigations into artificial spawning of milkfish broodstock in captivity. Therefore, based on the results of the Bangus Fry Resource Assessment in the Philippines conducted in 1996-1997, research studies have been conducted from 2000 up to the present, to increase the volume of fry from local hatcheries, and improve fry quality and performance to make the country's milkfish industry competitive.

Utilization of milkfish in the Philippines: value-added products

Value-adding is defined as increasing the worth or value of a product after it has undergone simple or complex processing operation, and turning simple products into value-added products in order to obtain better income, improve processing utilization and provide variety of products keeping at pace with consumers' needs (Alsons Aqua Technologies Inc., 2004). In milkfish, the most common form of value-adding occurs in filleting, deboning, smoking, and marinating the fish, the products of which are packed and sold chilled or frozen (Yap *et al*., 2007). Nowadays, filleted, deboned and smoked milkfish products are sold not only in local but also in international markets, especially in the USA, Japan and other neighboring Asian countries. Some processed products of milkfish are also exported to other European countries (Alsons Aqua Technologies Inc., 2004). The deboned form, locally known as "*boneless bangus*", is the most popular among the value-added products of milkfish. The by-product of the boneless bangus such as trimmings and bits of flesh that are removed with the bones, are combined to pay forward to another forms of local processed products such as fishballs, milkfish *lumpia*, *quekiam*, and *embutido*, while the milkfish skins are turned into *chicharon* (Yap *et al*., 2007).

Nowadays, commercial companies engage in canning industry are developing new forms of processed products using milkfish as main material, which are also gaining popularity because of the availability of raw materials, the milkfish which is grown locally in the country. The new processed canned milkfish product which is already available in the local market comes in different flavors derived from famous Filipino foods. The added ingredients are mixed with raw milkfish, and undergo cooking and several stages of processing techniques to make the final product more tasty and palatable. In some provinces, like in Pangasinan, not only is the milkfish "meat" utilized for value-adding but also the internal organs (intestines, lungs, heart, and stomach) which are used to produce "*bagoong*" (fish sauce) or fish paste, a famous condiment in Filipino cuisine. In local pastry shops, cookies mixed with milkfish bone have been developed and sold as calcium-rich snacks for kids while they are starting to develop their bones, and for adults needing additional calcium supply.

Tilapia

Tilapia culture in the Philippines began with the introduction of Mozambique tilapia (*Oreochromis mossambicus* Peters 1852) imported from Thailand in 1950s. However, culture of this "wonder fish" as it was called back then, failed to expand in the commercial production because of its unwanted characteristics such as early maturity resulting to overpopulation in fish ponds, stunted growth, small in size at harvest, became "pest" in brackishwater ponds, and unappealing dark-color (Bolivar, 1993; Guerrero, 1994). Therefore, the country's production of tilapia in 1960s was minimal (FAO, 2006), undermining the slow progress of tilapia farming that was not revived until a decade later (Yosef, 2009).

In 1970s, the fuel oil crisis severely damaged the country's marine fisheries industry (Guerrero, 1994), forcing the Philippine Government to give a higher priority in raising fish production from inland aquaculture to cover for the impending shortage of fish products. Tilapia was then chosen for such development because of its many desirable characteristics compared to other aquaculture fishes and its potential to benefit the resource-poor rural people as well as commercial growers. This is considering also that since 1972, different strains of Nile tilapia (*Oreochromis niloticus* L.) had been introduced to the country (Guerrero and Tayamen, 1988; Bolivar, 1993). Nile tilapia therefore, rapidly gained popularity to farmers and consumers because of its better characteristics (*e.g.* lighter color, faster growth, and high tolerance to various environmental conditions) over the Mozambique tilapia.

During that time, many developing countries were confronted with major constraints in tilapia culture that include inadequate supply of seeds and lower genetic quality of cultured stocks compared to the wild population because of inbreeding depression (Pullin and Capili, 1988; Eknath *et al*., 1993; Acosta *et al*., 2006). Thus, tilapia production during the 1980s continued to decline due to deterioration of the genetic quality of stocks that led to the significantly reduced performance of farmed Nile tilapia. Meanwhile, the public sector, national institutions, and international organizations based in the Philippines initiated selective breeding programs and other technologies for genetic improvement using Nile tilapia (Bolivar, 1993; Acosta *et al*., 2006), leading to significant advances in the genetic improvement of tilapia and development of different strains which had been sustained during the past three decades (**Box 1**). At the beginning, the main focus of most of these breeding programs was to improve the cultured tilapia's overall farm performance such as in the Fish Genetics Project of the Freshwater Aquaculture Center (FAC) of Central Luzon State University (CLSU), which produced the FAC-selected Tilapia (FaST) strain in 1986-1988, and its Genetic Improvement of Farmed Tilapia (GIFT) Project, which developed the Genetically Improved Farmed Tilapia (GIFT) strain in 1988-1997 (Eknath *et al*., 1993; Bolivar and Newkirk, 2000).

Both projects successfully produced tilapia strains which have higher growth and survival performance compared to the farmed local strain. Simultaneous with the GIFT program, YY-male and Genetically Male Tilapia (GMT) was developed using YY-male technology that was conceptualized as a form of breeding program that generates monosex tilapia (with YY genotypes instead of XY for normal males) providing an alternative to hormonal sex reversal and hybridization. After the development of GIFT, successive projects which intended to perform further enhancement of this strain were conducted and subsequently developed Genomar Supreme Tilapia or GST (Gjoen, 2001) and Genetically Enhanced Tilapia - Excellent (GET-EXCEL) strain (Tayamen, 2005).

Special breeds of tilapia that can perform well in different culture environments were also produced such as the COLD strain that can be farmed in low-temperature environments and saline-tolerant strains like BEST and Molobicus (Villegas, 1990; Romana-Eguia and Eguia, 1999; Tayamen *et al*., 2002; Rosario *et al*., 2004). At present, tilapia is the second most important food fish for domestic consumption in the Philippines, next to milkfish (Lopez *et al*., 2005; BFAR, 2006). This increase in the national demand for tilapia is a result of increased production brought about by the various efforts in tilapia genetics R&D. Over

Box 1. The "fruits" of genetic research on tilapia in the Philippines (Modified from Abella, 2006; Acosta, 2009)

Strain Developed (Popular Name)	Research	Project Year	Implementing institutions	Donor(s)	Significant Results	Producers	Date of Commercial Distribution
FaST (FAC-selected Tilapia also called "IDRC" strain in local market)	Fish Genetics Project of FAC	1986-1996	FAC-CLSU	International Development Research Centre (IDRC)	Produced fast-growing strains of *O. niloticus*	Hatcheries which purchase broodstock from FAC	1993
GIFT (Genetically Improved Farmed Tilapia)	Genetic Improvement of Farmed Tilapia	1988-1997	Institute of Aquaculture Research (AKVAFORSK) of Norway, FAC-CLSU, ICLARM, BFAR-NFFTC, UPMSI	Asian Development Bank and United Nations Development Programme	Produced fast-growing strains of *O. niloticus* and demonstrated that *O. niloticus* did respond positively to selection	GIFT - Genetically Improved Farmed Tilapia)	1997
GST (GenoMar Supreme Tilapia)		1999-2002		GenoMar	Application of DNA genotyping technology, selection of differential increases, and total genetic gain for growth rate are expected to result in 40% higher performance than the ninth-generation fish	GenoMar Philippines, Inc.	2002
YY male/ GMT (Genetically Male Tilapia or sometimes called "YY")	Genetic Manipulation for the Improvement of Tilapias	1988-1997	University of Wales, Swansea/FAC-CLSU, BFAR-National Freshwater Fisheries Technology Center (NFFTC)	Overseas Development Administration (ODA)	Produced genetically male tilapia for grow out and YY breeders for fingerling production	produced by Fishgen Ltd. and by Phil-Fishgen and its accredited hatcheries in Philippines	?
GET EXCEL (Genetically Enhanced Tilapia - EXcellent strain that has a Comparative advantage over other tilapia strains for Entrepreneurial Livelihoods)		2002	BFAR-NFFTC	DA-BAR	Combining strain crosses and adopting within family selection of four different strains of *O. niloticus*	produced by NFFTC and its accredited multipliers	
BEST (or Brackishwater Enhanced Selected Tilapia)	Development of Saline and Cold Tolerant Tilapia	1998-present	FAC-CLSU, BFAR-NFFTC, University of the Philippines in the Visayas	DA-BAR	Formed a base population from four different *Oreochromis* species by combining best performing purebreds and crossbreeds after rigid evaluation in different environments	produced by NFFTC and its accredited multipliers	
Cold-tolerant tilapia Molobicus	Development of Saline Tolerant Tilapia Hybrid (Molobicus Program)	1998-present	BFAR-National Integrated Fisheries Technology Development Center (NIFTDC)	PCAMRD and Centre de Cooperation Internationale en Recherche Agronomique pour le Development (CIRAD)	Developed saline tilapia hybrids through hybridization using *O.niloticus* and *O. mossambicus*	By NIFTDC and its accredited multipliers	
SST (SEAFDEC-Selected Strain)		1999-?	Aquaculture Department (AQD) of the Southeast Asian Fisheries Development Center		Produced a fast growing strain of *O. niloticus* from modified mass selection technique with collimation technique and development of a small-farm, low-cost selection program	SEAFDEC/AQD	

the last 25 years, the tilapia industry in the country has achieved tremendous progress due to the development and production of improved tilapia strains (Tayamen *et al*., 2006).

Status and trend of tilapia production in the Philippines

With the decline in the consumption of milkfish and roundscad, tilapia has become one of the cheapest sources of animal protein in the diet of Filipinos (Edwards, 2006; ADB, 2005). Currently, the tilapia industry in the country accounts for 12% of the total aquaculture GDP. Tilapia is also the main freshwater fish species cultured in the Philippines, comprising about 79% of the total freshwater aquaculture production in 2010 (BFAR, 2010). Improved strains of tilapia that farmers can choose from include: GIFT, FaST, GST, SST, BEST, COLD, EXCEL, and Molobicus (Toledo, *et al*., 2009). After the introduction of enhanced tilapia strains, the average per capita consumption of tilapia in the Philippines increased by 474 percent, from 0.66 kg/person/year (1979-1988) to 3.13 kg/person/year in 2010 (Yosef, 2009; BAS, 2010).

The tilapia industry in the Philippines increased eminently achieving a remarkable growth of 50% from 2002 to 2012 (**Fig. 3**). More than 90% of the total tilapia production in the Philippines comes from freshwater environments, of which 40% is produced from freshwater fishponds. Supply coming from brackishwater environments has yet to generate much impact on the total production despite having salt-tolerant strains available for farming. About 80% of the country's tilapia supply comes from central Luzon area (**Fig. 4**), of which production from Pampanga contributed the highest at 39% of the total annual supply followed by Batangas (24%), Rizal (5%), Laguna (4%), and Pangasinan (3%). The improved performance of the country's tilapia industry could be attributed to the accessibility of wide range of tilapia strains and increased resources and labor force as farming operations of tilapia became widespread.

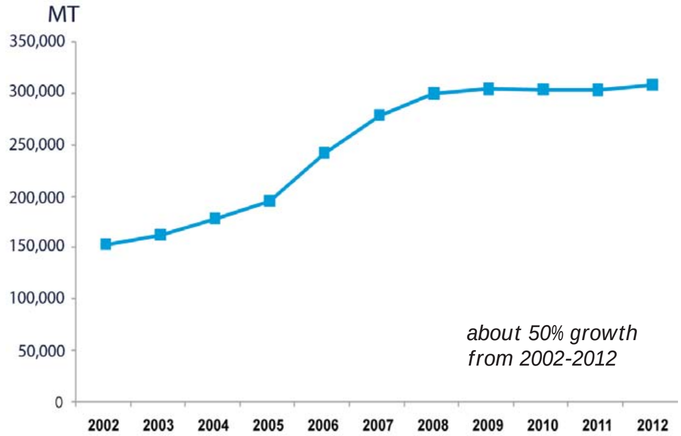

Fig. 3. Total annual tilapia production of the Philippines from 2002 to 2012 (BAS, 2012)

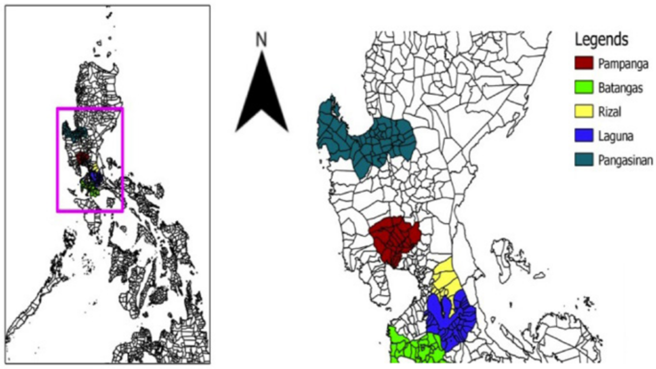

Fig. 4. Five top tilapia producing provinces of the Philippines

Moreover, in view of the increased accessibility to and availability of input supply, sustained advisory services, expanding consumer markets, rapid development of marketing channels in response to the market-driven demand, and increased availability of high performance tilapia seeds, production of farmed tilapia had tremendously increased from 1981 to 2001 (ADB, 2005). The development of genetically-enhanced tilapia from various breeding programs in the country increased the yields and kept tilapia affordable for the poor. GIFT and GIFT-derived tilapia strains comprised 68% of the total tilapia seeds produced in the country in 2003 (ADB, 2005) which validates the significant contribution of this genetic improvement to the increasing production of tilapia in the country.

In 2004, Philippines with a total production of 145,869 MT, ranked third among the top tilapia producers in the world. The ADB ascertained that GIFT and GIFT-derived strains are responsible for most of increasing tilapia production in the last two decades (Acosta and Gupta, 2009). It is important to note that tilapia production from marine or brackishwater culture areas, especially in Visayas and Mindanao has not yet been commercially significant to a great extent (ADB, 2007; Toledo *et al*., 2008). However, despite the increasing production of tilapia in the Philippines, such feat is still not as significant as those in other Asian countries due to certain obstacles encountered in the tilapia culture industry with the still nascent management and dissemination techniques (Yosef 2009).

Utilization of tilapia in the Philippines: Value-adding

Of the total tilapia supply, only a small portion is processed as value-added products due to household consumers' preference for live fish. In domestic markets, tilapia is usually sold as whole fish, either frozen or fresh but sometimes could also be available in dried and fillet forms that are supplied to major outlets such as supermarkets and other food chains. In 2002, a project of BFAR on "Value-added products from Tilapia" sought for an appropriate processing technology to create value-added products for tilapia, with the objective of increasing the economic returns from its production (dela Cruz, 2010). The project successfully developed four different products, namely: *longganisa*, nuggets (breaded tilapia), *tocino*, and rolls. In addition, another processed tilapia product is known as *tilanggit*, a small (juvenile stage), dried, and deboned tilapia similar to juvenile stage of rabbitfish known as *danggit* in the Philippines (Fernandez, 2008).

Biofactory Opportunities and Challenges for Tilapia and Milkfish

Biofactories utilized nowadays are microbial cells, plant cells, algal cells, and mammalian cells, most of which are already established biofactories that cover wide range of applications in various industries especially in agriculture and biomedical fields (Sarmidi and El Enshasy, 2012). Most biofactories are sourced primarily for bioactive metabolites including enzymes (*e.g.* amylases, glucose oxidase, cholesterol oxidase), antibiotics (*e.g.* penicillins, erythromycin, rifamycins), recombinant proteins (*e.g.* insulin, human growth hormones), and other biopharmaceuticals while other biofactories produce bioplastics and biodiesel (Sarmidi and El Enshasy, 2012). Milkfish and tilapia conform to the general advantages of fish as potential biofactories. Both are relatively cheap, easy to manage and culture, can be produced in high volume, and are renewable resources. Commercially-valued compounds known to have been extracted from fish include collagen, fish oil-derived oils, and fish protein hydrolysates.

Interestingly, these products can be extracted from fish by-products including head, skin, fins, trimmings, fins, frames, viscera and roes (Chalamaiah *et al*., 2012). The fish processing industry has been reported to generate 60% of fish wastes and only 40% fish products for human consumption (Dekkers *et al*., 2011). These by-products contain good amount of protein rich material that are normally processed into low market-value products, such as animal feed, fish meal and fertilizer (Hsu, 2010). In the Philippines, by-products generated from tilapia and milkfish industry, and fisheries in general, are considered as wastes and often thrown away after fish processing such as deboning and filleting. Although efforts on value-adding are also employed, these are not very extensive. With increasing tilapia and milkfish production every year, fish by-products discarded as wastes will also continue to rise. Therefore, establishing milkfish and tilapia as biofactories may become the practical alternative for fish-processing waste management while generating additional profits at the same time.

Tilapia and milkfish as biofactories for collagen

In its purified form, collagen has been used in various pharmaceutical and biomedical applications such as treatment for hypertension, urinary incontinence and pains associated with osteoarthritis; in tissue engineering for implants in humans; and inhibition of angiogenic diseases, such as diabetes complications, obesity, and arthritis (Ogawa *et al*., 2004). In the cosmetics industry, collagen has been utilized in skin care products as humectant or moisturizing agent (Peng *et al*., 2004). At present, collagen extracted from aquatic organisms is more preferred for human consumption than mammalian-derived collagen because currently, the main sources of collagen in many fields are limited to those of bovine or porcine dermis which pose health risks due to the outbreak of transmissible spongiform encephalopathy (TSE) and bovine spongiform encephalopathy (BSE), as well as foot-and-mouth disease (FMD) crisis (Zhang *et al*., 2011). Tilapia has been reported to be an excellent source of Type I collagen (Ikoma *et al*., 2003; Sujithra *et al*., 2013), which could be collected from the skin, scales, fins, and bones of tilapia (Ogawa *et al*., 2004; Pang *et al*., 2013). Nevertheless, the feasibility of different milkfish parts as potential source of collagen has yet to be explored. Thus, characterization and screening should be initiated to determine its utilization in collagen production. The emerging demand for fish-derived collagen is a very potent driver to develop and establish fish biofactories for this product in the Philippines. In Southeast Asia, the University of Putra Malaysia and Bionic Lifesciences Sdn. Bhd. have already ventured into this market, establishing the first halal collagen extractor factory from tilapia fish skins and started producing aquatic collagen in commercial scale (UPM News Portal, 2011).

Tilapia and milkfish as biofactories for fish oil-derived fatty acid and biodiesel

Fish wastes, especially the viscera, are essential raw materials to produce fish oil. Representing up to 15% of the total fish body weight, fish viscera usually have no commercial value (Oliveira *et al*., 2013) but these parts are primary source of fish oil which is subsequently used to extract omega-3 and biodiesel, the other valuable biochemical products that can be potentially sourced from tilapia and milkfish. Omega-3 oil can be utilized as food supplement and to fortify various food products such as orange juice, bread, yogurt, and butter (Fitzsimmons, 2008). Fish wastes could also be used to produce biodiesel after the fish oil has been extracted and processed. Compared to petroleum diesel, biofuel from vegetable oils and animal fats is biodegradable, has non-toxic profile and creates low greenhouse gas emissions (Oliveira *et al*., 2013). Two successful companies are making significant contributions to local energy production using fish residues: Aquafina in Honduras using tilapia wastes and Agifish in Vietnam which uses catfish wastes (Piccolo, 2008). It has been estimated that Aquafina has been producing over 15,000 liters/day of biodiesel from tilapia fish oil (Piccolo, 2008). Recently, Brazil's National Department of Works Against Drought (DNOCS) has announced its planned establishment of fish waste biodiesel plants to cut down 50% of tilapia wastes while producing more than 8,000 liters of biodiesel per day (Lane, 2013). Converting tons of fish wastes from tilapia, milkfish, and other fish species into omega-3 or biodiesel is another opportunity to boost revenues of these two fish industries. One of the good news about the technology used in the production of biofuels from fish wastes is that it is transferable (Lane, 2008) adding to another reason for developing tilapia and milkfish as biofactories.

Tilapia and milkfish as biofactories for fish protein hydrolysates

Fish protein hydrolysates (FPHs) are smaller peptide fragments of usually 2-20 amino acid in length produced from the enzymatic breakdown of fish proteins (Chalamaiah *et al*., 2012). FPHs have been utilized as nutritional supplement, functional ingredients in different foods, and aquaculture feeds for enhancing the growth and survival of fish (Chalamaiah *et al*., 2012). FPHs can also be extracted from fish by-products, hence, another alternative for the utilization of increasing fish processing wastes. Protein hydrolysates from fish are currently considered as the most important source of protein and bio-active peptides which is why fish FPHs have gained great attention to food scientists and have been utilized in various industrial applications (Chamalaiah *et al*., 2012). Tilapia has been reported to be good source of desirable quality of FPH (Foh *et al*., 2011) and studies have exemplified the potential of tilapia FPHs as antioxidant agents (Raghavan *et al*., 2009; Shamloo *et al*., 2012). On the other hand, protein hydrolysates from milkfish have yet to be sufficiently characterized and documented. This is a good avenue for exploring the potential of milkfish or its by-products as a new source of high-grade FPHs.

Tilapia and milkfish as biofactories for recombinant proteins

Production of recombinant proteins requires transgenic technology to genetically alter organisms to express the desired protein. Producing recombinant proteins using transgenic animals offers a renewable source of bioactive products that are difficult to obtain by other means (Houdebine, 2000; Lubo, 2000). This "biopharming" concept (also known as "molecular farming" in plant biotechnology) is the combination of current agricultural practices and biotechnological approaches for the low-cost production of molecules of commercial value (Twine, 2005) and is considered the next major development in both farming and pharmaceutical production (Kaye-Blake *et al*., 2007).

The use of fish as biofactories or bioreactors is an emerging approach for the production of eukaryotic recombinant proteins (Zbikowska, 2003). However, fish have not been used as a biofactory (Rocha *et al*., 2003) even with the advances in the applications of transgenic technology such as growth enhancement, disease resistance, and cold resistance which have already been established in different species of fish. Using fish offers several advantages such as the large number of eggs produced and their development outside the female, which does not occur in mammals (Rocha *et al*., 2003). In addition, fish is also a good option for biofactory because of its short generation time, low cost of cultivation, easy maintenance, and its use for experimentation is more ethically acceptable than using mammalian or avian models, and there is no present evidence of the replication or transfer of prions in and from fish (Maclean *et al*., 2005; Hu *et al*., 2011).

To date, only few researches explored the use of fish as pharmaceutical biofactory, although several companies have already ventured in the development of fish as biofactory (Bostock, 1998). Calcitonin has been produced using a transgenic salmon through the initiative of DiverDrugs in Spain. Japan's Shina Canning Co. Ltd. has also produced collagen from transgenic fish. The most notable advancement in this field is the production of humanized insulin from islet cells (Brockmann bodies) of transgenic tilapia (Pohadjak *et al*., 2004). This transgenic tilapia could become a suitable, inexpensive source of islet tissue that can be easily mass-produced for clinical islet xenotransplantation to treat insulin deficiency (Pohadjak *et al*., 2004). Fish eggs from transgenic fishes have also been utilized in the production of heterologous recombinant proteins. For example, human coagulating factor VII (hCFVII), a blood clotting factor released during internal tissue injury, has been reported to be expressed ubiquitously in tilapia embryos (Hwang *et al*., 2004) while successful production of functional recombinant goldfish luteinizing hormone (gfLH) was done using transgenic rainbow trout embryos (Morita *et al*., 2004). The latter experiment which highlighted on the use of fish eggs as bioreactors has advantages including high expression of target protein at low cost and the capability of performing complex post-transcriptional modifications. Recently, Hu *et al*. (2011) used zebra-fish eggs as bioreactors to produce mature tilapia insulin-like growth factor (IGF) proteins using the oocyte-specific zona pellucida (zp3) promoter. From the 650 fish eggs, about 0.58 and 0.49 mg of purified recombinant tilapia IGF-1 and IGF-2, respectively, were extracted from the cytoplasm of the eggs. Insulin-like growth factors, especially IGF-1, promote growth by stimulating somatic growth and cell proliferation in vertebrates (Castillo *et al*., 2004). The biologically-related roles of tilapia IGFs have attracted attention among researchers in aquaculture, biomaterials and cosmetic biotechnology (Hu *et al*., 2011). In fact, there has been an initiative to incorporate IGFs as feed additive to enhance growth (Liao *et al*., 2008). These studies demonstrate that transgenic fish as biofactory or bioreactor has a great potential in the practical and commercial production of valuable therapeutic proteins.

Research in fish biotechnology has not been proliferative in the Philippines. The earliest effort in the application of fish transgenesis in the production of pharmaceutical biomolecules was made through a collaboration between the formerly-known Department of Science and Technology-Philippine Council for Aquatic and Marine Research and Development (DOST-PCAMRD) now Philippine Council for Agriculture and Aquatic Resources Research and Development or DOST-PCAARRD) and a team of Canadian scientists. Their study aimed to produce transgenic tilapia that could produce human insulin (AquaNews, 1998). Unfortunately, no subsequent studies followed through as a continuation for this project. It is also important to note that there have been no transgenic-technology applications in aquaculture after the completion of this project, which could be due to the need to address more pressing concerns such as performance improvement in the fish aquaculture sector, particularly in tilapia industry.

The research efforts had since then been focused on addressing the deteriorating quality of tilapia being farmed using classical genetic techniques while biotechnology-based experiments, such as transgenesis, were not as relevant as conducting genetic improvement programs at that period and, therefore, were least prioritized. Tilapia is one of the fish species that has attained tremendous success in terms of advanced genetic applications. Robust genetic information on tilapia can now be accessed including its whole genome sequence. Unlike tilapia, milkfish has not been subjected into intensive genetic experimentations, adding up to the piling challenges if transgenic technology is sought to be applied. In addition, obstacles that will transpire when considering research programs using transgenic fish models in general, aside from financial constraints, also include lack of facilities and limited personnel with technical expertise in the field. However, these limitations should be perceived as another opportunity to promote R&D in this field.

Conclusion and Way Forward

Reports have shown that in 2012, production of milkfish and tilapia in the Philippines accounted for 15% and 12% of the total aquaculture production of the country, respectively (Bureau of Agricultural Statistics, 2012). Production of these commodities was reported to have increased in terms of volume and value during the succeeding years. Increase in milkfish production has been attributed to the result of good farm management, availability of quality fry/fingerlings, and proper feeding practices, while increase in the country's production of tilapia has been possible due to the easy access to wide range of tilapia strains, and increased resources and labor force in tilapia farming operations. These commodities are generally consumed in the country as fresh or frozen or processed products or in modified form as value-added products. It is a fact that the sustainability of tilapia and milkfish production has been one of the paramount concerns of the country's aquaculture sector, however, profitability and competitive advantage of these industries will also have to eventually rely on new approaches that involve value-adding strategies and genetic technologies. With the availability of advanced technologies at present and a potential market for the production of bioactive compounds and molecules of commercial value, tilapia and milkfish industries could start to shift gear towards the utilization of both fish species as new and renewable source of valuable compounds, leading to the establishment of biofactories. Tilapia and milkfish are relatively advantageous because they are relatively cheap to cultivate and manage and can be easily produced in large quantities.

Associated with the increase in tilapia and milkfish production is also the increase in fish processing by-products that are usually underutilized or considered as wastes. Essentially, these biofactories will strongly depend on fish processing by-products as the main source of raw materials in the production of bioactive compounds and molecules such as collagen, biodiesel, and fish protein hydrolysates. This effort does not only entail adding revenue and value to both fish industries but also maximizing the utility of the growing volume of fish processing by-products while reducing the possible unwanted environmental impacts of these wastes. Tilapia and milkfish as biofactories for the production of pharmaceutical recombinant proteins is also a very attractive option. However, intensification of R&D in fish biotechnology is an initial but imperative requirement to allow progress in this field. In general, future research on tilapia and milkfish biofactories should therefore be directed towards the development of designs, from the cultivation of the organism to extraction and purification of bioactive compounds. In addition, if industrial platform will be established in the future, bioprocess development and complete bioprocess design are required and should be carefully considered (Sarmidi and El Ensashy, 2012).

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LED Light Trap Fishing as Alternative for Harvesting American Crayfish

Ahmadi

American crayfish or red swamp crayfish (*Procambarus clarkii*, Cambaridae) is one of the most prominent species of crayfish that supports in one way, the aquaculture industry with remarkable commercial success, *e.g.* in Louisiana, USA (Romaire, 1995), Kenya (Olouch, 1990), China (Huner, 1998), and in Spain (Ackefors, 1999) because of its rapid growth and ecological tolerance (Huner and Lindqvist, 1995). Farmers in Louisiana produce soft-shell crayfish not only for fish bait but also for the seafood industry (Culley and Duobinis-Gray, 1989), as well as egg-bearing females for breeding purposes (Richards *et al.*, 1995). On the other hand, many countries have been regulating the introduction of this invasive species due to their adverse impacts on the native species and the ecosystems (Bernardo *et al.*, 1997; Usio *et al.*, 2001; Nakata *et al.*, 2006), including damages to substrates, especially to rice paddies due to their burrowing habit, and interference with fishing operations and consumption of eggs of other fishes (Maitland *et al.*, 2001). Collecting crayfish from the wild and ponds makes use of conventional gears (*e.g.* baited traps, fyke nets) but since these had been found to be ineffective due to their impacts on the natural resources, the use of lights in trapping the crayfish is therefore being promoted to improve the harvesting procedures and address the need to reduce the population of the invasive crayfish while minimizing the impacts of the fishery on the environment.

The use of light emitting diode (LED) in fishing has been introduced in many countries to optimize fish catch considering that fish and other aquatic species have color receptions in their eyes that could recognize various intensities of light that lead to their aggregation in lighted areas. The use of LED lights is one of the most recent advances in light fishing being promoted in fisheries, instead of using incandescent, halogen, and metal halide illuminations. In order to adapt the use of LED lights in harvesting the American crayfish (*Procambarus clarkii*), their phototactic responses were tested using incandescent and LED lights in laboratory experiments as well as in pond trials. Four incandescent lights with intensities ranging from 215 to 2050 lx and four standardized LED colors (blue, green, yellow and red) were used as light sources.

In the laboratory experiment with no shelters, positive group responses of the crayfish were more pronounced in lower light intensities as well as in green, blue and yellow colors, and were significantly different with the control. Subsequent fishing trials conducted in a pond using four box-shaped traps (same shape and material) with particular lamp and repeatedly used every night indicated that both incandescent light and LED light traps can be used to harvest crayfish from ponds. However, the use of LED light traps provides a considerable advantage over incandescent lights because of high energy efficiency of LEDs with greater variability of available LED colors, and greater durability. Results of these trials supported observations from other studies that *P. clarkii* has true color vision and are able to alter independently their behavioral responses to different colors. The method of trapping fish and other aquatic species with lights could be replicated for other fishing gears, habitats and target species.

Light Trap Fishing Trials

The trials in collecting crayfish using light through laboratory and pond experiments, has established the magnitude of group responses of crayfish towards different intensity of incandescent lights or different color of LED lights. Specifically, the pond trials were considered crucial in addressing the essential requirements for commercializing the culture or developing environmental control measures of the species.

Laboratory Experiment

Conducted at the Laboratory of Fishing Technology, Faculty of Fisheries, Kagoshima University, Japan in August 2007, the laboratory experiments were done in PVC tank (190×42×40 cm) using 26 adult crayfish (109–151 mm total length) at 1:1 male to female sex ratio, and kept in tank with tap water at 23-26.5°C during 12 h light:12 h dark. The tank had sand substrate at the bottom with an under-gravel filter system. The animals were fed twice a week with crayfish pellets at 0.5 % body weight. Dissolved Oxygen (DO) concentration was 4.8 mg L^{-1} while turbidity of the water was 10 FTU. In order to examine the phototactic responses of *P. clarkii* towards different intensities of incandescent lights in the PVC tank, four incandescent lamps with different intensities were used as light sources (**Fig. 1**). Light intensity of each lamp was 215 lx (SIL-1), 398 lx (SIL-2), 1010 lx (DIM) and 2050 lx (LIGHT) where SIL-1 = 0.45 W and SIL-2 = 1.5 W. For DIM and LIGHT, 4.5 W lamp was placed inside a waterproof acrylic box (14×8×15 cm), the walls of which were lined with white-paper, and 1 to 4 1.5 V batteries. Meanwhile, four selected colors of LEDs were used as light sources (**Fig. 1D**) with

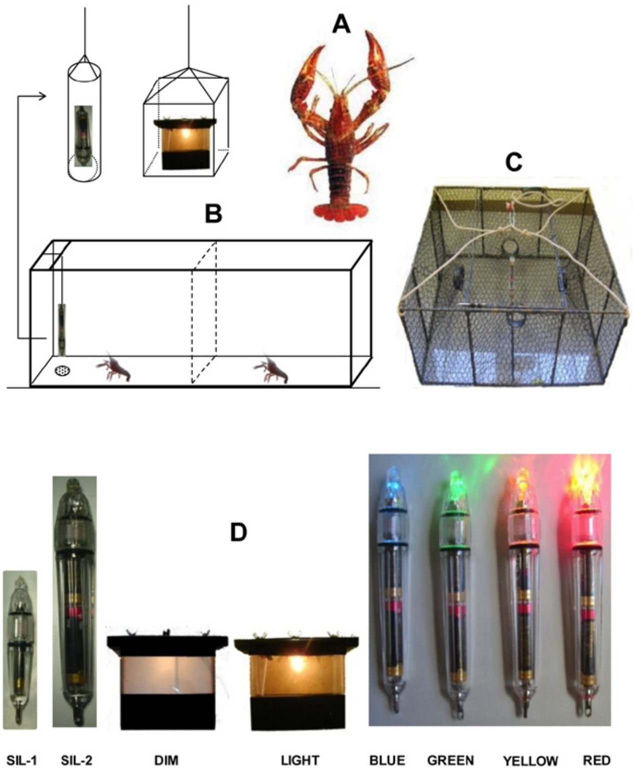

Fig. 1: A: American crayfish (*Procambarus clarkii*); B: laboratory tank experiment; C: typical trap used in the pond; and D: typical lamps used in laboratory and pond experiments

each color placed inside a lamp case of SIL-2 which was generated by 3 V dry-cell battery (0.06 W). The light intensity of LEDs was set at equal quanta intensities by placing a grey fiberglass window screen inside each lamp, and the spectral irradiance for each color was determined using a spectroradiometer.

Recapture experiments were carried out at night before and after setting the lamps under ambient light environment. While the LED lamp was placed downright to the bottom anchored with a weight with the other tip tied to a stationary rod, the incandescent lamps had weights placed on top of the lamp to hold them in upward pressure. Lights were stabilized by caging the lamps with a piece of PVC pipe (15 cm long and 4.8 cm dia) for LED lights and a plastic mesh box (18×18×20 cm) for the incandescent lamps for 30 sec before exposing the animals to the lights.

Trapping Experiment

Trapping experiments were conducted at night in a concrete pond (10.0×5.8×0.7 m, 55 cm deep) using 197 adult crayfish (68-111 mm TL) with 1:1 male to female sex ratio and kept in 3200 L tap water at 16-28°C. The animals were fed twice a week with commercial prawn feed at feeding ratio of 0.5-1.0% body weight. Shelters made of PVC pipes (approx. 15 cm long and 6 cm dia) were distributed at the bottom, and aeration was applied for 24 h; DO concentration was 6.65 mg L^{-1} while turbidity of water ranged from 1 to 14.6 FTU.

Four box-shaped traps were constructed with 6-mm iron frames (60 cm x 50 cm x 25 cm) and black 3/5 inch hexagonal mesh wire (16 gauge PVC-coated wire). The traps had four large entry funnels on each side with 6 cm inside ring entrance, with a trap door on top (48×25 cm) to release the animals (**Fig. 1C**). The light sources were the same as those used in laboratory experiments and were repeatedly used every night in two pond experiments to test light intensity and light color preference.

The traps were lowered on the pond before sunset and retrieved the following morning, with each trap set at a distance of roughly 4.5-8.5 m from each other following the pond shape and rotated each night, while soaking time varied from 13 to 14 h. The crayfish were counted when traps were hauled and checked for sex, carapace length, body length, chelipeds length, weight, and released back into the pond. Of the total 37 trials (148-trap hauls), 15 used incandescent light traps and 22 with LED light traps.

Results of Light Trap Fishing Trials

Laboratory Experiment

Results from the control with ambient light indicated that most of the adults seemed to remain motionless regardless of the shelters provided. Response of the control group was between 3.1±5.0 (mean%±SD) and 6.2±5.8 (**Fig. 2A**). During the trial periods, the animals showed significant photopositive responses towards SIL-1 (26.9±7.7%) at 215 lx, SIL-2 (23.1±7.7%) at 398 lx, and LIGHT (13.8±6.4%) at 2050 lx. Most of the time, the crayfish exhibited higher magnitude of group response in the absence of shelters than with shelters. Positive photo responses were more pronounced in lower than in stronger light intensities, but

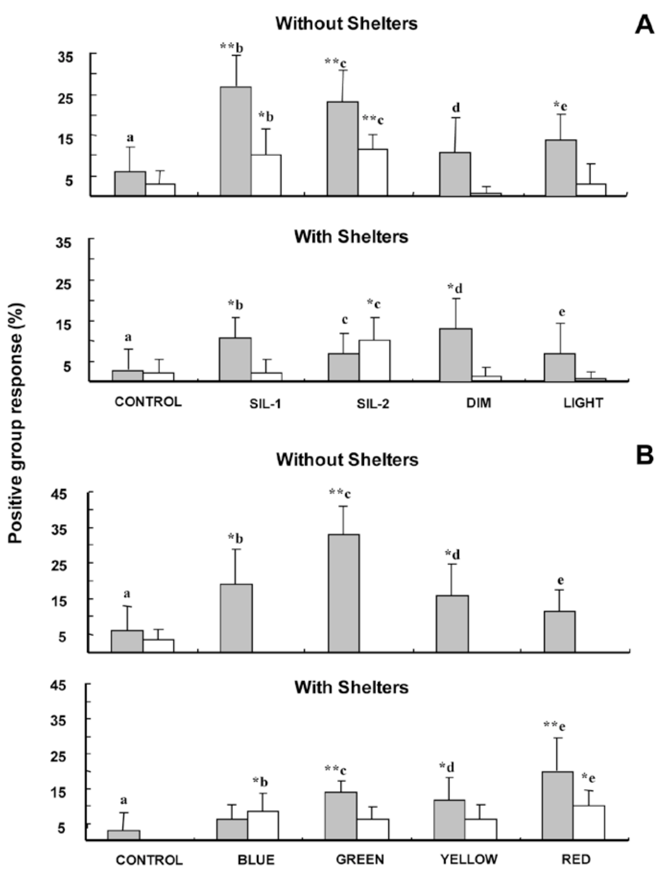

Fig. 2. Positive group responses (mean % ± SE) of crayfish when exposed to incandescent lights (A) and LED lights (B) with or without shelters. Left bars with grey area show strong response of the animals towards the lamps and right bars show weak response. There were significant differences between control (a) and tests (b, c, d, or e) at *p<0.05; **p<0.01

the magnitude of group responses declined significantly when shelters were employed (**Fig. 2A**). Some animals only responded to the DIM (13.1 ± 7.5%) at 1010 lx and SIL-1 (10.8 ± 5.0%) at 215 lx. In all trials, most animals rested in the dark area while their bodies were orienting to the light at random, *i.e.* animals hide in the shelters to be away from strong light intensity (LIGHT) or were moulting during the trials.

In the second laboratory trial, the control group response was between 3.1±5.0 (mean % ± SD) and 6.2 ± 7.0 (**Fig. 2B**). When the animals were exposed directly to color LED in the absence of shelters, the magnitude of group responses was more pronounced to green, blue and yellow lights than that of the control, but there was no significant difference between the control and red light. In the presence of shelters, phototactic responses towards green, yellow and red were significantly higher than that of the control, but no significant difference between the control and blue.

Under light stimulation, the animals behaved similarly to each type of lamp, *i.e.* spontaneously changed their positions by crawling forward along sidewall of the tank while waving their chelipeds and antenna whips pausing near a lamp, moving for short distances, or remaining motionless while facing the light. Some animals failed to reach the lighted area when larger animals ambushed them, but the shelters appeared to be helpful for the egg-bearing females. There were no significant differences in the attractability of males and females in the tank experiments. Moreover, the duration of animals' concentration near a lamp seemed to be longer when the light was obscured conforming to the lack of visual field of the animals.

Trapping Experiments

Crayfish in the pond were exposed to SIL-1, SIL-2, Lighted and Dimmed light traps simultaneously. The animals crawled slowly towards the lighted traps with or without waving their chelipeds while searching for the funnel entrances. Inside the trap, the animals crawled around while holding on to the netting or elevating their postures in front of a lamp. Outside the traps, some animals moved around or crawled along the sidewall of the pond for some distances, but most remained motionless while facing the lamps. Movement of the animals during each trial in the pond was directly observed by ocular inspection. The average catch per trap per night ranged between 1.3 ± 0.5 and 7.5 ± 2.4. Results of the test showed no significant differences in the total catch or in terms of average sizes between males and females. Despite the original 1:1 male to female sex ratio in the pond, many more males were caught than females (sex ratio of 1.6:1.0).

In the second pond experiment, the performance of blue, green, yellow and red LED light traps were investigated simultaneously. While the animals behaved almost the same as described in the above findings, behavior was difficult to observe during the last 22 trials because of low water clarity. The average catch per trap per night ranged between 1.0 ±

0.8 and 7.0 ± 0.8 and there were no significant differences in the total catch or in the average sizes between males and females. As in the first pond experiment, more males were significantly caught in all LED light traps with sex ratio of 2:1 male to female. In addition, 15 egg-bearing females were also observed although there were no indications that they behaved differently than females without eggs.

Before each trial, the animals were confined to one end of the tank using a black PVC partition, providing them with enough space to crawl freely. At the start of each trial, ambient light was applied for 10 min (control), partition removed and the animals allowed to move freely. When the partition was returned to its original place confining the animals again, it was observed that putting and removing the partition did not affect the behavior of crayfish. The trials consisted of submerging the lamp, removing the partition, applying the lamp for 10 min, and capturing crayfish with a scoop net. Shelters made from PVC pipe were distributed at the bottom. Out of 20 trials, 10 were with shelters and the other 10 without shelters, and incandescent or LED lamps were applied in rotation, with each lamp repeatedly used for 5 trials including the reverse of a lamp from one side of tank to the other. The animals were given 10 min to rest after each trial. Movement of the animals during each trial was recorded with a digital video camera while the animals' behavior in ambient light (control) was observed by eyes. The animals' directional crawling towards the light within the 10 min test period was considered a *positive response*, where a strong positive response is defined when animals approach a lamp within 2 min and remain at least 75 cm from the lamp's radius. A weak positive response is considered when animals crawl slowly towards a lamp within 10 min per trial, while crawling away from the lamp and remaining in dark area for a long period of time (within 50 min) is defined as a *negative response*. After statistically comparing the percent values for the 5 trials at each lamp with the percent value for the control (Conover, 1980), results showed that the test values for the trials were significantly higher than that of the control, therefore the group response was considered *positive*.

Discussion

Results from the pond experiments seem not to support the findings from the laboratory experiments indicating the possible effect of the size of the tank. The difference between the light intensity in small tank and large tank may be significant to the animal. Moreover, although the light intensity of LED was set at equal quanta intensities in air, the intensity may not be the same in water because of the waters' different levels of absorption of light wavelengths (colors). Therefore, it could not be established whether the color or light intensity of LED affects the difference in "*attraction*", which is still arguable as with the findings of Marchetti *et al*. (2004) in using chemical light sticks for collecting fish larvae.

Nevertheless, the trials strengthened the findings of a previous research that *P. clarkii* have true positive phototaxis (Ahmadi *et al*., 2008), while the form and optical characteristics of lamps used in this trials were able to attract crayfish into the traps. The total number of 362 crayfish taken from the pond using selected LED light traps was sufficient enough to support previous studies that *P. clarkii* have multicromatic visual system between blue and red (Nosaki, 1969; Cummins and Goldsmith, 1981) or have true color vision (Kong and Goldsmith, 1977), that enables the crayfish to alter independently their behavior responses to different colors, considering that true color discrimination is only possible when an animal has at least two receptor types with distinct but overlapping spectral ranges. Color discrimination requires inputs of different photoreceptor cells that are sensitive to different wavelengths of light. Anatomically, *P. clarkii* possessed two photosensitive systems, one of which is their sensitivity to blue light developed in their early life stage and the other, is sensitivity to red light which is developed later (Fanjul-Moles and Fuentes-Pardo, 1988; Fanjul-Moles *et al*., 1992), implying that the photosensitivity of crayfish changed in their different life stages. The physiology of vision of *P. clarkii* has been generally well documented, *e.g.* the formation of retina and eyestalk in *P. clarkii* was described by Hafner and Tokarski (1998), while the primary structure of their photo pigment was described further by Hariyama *et al*. (1993). Although their vision has been widely studied, their behavioral responses to different intensities or colors under field conditions (*e.g.* stream, lake, wild paddy field) are lacking, and future research on this aspect is strongly underlined.

Moreover, the movements and behaviours of *P. clarkii* in indoor tanks under light are still poorly described. While Fernández-de-Miguel and Aréchiga (1992) reported on the attraction and withdrawal responses as important adaptive mechanisms in crayfish, Fanjul-Moles *et al*. (1998) paid more attention on the effect of variation in photoperiod and light intensity towards survival and behavior in crayfish. While Kozak *et al*. (2009) devoted to the assessment of light intensity preferences, only the "*light source directional behavior*" was described in detail but not the "*exploratory behavior*", where exploratory behavior is defined as the animal directing its body towards the object surrounding it then roving around the tank at a certain distance, with or without lights, looking for '*something*'. Presumably, when refuge/shelter and certain conditions of lights were provided, the animals are likely to crawl inside/under the shelter and stop moving.

However, adding shelters did not conform to such hypothesis because the animals did not cease their explorative behavior either in light or dark conditions. In this regard, exploratory behaviour could still be considered a form of complicated and dynamic behavior as opposed to the more simple responses, either positive or negative to a light source, due to the instability of the environment and the rapid interactions between the animal and the world surrounding it. In the pond, typical exploratory behaviour includes free movement of the animals upon reacting discriminately to light intensity or color. Therefore, other behaviors such as looking around while remaining in one location or resting against any object could not be considered exploratory.

The critical conditions in exploratory behavior which could immediately shift to escape and display avoidance behaviors were identified, *i.e.* when animals were being exposed to strong light intensity, during the moult and post-moult or competitive interactions among gender/size of animals while approaching the light source. During exploration, males were more aggressive than females because they had larger chelae, with larger individuals often intimidating and out-competing the smaller ones from the shelters. This could also imply that crayfish should be harvested from ponds upon reaching marketable size to reduce aggression and provide living space and food resources for undersized animals. Understanding the way of catching, light traps could be employed for possible solutions in developing environmental control measures. Similar method of trapping with lights has been successfully replicated for other traditional fishing gear (*e.g.* "*tempirai*" or bamboo-stage trap) for collecting crustaceans and fish from Barito River of Indonesia (Ahmadi and Rizani, 2012), and thus, could most likely be adapted in the Southeast Asian region.

Conclusion

The ratio of catches to catch per unit of effort (CPUE) in all treatments could not be standardized because the soaking period of the lights during operation was variable and dependent on the type of light devices and variance in battery life. For example, a 0.45 W lamp SIL-1 (1.5 V) in the laboratory experiment would frequently turn off the four lamps, although it was established that the use of LED lights provide a considerable advantage over incandescent lights because of the higher energy efficiency of LEDs, greater variability of available LED colors, and greater durability. In the laboratory experiment with no shelters, positive group responses were more pronounced to lower light intensities than higher ones as well as green, while blue and yellow lights were significantly different with the control. The trapping experiments showed that both incandescent light and LED light traps can be used to harvest crayfish from ponds while their implications for environmental control measures were established. The results also supported findings from other studies that *P. clarkii* had true color vision and able to alter independently their behavior responses to different colors. The method of trapping with lights could be replicated for other fishing gears, habitats and target species.

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Assessing the Marine Biodiversity of Manila Bay:
Status and Strategies for Resources Management

Laureana T. Nepomuceno, Rafael V. Ramiscal and Jennifer G. Viron

Based on the results of deep-sea surveys conducted by the M.V. DA-BFAR, waters approaching the Manila Bay area abound with deep-sea shrimp resource, and that traps had been found to be the most suitable gear to harvest the resource. However, there is a need to develop management measures in order that the resource would not be depleted in the long-term.

Being located within the Coral Triangle (**Fig. 1**), the Philippines is teeming with biodiversity and thus, has been considered as one of the 18 mega-biodiversity countries containing 2/3 of the Earth's biodiversity and inhabited by about 70-80% of the world's aquatic plant and animal species. National records have also indicated that the country's waters abound with various aquatic species, *i.e.* 468 scleractinian corals, 1755 reef-associated fishes, 648 species of mollusks, 19 species of sea grass, and 820 species of algae (Fishbase, 2008; BFAR-NFRDI-PAWB, 2005). Carpenter and Springer (2005) also declared that the concentration of species per unit area in Philippine waters is higher than that of Indonesia including the group of Indonesian islands known as Wallacea. In addition, the country has been declared as the center of 46 marine shore fish diversity in the world (DENR-PAWB, 2009).

As defined by the United Nations (1992), biodiversity is the variability among living organisms from all sources, including, *inter alia*, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part such as: diversity within species, between species,

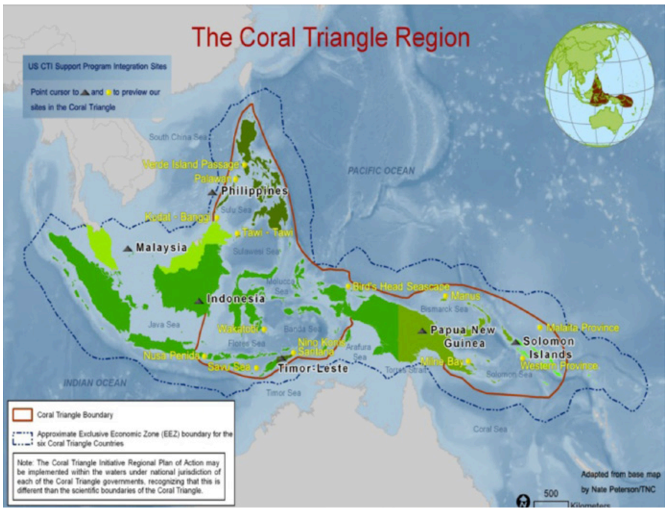


Fig. 1. The Coral Triangle Region with the Philippines at its apex

and of ecosystems (New World Encyclopedia, 2008; Wikipedia, 2011). Unfortunately, reports have indicated that the Philippine biodiversity is under threat. Reports from the Biodiversity Indicators for National Use (BINU) in 2005 indicated declining trend in the state of most coral and marine ecosystems of the Philippines. Nevertheless, reports have also identified the lack of comprehensive data and information to better understand the state of the resources and habitat, as the most glaring gap in the effective conservation and management of coastal and marine biodiversity (DENR-PAWB, undated). Likewise, DENR-PAWB (2009) cited that the Philippines had been included in the list of the world's hot spots, a top global priority area due to the large numbers of endangered and threatened endemic species.

Assessment Survey

In support of the goal of the Convention on Biological Diversity to limit biodiversity loss and the need to improve information systems about the Philippine marine biodiversity, particularly deep-sea biodiversity, a deep-sea fisheries survey was conducted by the Philippine Bureau of Fisheries and Aquatic Resources (BFAR) in western Philippine Sea using the M.V. DA-BFAR. Conducted in May 2011, the survey brought out the potential resources of the target area (**Fig. 2**) for fisheries based on abundance and came up with information on the distribution of deep-sea shrimps (Family Padalidae), a prospective resource found abundant in the area (Nepomuceno *et al.*, 2013). Focusing on the index of marine biodiversity, the study made use of traps and trawls as sampling gears considering that these are the most common implements used for deep-sea fishing although their target catch and impacts could be different. It is the goal of the survey that marine diversity loss can be minimized if marine resource users including the fisheries sector have adequate understanding and awareness of the current status of fisheries and thus, would resort to adopting sustainable fishing operations.

The survey was conducted along the continental shelf and slope of southwestern Luzon in western Philippine Sea, covering the waters of Batangas, Bataan, and the approaches to Manila Bay. Ten stations were used to deploy traps at minimum depths of 61-71 m and maximum depths of 802-844 m. In addition, six (6) beam trawl fishing

Fig. 2. Map of the Philippines showing the survey area along the continental shelf and slope of western Philippine Sea

operations were conducted in Bataan waters with minimum sampling depths of 100-104 m and maximum of 609-904 m.

Fishing Gear Used

Traps

Traps are among the most popular passive gears used in many localities in the country to catch selective species of fish and crustaceans. In this survey, traps were used to catch deep-sea scavengers particularly the species of deep-sea shrimps belonging to the Family Padalidae. The traps are cylindrical in shape and measured 65 cm in length and 30 cm in diameter. Flatbars are used as frames and polyethylene screen as covering material. Three trap designs were used in the survey, *i.e.* fully covered where the inner side of the trap is fully covered with fine-mesh black plastic screen; partially covered where the opening at both sides were not covered, and uncovered where the frame was covered only with polyethylene screen (**Fig. 3**). About 30-45 traps were deployed for every fishing operation and immersed for a period of 12-19 hours. Chopped *Sardinella* spp. was used as bait.

Fig. 3. Three types of traps used in the survey: fully-covered, partially covered and uncovered

Beam Trawl

Beam trawl is an active fishing gear which is operated by towing and used to assess demersal or benthic organisms. The trawl used is a 4.2 m wide bottom trawl which was kept open by a 4.15 m wooden beam. The height of the beam over the bottom is 0.35 m while the iron runners used to stabilize the net measure 0.5 m in height and 0.45 m in length (**Fig. 4**). Dragging time for every fishing operation lasted for 30-60 minutes.

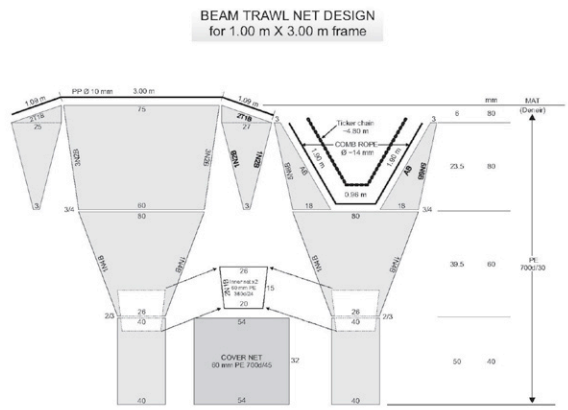


Fig. 4. Beam Trawl used in the survey

Results and Discussion

Sorting and Identification of Samples

The samples were temporarily grouped into mollusks, fishes, crustaceans, and other invertebrates at the main deck of the vessel, after which these were brought the laboratory onboard the vessel for identification, based on morphological features of the organisms described by various authors. However, there were samples that could not be identified by species-level therefore, most of the samples were identified by family-level only, while some were identified to the most possible taxonomic level such as Phylum, Infraorder, and Class.

The survey was able to collect a total of 4043 samples (**Fig. 5**) comprising mostly crustaceans (about 70%), mollusks (about 9%), fishes (more than 7%), and other invertebrates (about 14%). Moreover, the crustaceans have been classified into 39 taxa, mollusks into 32 taxa, fishes into 32 taxa, and other invertebrates into 9 taxa.

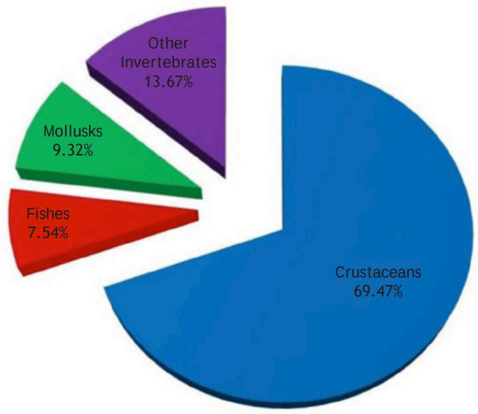


Fig. 5. Samples collected during the survey comprise mostly crustaceans followed by other invertebrates

Analysis of Data

In measuring the biodiversity, Simpson's Index (D) was used in view of its characteristics of giving meaningful ecological interpretations, and the Index being cited by various authors (Bertram, 2010; *wsc.malaysia.org*, 2007; Khan, undated) for its efficiency especially in estimating without bias, the probability of any two individuals drawn randomly from an infinitely large ecosystem, to belong to different species or some category other than species. The Simpson's Index (D) was computed using the formula:

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where: ***n*** = total number of organisms of a particular category used
N = total number of organisms of all category used

Moreover, other modifications of D were also employed in the analysis, *i.e.* Simpson's Index of Diversity (I-D) and Simpson's Reciprocal Index (I/D), especially in determining the richness and evenness of the samples. While richness is the total amount of different taxa in the samples, evenness is the value of I/D divided by the richness value (r) of the samples.

The samples taken from the beam trawl and trap fishing operations were separately treated considering the disparity of the two gears in terms of catchability. However, a comparison by sampling stations for every gear was undertaken. The most abundant organisms in every sampling station were derived from the computed value of Simpson's Reciprocal Index. Using the abovementioned formula, the biodiversity from different trap stations was computed as shown in **Fig. 6**.

As shown in **Fig. 7**, the black dots represent the depth range covered by each trap fishing operation and the corresponding computed biodiversity index. Generally, the largest dot indicates the highest biodiversity index (BI) and the smallest dot the lowest, except for the Simpson's Index (D) shown in **Fig. 6(1)**, that indicated otherwise. Highest BI and evenness (E) was constantly observed in Trap Station (567) at depths of 280-297 m along Bagac in Bataan, while the lowest BI was recorded in Trap Station (558) at depths of 627-651 m also along the waters of Bataan. While highest richness was noted at Trap Station 562 it also exhibited the lowest evenness of the samples (**Fig. 8**).

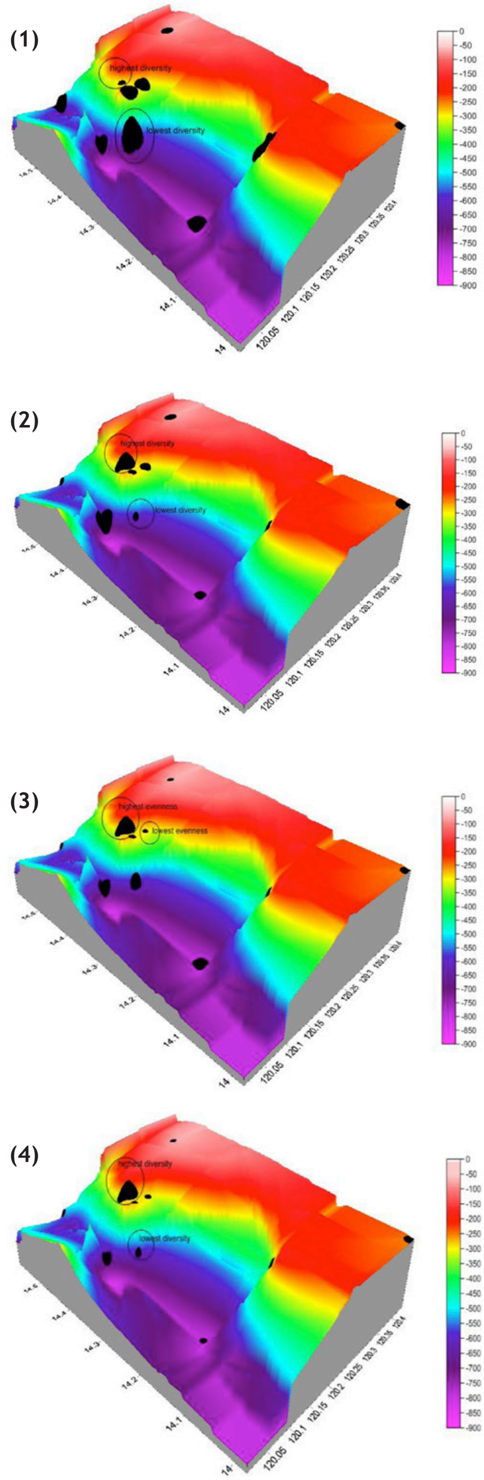


Fig. 6. Biodiversity of the different trap stations: **(1)** – Simpson's Index (D); **(2)** - Simpson's Index of Diversity (I-D); **(3)** – Evenness; and **(4)** - Simpson's Reciprocal Index (I/D)

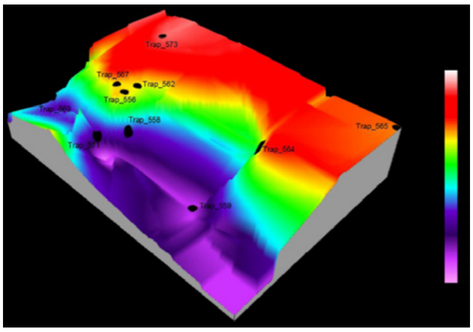


Fig. 7. Trap sampling stations

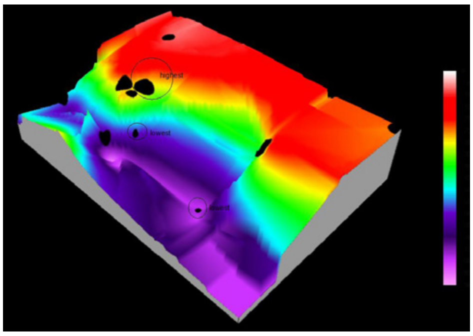


Fig. 8. Richness of samples from different trap stations

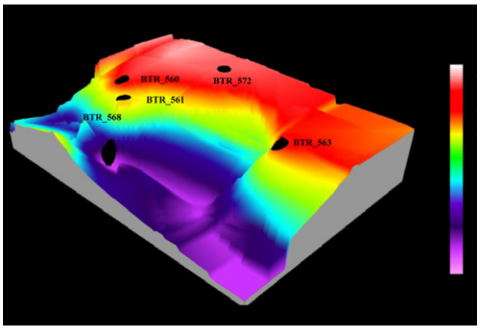


Fig. 9. Beam trawl sampling stations

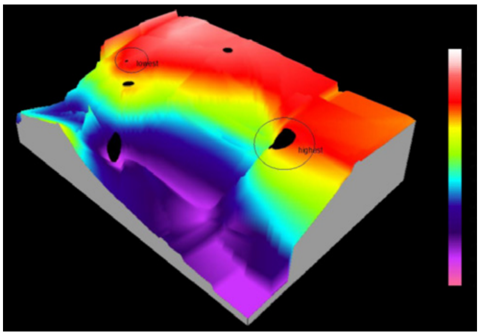


Fig. 10. Richness of samples from different beam trawl stations

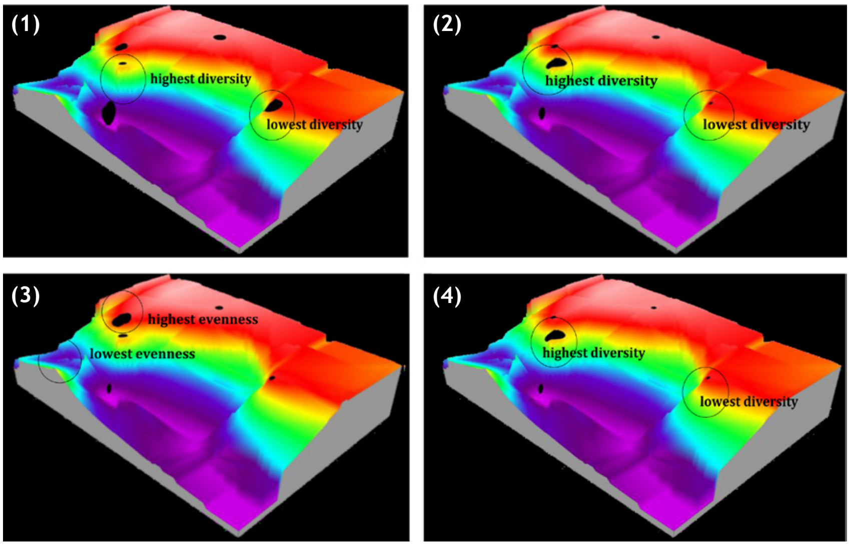


Fig. 11. Biodiversity indices from different beam trawl stations: **(1)** – Simpson's Index (D); **(2)** - Simpson's Index of Diversity (I-D); **(3)** – Evenness; and **(4)** - Simpson's Reciprocal Index (I/D)

The different beam trawl sampling stations are shown in **Fig. 9**, and the richness of the samples generated from the different beam trawl stations in **Fig. 10**, while the biodiversity indices of the different beam trawl stations are shown in **Fig. 11**.

On the overall, the biodiversity indices (BIs) in the beam trawl stations were high, with the highest observed in BTR 561 at depths of 200-295 m while the lowest was in BTR 563 at depths of 180-190 m. There were approximately 15 dominant taxa from the samples in BTR 561 and at least seven (7) at BTR 563. In terms of richness (r), the highest r was found in BTR 563 (46 taxa) and lowest at BTR 560 (15 taxa). The low evenness of the samples from BTR 563 could have contributed to its lower BI compared to other beam trawl stations while the high evenness of the samples from BTR 560 (in spite of its low richness) could have led to its increased BI.

Grouped-catch of Fishing Gears

A total of 1220 samples have been collected from the trap stations and 1383 samples from the beam trawl stations. Majority of the samples from the trap stations were crustaceans while those from beam trawl stations comprise other invertebrates (**Fig. 12**).

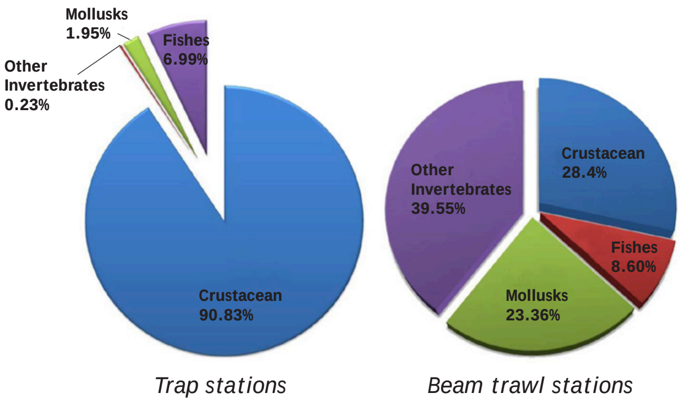
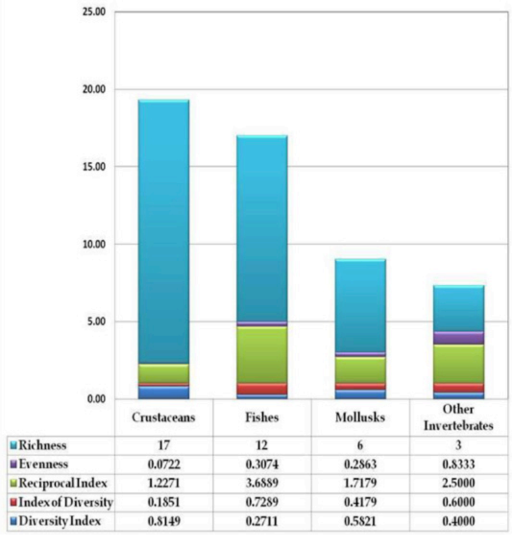
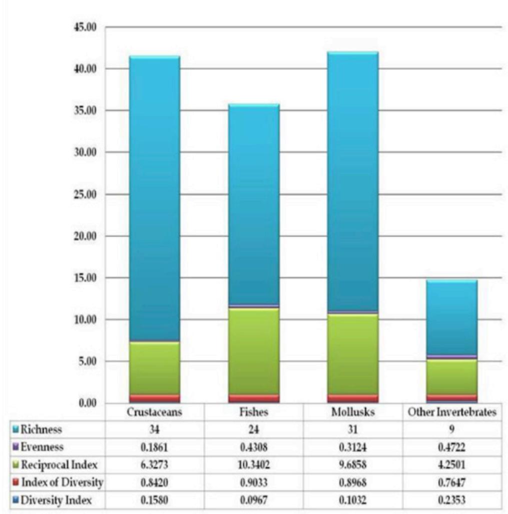


Fig. 12. Percentages of grouped-catch: *left* – from trap stations, and *right* – from beam trawl stations

The comparative analysis of the BI of the grouped-catch, showed higher diversity of fishes from the catch of both gears compared to other groups of species. This implies the least diversity of crustaceans from the catch of traps and other invertebrates from the total catch of beam trawl despite of the bulk catch (**Fig. 13**). The low BI of the 2 groups could be due to the dominance of Family Pandalidae among the crustaceans sampled from traps and of 4 classes of invertebrates (*Anthozoa*, *Asteroidea*, *Echinoidea* and *Ophiuroidea*) on the catch from beam trawls. The fish families that dominate the catch of traps were: *Apogonidae*, *Chlopsidae*, *Myxinidae* and *Scyliorhinidae* while deep-water fish families such as *Macrouridae*, *Ogcocephalidae*, *Ophidiidae*, *Chaunacidae*, *Myctophidae*, *Lophiidae*, *Halosauridae*, *Congridae*, *Scorpaenidae* and *Tetrarogidae* dominate the catch from beam trawl.



Traps

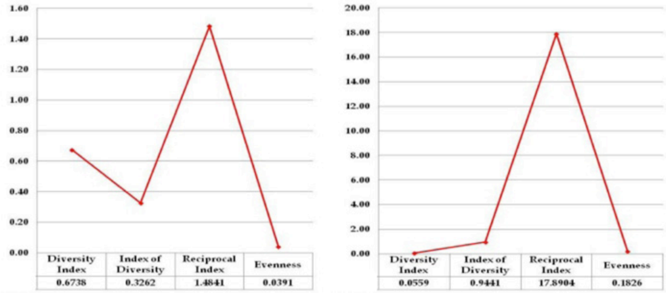


Beam trawl

Fig. 13. The ***r*** and BI of the grouped-catch by traps and beam trawl

Total Catch of Fishing Gears

As shown in **Fig. 13**, the computed BI of the total catch by the traps was moderately low with very low evenness, strongly suggesting the dominance of 1 family (Pandalidae) in the total samples, while on the contrary, the BI of the beam trawl proved high with low evenness. At least 18 taxa dominated the catch by beam trawl including *Anthozoa*, *Aristeidae*, *Asteroidea*, *Echinoidea*, *Holothuroidea*, *Ophiuroidea*, *Polychaeta*, *Conidae*, *Fasciolariidae*, *Galatheidae*, *Gastrochaenidae*, *Macrouridae*, *Ogcocephalidae*, *Pandalidae*, *Ranellidae*, *Thallasidae*, *Trochidae* and *Turridae*. The BIs of the total catch by traps and beam trawl are indicated in **Fig. 14**.



Traps *Beam trawl*

Fig. 14. BIs of total catch by traps and beam trawl

Potential Fishing Grounds for Deep-sea Shrimps

The areas that were found to have been dominated by *Pandalidae* could be gleaned from **Fig. 15**, where the potential deep-water shrimp fishing areas are identified by circles. The fishing areas were identified based on absolute dominance in the catch by the beam trawl. Nevertheless, the deep-water shrimps were only present in stations with depths > 200 m although deep-water shrimps exhibited greater abundance in stations with average depths of 300-700 m.

Conclusion and Recommendations

Based on the abovementioned discussions, the catchability of the gears mainly influenced the diversity of the samples. Likewise, the zonation (depth deployment) and possible avoidance of some marine organisms of the gear might have also affected the type and abundance of the catch. Nevertheless, area along 14.4385-14.4475° E Latitude and 120.1803-120.1858° N Longitude (southwest of Bagac in Bataan) was monitored with highest biodiversity index among the stations. The most potential resource in the sampling area was Pandalidae as represented by its dominance from the total catch of the two sampling gears. However, the selective characteristics of traps make it an ideal fishing implement for deep-sea shrimps compared to beam trawl as observed from the beam trawl stations which had low abundance of Pandalidae and diversity of less valuable catch. Therefore, the area along Bataan waters and approaches to Manila Bay at depths (300-700m) had been found to be good fishing grounds for deep-sea shrimps.

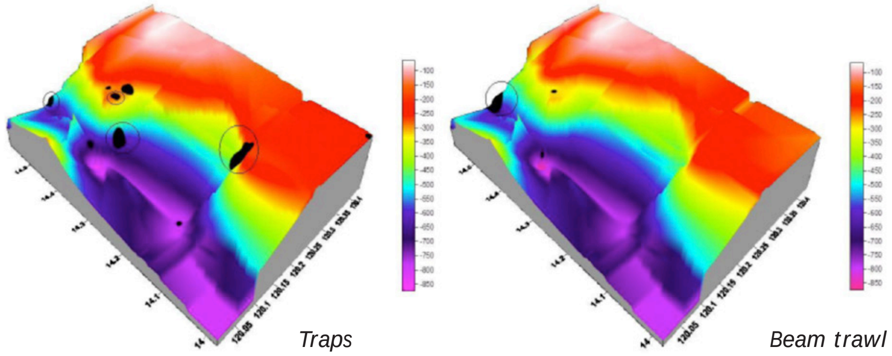


Fig. 15. Fishing areas known to have abundant deep-water shrimp resources

In this regard, traps are strongly suggested to be used in deep-water shrimps fishing because of the tool's efficiency and less ecological impact. Nonetheless, other trap models could be developed to study the efficiency of different gear designs. Furthermore, another study on the sampling area could be conducted to substantiate the results of this study.

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CALENDAR OF EVENTS

Date	Venue	Title	Organizer(s)
		2014	
5-7 March	Iloilo, Philippines	RESA 2014: International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia	SEAFDEC/AQD
10-14 March	Binangonan, Philippines	Training Course on Tilapia Hatchery and Grow-out Operations	SEAFDEC/AQD
10-14 March	Ulaanbaatar, Mongolia	32nd FAO Regional Conference for Asia and the Pacific	FAO/RAP
11-13 March	Vientiane, Lao PDR	ASEAN Regional Workshop for Enhancement of National Support Officer System to Improvement of Autonomous Resources Management and Fisheries Communities	SEAFDEC/TD
17-21 March	Vietnam	On-site Training for Standard Measurement of Fishing Vessels in Vietnam	SEAFDEC/TD
24-28 March	Cebu, Philippines	On-site Training on Optimizing Energy and Safety at Sea for Fishing Vessels	SEAFDEC/TD
24-28 March	Lao PDR	25th Meeting of the NACA Governing Council	NACA
21-25 April	Binangonan, Philippines	Training on Carp Hatchery and Grow-out Operations	SEAFDEC/AQD
22-24 April	Phuket, Thailand	Regional Technical Working Group Meeting on Data Collection for Sharks in Southeast Asia	SEAFDEC/TD
22-25 April	The Hague, The Netherlands	Global Oceans Action Summit for Food Security and Blue Growth	Gov. of The Netherlands
22 Apr-6 May	Iloilo, Philippines	Training Course on Sandfish (*Holothuria scabra*) Seed Production, Nursery and Management	SEAFDEC/AQD
24-30 April	Prachuap Khiri Khan, Thailand	Training Course on Essential Ecosystem Approach for Fisheries Management (E-EAFM) with a Special Focus on Southeast Asian Asian Trawl Fisheries	SEAFDEC/TD
28 Apr-1 May	Indonesia	Regional Validation Workshop for the Preparatory Phase of the UNEP/GEF *Refugia* Project	SEAFDEC/TD
29 April	Malaysia	5th Meeting of the ASEAN Shrimp Alliance (ASA)	ASA
5-7 May	Bangkok, Thailand	Regional Workshop on REBYC-II CTI Work Planning: 2014-2015	SEAFDEC/TD
7-27 May	Iloilo, Philippines	Training Course on Abalone Hatchery and Grow-out Operations	SEAFDEC/AQD
13-15 May	Fujian Province, China	Regional Consultative Workshop on Capacity Assessment for the Implementation of New CITES Listings of Sharks and Manta Rays	FAO
14-15 May	Penang, Malaysia	Sub-regional Technical Meeting on Effective Fisheries Management Between Malaysia and Thailand	SEAFDEC/Secretariat
14-16 May	Manado, Indonesia	World Ocean Business Forum and World Coral Reef Conference	MMAF, Indonesia
21-23 May	Bangkok, Thailand	13th INFOFISH World Tuna Trade Conference & Exhibition	INFOFISH
25-30 May	Paris, France	82nd General Session of the World Assembly of Delegates of the OIE	OIE
27-28 May	Phuket, Thailand	Sub-regional Consultative Meeting on the Collaborative Fisheries Management Around the North Andaman Sea/Myeik Archipelago	SEAFDEC/Secretariat
27-28 May	Sarawak, Malaysia	Sub-regional Technical Working Group Meeting of SEAFDEC Joint Program for Tuna Research in Sulu-Sulawesi Seas	SEAFDEC/TD
27 May-18 June	Iloilo, Philippines	Training Course on Mud Crab Hatchery, Nursery & Grow-out Operations	SEAFDEC/AQD
2-6 June	Binangonan, Philippines	Training Course on Tilapia Hatchery and Grow-out Operations	SEAFDEC/AQD
9-13 June	FAO Rome, Italy	31st Session of Committee on Fisheries (COFI)	FAO
18-20 June	Surat Thani, Thailand	1st Meeting of the Core Expert Group for the Regional Cooperation for Sustainable Utilization of Neritic Tunas in Southeast Asia	SEAFDEC/Secretariat
21-22 June	Bandung, Indonesia	International Conference of Aquaculture Indonesia 2014 (ICAI 2014)	Indonesia
19-21 June	Hyderabad, India	APFIC Regional Consultative Forum	APFIC
23-25 June	Hyderabad, India	33rd Session of the Asia-Pacific Fishery Commission	APFIC
11-15 August	Binangonan, Philippines	Training Course on Tilapia Hatchery and Grow-out Operations	AQD
2-4 September	Palembang, Indonesia	4th International Conference on Southeast Asian Inland Waters	Indonesia

Southeast Asian Fisheries Development Center (SEAFDEC)

What is SEAFDEC?

SEAFDEC is an autonomous intergovernmental body established as a regional treaty organization in 1967 to promote sustainable fisheries development in Southeast Asia.

Mandate

To develop and manage the fisheries potential of the region by rational utilization of the resources for providing food security and safety to the people and alleviating poverty through transfer of new technologies, research and information dissemination activities

Objectives

- To promote rational and sustainable use of fisheries resources in the region
- To enhance the capability of fisheries sector to address emerging international issues and for greater access to international trade
- To alleviate poverty among the fisheries communities in Southeast Asia
- To enhance the contribution of fisheries to food security and livelihood in the region

SEAFDEC Program Thrusts

- Developing and promoting responsible fisheries for poverty alleviation
- Enhancing capacity and competitiveness to facilitate international and intra-regional trade
- Improving management concepts and approaches for sustainable fisheries
- Providing policy and advisory services for planning and executing management of fisheries
- Addressing international fisheries related issues from a regional perspective


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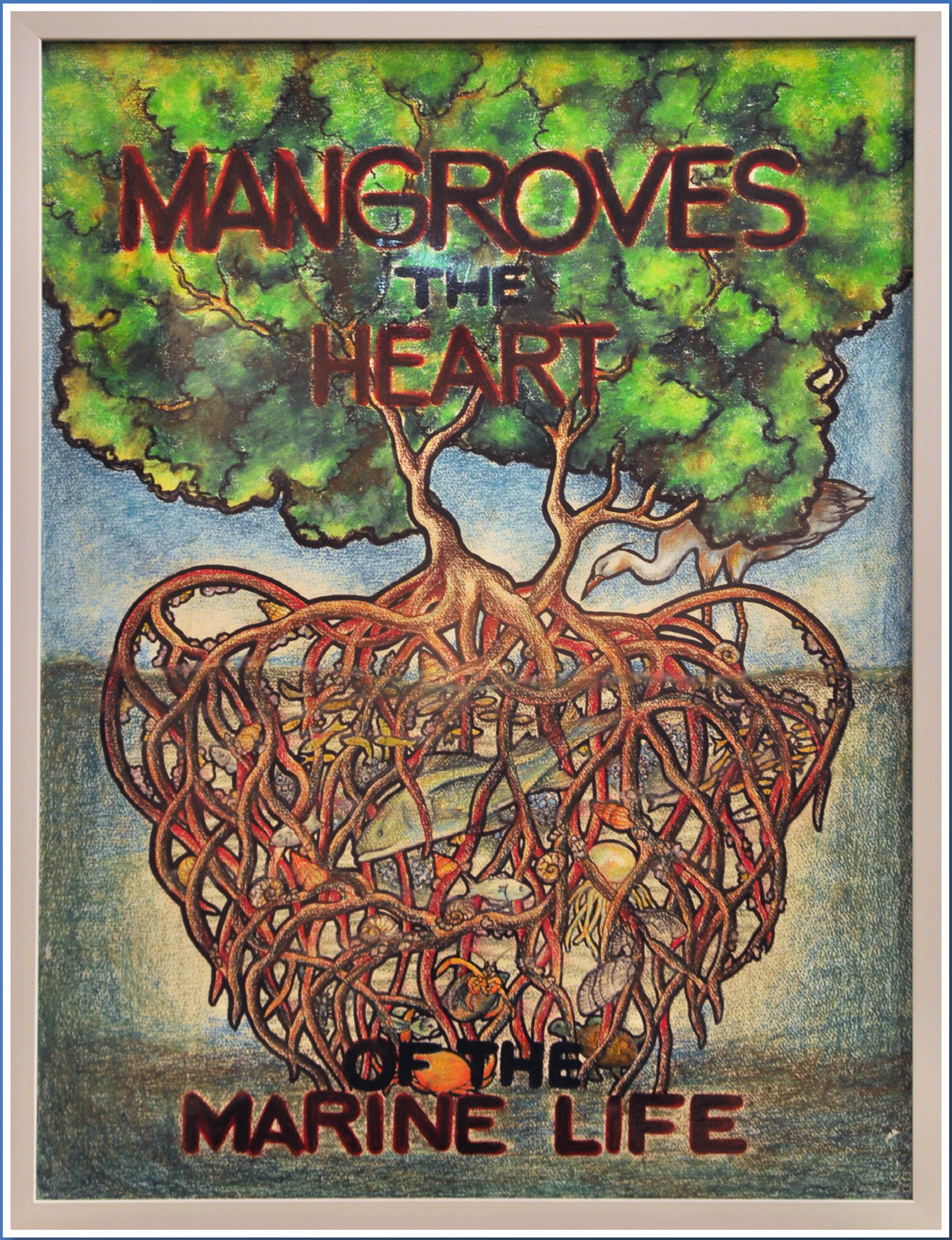

The first prize drawing winner, *Jann Martine Esperancilla*, from the national drawing contest in the Philippines

National Drawing Contests were organized in all ASEAN-SEAFDEC Member Countries as part of the preparatory process for the ASEAN-SEAFDEC Conferene on Sustainable Fisheries for Food Security Towards 2020 “Fish for the People 2020: Adaptation to a Changing Environment” held by ASEAN and SEAFDEC in June 2011 in Bangkok, Thailand, in order to create awareness on the importance of fisheries for food security and well-being of people in the region.